

# Great Sea Reef (Cakaulevu) in Fiji

ENV S 137  
Spring 2023

By: Audrey Engelsgjerd, Chloe Carlstrom, Charlotte Smith, Cece Marino,  
Karmenita Cox, Ivan Ortiz, Jeanne Couture

University of California, Santa Barbara, Environmental Studies Department



(Source: Jürgen Freund)

## **Executive Summary**

Referred to as the ‘Protector of Fiji’ by local communities, the Great Sea Reef (GSR) acts as a natural barrier between the country’s two islands. Third longest reef in the world, a diverse marine population, including corals, fish and mangrove ecosystems, lives within the GSR, many of which are endemic and/or threatened. Not only does it protect shorelines from coastal erosion and natural disasters, but its yearly contribution to fisheries and tourism value make up for 20% of the country’s GDP and is responsible for 10% of the Fijian population’s income and subsistence. Global climate change, illegal and overfishing and tourism threaten the ecosystem’s health, however, thus reducing its natural and economic productivity. Not only is the stability of marine ecosystems at stake through the preservation of the reef, but the well-being of the Fijian population as well.

This conservation plan draws on coastal management and coastal planning organizations, educators, local authorities and communities for its decision-making. The main decision-makers remain government agencies and non-profit organizations, in charge of the project’s approval, implementation and funding. The team includes policy experts from Conservation International and the Fijian Government, the Green Climate Fund and the Ministry of Labour, Industrial Relations, Tourism and Environment, who represent the socio-economic interests of Fiji. Finally, actors will work hand-in-hand with the Fiji Locally-Managed Marine Area Network, already implemented in the area, which will approve the plan before its implementation. Additionally, stakeholders including fishers, local communities, indigenous groups, tourist agencies and researchers will be considered in decision-making.

The primary environmental objectives in the GSR are the preservation and increase of fish and coral biodiversity, as they represent the ecosystem’s key species. In terms of social objectives, the plan focuses on the increase of the overall livelihood of local communities. Finally, the main economic objective is the increase of profits made by local communities through more sustainable practices.

The three primary strategies considered by this conservation plan are the reduction of illegal mining and reuse of mining waste, the implementation of zoning laws and the enforcement of MPAs, all prioritized for their efficiency and ability to respond to stakeholders’ interests. These policies indeed all represent solutions to biodiversity loss and provide

community members with high standards of living. They will be implemented through partnerships with Fijians, NGOs and local authorities.

## **Table of Contents**

Executive Summary.....	2-3
Planning Context.....	5-7
Planning Team and Management Process.....	8-16
Situation Analysis.....	16-18
Project Scope.....	18
Fundamental Objective and Desired Outcomes.....	19-22
Conservation Features.....	23-24
Range of Strategies.....	24-27
Strategy Selection.....	27-31
Data and Knowledge.....	31-32
Risk and Uncertainties.....	32-34
Conclusions.....	34
Bibliography.....	35-39

## Planning Context

### Introduction

This document addresses the Great Sea Reef in Fiji, where overfishing, pollution, habitat degradation, and climate change have resulted in declining key fish populations and loss of mangroves, which increases the risk of inundation of coastal settlements, social and economic hardships, and loss of biodiversity.

Located on the northern shore of the island of Vanua Levu in Fiji, the Great Sea Reef, or Cakaulevu Reef, is the third longest continuous barrier reef in the world, covering 20 700km<sup>2</sup> and stretching over 450 km. Consequently, the reef fosters a diverse marine population, with over 1000 fish species and over 300 coral species, including unique mangrove ecosystems and endemic fish. A survey led by WWF in 2004 revealed that the reef fosters “55% of the known coral reef fish in Fiji [...], 74% of the known corals in Fiji and a total of 40% of all the known marine flora and fauna in the Fiji Islands (WWF, n.d.). Twelve threatened species live within the reef, including 10 fish species, the green turtle and the spinner dolphin, all listed in the IUCN Red List.

With 75% of the population living on the Fijian coast, 70,000 people depend on this reef for its food, income and natural protection from erosion, storms and floods. In terms of revenue, 65% of foreign exchange earnings and 20% of GDP in Fiji comes from reef-related activities. The GSR indeed contributes between \$12 to 16 million annually to Fiji’s economy only through the inshore fisheries sector, making it responsible for the income livelihood of 1/10 of the population.

Although the reef remains one of the most resilient in the world, Fiji’s rapid economic development continues to threaten its health. Overfishing, agricultural run-off, tourism and global climate change drastically reduce the reef’s natural and economic productivity. In recent decades, a 33% decline in fish population has been observed, while mangroves have lost over 5km<sup>2</sup> between 1996 and 2016. Not only does this represent a menace to the overall stability of marine ecosystems, but it directly threatens the well being and prosperity of local communities.

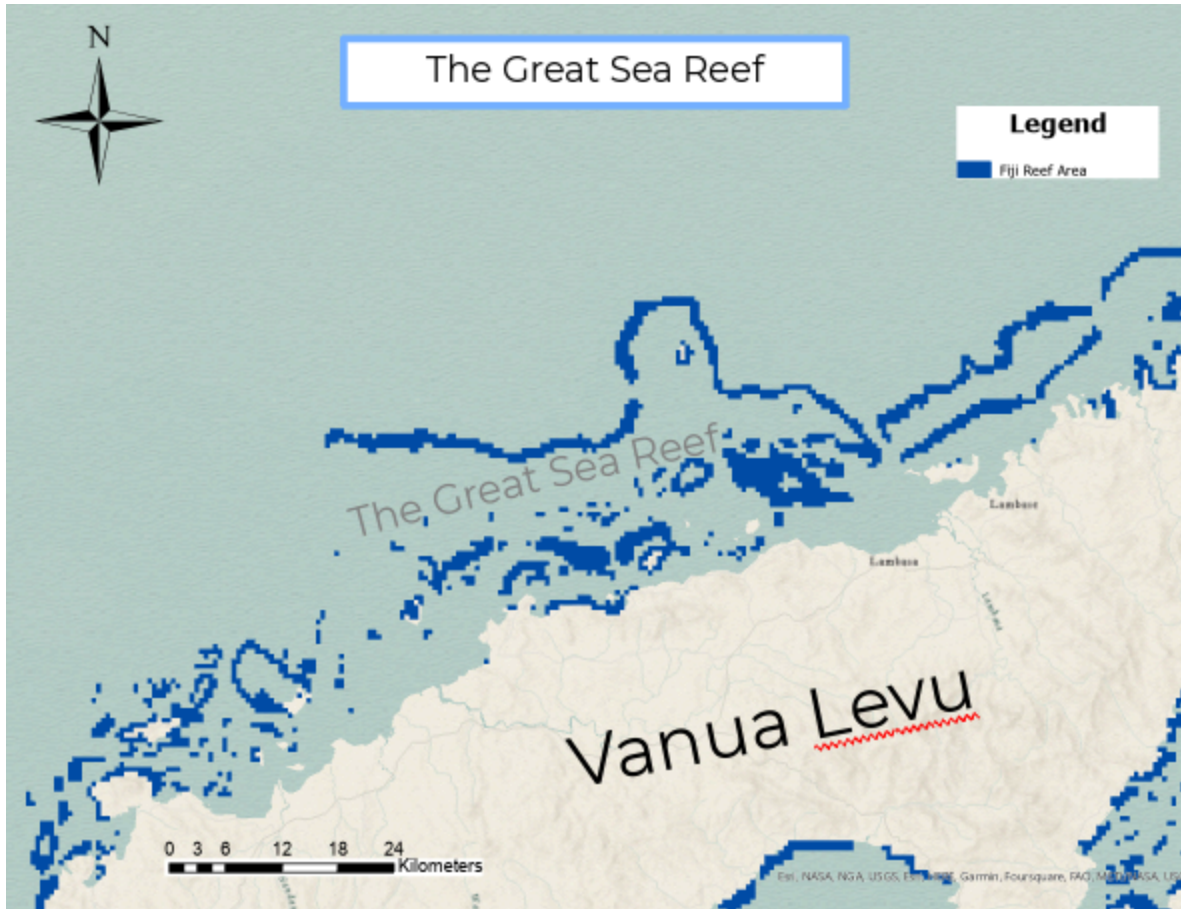
In an effort to improve conservation in the area, the Fijian government has supported communities in the delimitation of marine protected areas with the goal to replenish fish stocks, limit illegal fishing and slow down the reef’s degradation. The application of regulations and

management of ecosystems within these MPAs have been criticized however, for their lack of enforcement and efficiency. NGOs, in collaboration with local authorities and communities, have also participated in the conservation of this area. In 2017, WWF-Pacific and WWF Landscape Finance Lab launched the Sea Reef Resilience Programme, aiming to improve coastal ecosystems' resilience to climate change through new marine landscape management techniques and a renewal of existing financial systems for sustainable practices.

Overfishing and pollution nevertheless remain major threats to the Great Sea Reef's ecosystems and the well-being of Fijian communities. This document therefore addresses related issues and presents effective strategies to improve the reef's health and create more sustainable practices, for a greener planet.



Map 1. Giant Sea Reef, Fiji (*Source: NASA Earth Observatory*)



Map 2. Great Sea Reef Fiji (Data: Institute for Marine Remote Sensing, University of South Florida)

*Image 1: Camouflage Groupers*



*Source: RNZ News*

*Image 2: Coral Reef*



*Source: Living Oceans Foundation*

## **Planning Team and Management Process**

### **Decision Makers and Target Audience**

The main decision makers for the Great Sea Reef (GSR) conservation plan include both government agencies and non-profit organizations. These decision makers will be in charge of project approval, as well as implementation and funding allocations.

We will work closely with Conservation International, a global non-profit organization that is on the planning team and will also serve as a decision maker. Conservation International provides governments with “cutting-edge science that helps guide sound policy decisions for conservation and human wellbeing” as well as working with local and global corporations to help them adopt more sustainable production practices. (Conservation International, n.d.). One of the main reasons behind them being a decision maker is their history and experience with sustainable aquaculture projects in other parts of the world. In addition to this as a member of the Green Climate Fund (GCF), Conservation International will be able to provide funding and resources for the GSR conservation plan. The GCF is a part of the United Nations Framework Convention on Climate Change and was developed to provide funding for environmentally friendly projects in developing countries. (Green Climate Fund, n.d.).

Another organization that will serve as a decision maker is the Ministry of Labour, Industrial Relations, Tourism and Environment. This organization was selected as a decision maker due to their expertise in policy development and regulation enforcement. They represent the socio-economic interest of Fiji and would ensure that community feedback is being considered and if appropriate implemented. Due to their experience they will also be working on finding funding and implementation of the conservation plan.

The last decision maker will be the Fiji Locally-Managed Marine Area Network. Due to the conservation plan focusing on the coral reef system, some of it being located in marine protected areas, we will need to consult and have the plan approved by the Fiji Locally-Managed Marine Area Network before it can be implemented.

### **Planning Team**

The following table (*Table 1*) illustrates the members of our planning team. These government agencies, independent organizations, expert researchers, and community representatives have agreed to develop and implement a conservation plan for the Great Sea Reef



(GSR) in Fiji. We have gathered this specific group in order to ensure the conservation plan focuses on ecological struggles, political and socio-economic wishes and is environmentally just. With their diverse background and specializations, our planning team possesses the unique skills and knowledge to preserve the GSR's biodiversity while also helping the local communities needs to be met and increase Fiji's economic growth.

Member	Skillset	Organization	Role
Coastal Management Organizations	Community based marine resource management	Fiji Locally-Managed Marine Area Network	Engage community in conservation efforts/ lead volunteer projects
Educators	Educational outreach, research, community involvement	Fiji National University	Facilitate learning of the importance of conservation, erosion, and proper waste management
Conservation Planning Organizations	Restoration, project management, leadership	Marine and Coastal Biodiversity Management in Pacific Island Countries Conservation International Aquaculture Development for the Environment	Supporting Fiji in meeting their national biodiversity targets through economic assessments of marine and coastal ecosystem services Implementation of the conservation plan
Federal/ Municipal/ Local Government	Understanding of local laws/policies/permits and licencing	Ministry of Waterways and the Environment Fiji Government	Enforce conservation area protections (MPAs) and fine violators Allocate permits and funding Enforce zoning laws and other restrictions

Indigenous Communities	Long term knowledge of the land and marine areas	Fijians (iTaukei) Ministry of iTaukei Affairs	Ensure indigenous land and community resources are being respected and environmental justice is being met through local resident feedback
------------------------	--	--	---

*Table 1 - Planning Team*

### Stakeholders

Stakeholders are the people who will be affected by the conservation plan. Due to the direct connection between the conservation plan and the stakeholders the stakeholders will have opportunities to participate in the planning and implementation part of the conservation plan. The stakeholders include but are not limited to: fishers, local community members, indigenous groups, the tourism industry, and government/nonprofit organizations as seen in *Table 2*.

Member	Skillset	Organization	Role
Fishers	Understands fish populations migration and behaviors  Supports local and global economies	Ministry of the Fisheries, Fiji	Practice sustainable fisheries  Create economic incentive to protect GSR
Local Communities	Knowledge of the area	Homeowners association  Fiji Locally-Managed Marine Area Network	Traditional knowledge sharing, sustainable resource use, participation in conservation initiatives.
Indigenous groups	Long term knowledge about the GSR and storm patterns  Cultural knowledge	Ministry of iTaukei Affairs	Provide ecological and cultural expertise  Spread awareness in local communities

Tourism industry	Supports local economy  Connection with global population	Nukubati resort	Educate tourist on issues affecting GSR  Foster connections to marine species and ecosystems
Environmental NGO's	Have resources and experts	WWF  Pacific Island News Association  Coral Reef Alliance	Conducting research, raising awareness, advocating for policies, and implementing conservation initiatives
Government agencies	Have both law and policy making ability	Ministry for Justice, Electoral Reform, Public Enterprises & Anticorruption, Industry, Tourism  Ministry of Labour, Industrial Relations, Tourism and Environment	Expertise in policy development and regulation enforcement.
Scientists and Researchers	Understanding of environmental science and ecology.  Experts on ecosystems and ecological processes.	Global Coral Reef Alliance  Living Oceans Foundation  Institute of Marine Resources	Conducting studies, data collection, offering guidance.
International Organizations	Have resources, funding, spread awareness	IUCN	Financial support, collaboration opportunities, technical assistance
Coastal homeowners	Knowledge of high risk areas  Support local economy	Housing authority of Fiji  Integrated Coastal Management	Economic incentive to maintain mangrove

			Spread awareness of local effects of the issues.
Conservation planners	<p>Experience in past successful conservation efforts</p> <p>Toolkit to create effective conservation plan</p>	Fiji Locally-Managed Marine Area Network	<p>Involve local stakeholders in creating a conservation plan</p> <p>Consider human wellbeing of local communities</p> <p>Provide past examples of effective conservation plans</p>

*Table 2 - Stakeholders*

### Fishers

Local fishers have a significant stake because their livelihood relies on the wellbeing and productivity of the reef. If fish populations decline, they will be harmed. They are key because they can implement conservation-based management of fisheries, so they have a major impact on the health of the reef system. The wellbeing of fisheries affects their success, and local and national economies, since fishing is a large source of income for citizens of Fiji. Not only do fishers have a financial stake in the Great Sea Reef, but the fisheries in the reef are also needed for the subsistence of many Fijian communities. For many citizens, the fish from the ocean is their main food source. Their contribution to the planning process is important, as they understand fish populations' migration, patterns, and behavior. Overfishing is a major threat to the health of this reef, so the cooperation and involvement of fishers in the planning process is crucial.

### Local Communities

Since the Great Sea Reef is their home, local communities have a stake in conservation plans. The reef provides financial and recreational benefits, as well as creating a connection between the land and the people. The picturesque reef can also play a major role in the happiness of the residents. Local community members are important to the conservation strategies for the

reef, as they hold knowledge of the area that no one else has, so they can provide key insight into how the ecosystem functions and what can be done to protect and preserve it.

### Indigenous groups

The Itaukei have a very strong sense of belonging in their culture and community, and it is heavily reliant on the land as it ties the community together. Their cultural knowledge will provide important insight that can help shape conservation plans. They can also shape conservation in a way that ensures it doesn't harm indigenous peoples or ways of life. Including them in the planning process ensures that indigenous interests are not overlooked, and that it benefits them. Additionally, they have an accumulation of centuries of knowledge about the ecosystem as well as the way storm patterns work. So, they can be monumental in the planning process to provide cultural and ecological expertise. They will also be key players in the implementation of conservation efforts as they can spread awareness throughout local communities and help enforce the conservation strategies. By giving insight into the ways their communities work and the cultural values they hold, they can shed light on what conservation efforts they think should be implemented and which should be avoided, in order to preserve indigenous ways of life (and prevent harming communities).

### Tourism Industry

Since tourism is Fiji's biggest source of revenue, accounting for almost 40% of its GDP (Export Finance Australia, n.d.), the tourism industry is a key stakeholder. Tourism companies provide boat tours, snorkeling, diving, recreational fishing and more. Fiji attracts tourists from across the globe, and since it is a major part of the economy, many Fijians rely on the tourism industry for jobs. Since tourist companies primarily focus on ocean activities, the health of the reef significantly impacts the success of tourism in the area. The tourism industry can implement conservation efforts, educate tourists and spread awareness to make sure that visitors don't harm the local environment. The tourism industry will be instrumental in encouraging sustainable fishing and overall management of the reef, and it is important to work closely with them to promote sustainable tourism in a way that benefits the environment and the tourism sector of the economy.

### Environmental NGOs

Experts in ocean conservation have a stake in protecting the third largest barrier reef in the world (WWF, n.d.). Their research will be useful in the conservation planning process as they have experts who hold knowledge on the ways the ecosystem functions and have expertise in devising and implementing plans. They also hold some political power and can help influence and work with local politicians to undertake and embrace conservation efforts. These organizations, such as the WWF, are crucial in spreading public awareness of threats that face the reef as well as conservation efforts to protect it. Environmental NGOs have a stake in creating sustainable management of oceans and reefs, so their involvement and input in this project is necessary.

### Government Agencies

Both local and national government agencies will play a key part in drafting and enforcing conservation laws. They have a stake in figuring out what conservation efforts will be created and what areas of the reef will be included in the plan, and ensuring the efforts work in concert with the culture and wellbeing of their citizens and communities. Additionally, since reefs protect coastlines from storms and erosion, they are important in protecting coastal infrastructure. Large storms can wipe out coastal infrastructure and electricity, as well as flood coastal areas, posing threats to citizens safety as well as the overall functioning of society and the economy. Also, working with these agencies will allow the creation of more marine protected areas in the reef.

### Scientists and Researchers

Scientists are stakeholders in the efforts to protect the reef since oceans play many integral roles such as regulating the global climate, providing us vital oxygen, and being a carbon sink which has absorbed significant amounts of carbon dioxide, helping slow climate change. Scientists and researchers have a stake in protecting such a biodiverse ecosystem, and the research they put forward can help further the project's understanding of the weather patterns, fish and ecosystem populations and dynamics, etc. This information is very important in the planning of this conservation project. The studies that scientists conduct on the reef and the data they gather can be very useful in this project.

### International Organizations

Since the IUCN or International Union for Conservation of Nature is an international organization dedicated to conserving earth's ecosystems, they will be a stakeholder in this project. Since they have interests in the sustainable management of reefs and overall success of the project, they can provide financial support, collaboration opportunities as well as technical assistance with research.

### Coastal Homeowners

Coastal homeowners are stakeholders because the Great Sea Reef is their backyard. A significant portion of coastal homeowners' property value is the ocean, and if the reef ecosystems are collapsing, coral are bleaching, etc., it will negatively impact the coastal homeowners' property and its value. Coastal mangroves, which the reef ecosystem protects, protect coastal homes. They provide benefits including improving water quality, stabilizing the coastline by reducing erosion from storms, and absorbing water during storms, which helps prevent flooding. So, coastal homeowners have a stake in conserving both the reef itself and the mangroves it supports, which this project achieves. Additionally, the declining health of the ocean will affect their aesthetic views. Coastal homeowners want to protect their home, which is why they have a stake in this project. Since the reef protects against climate change's effects like sea level rise, storm frequency and intensity, and flooding, which coastal communities are especially vulnerable to, the GSR is important in boosting its coastal communities' climate resiliency.

### Conservation Planners

Conservation planners are vital in this project since their past experience in other conservation projects and expertise is very important in the success of this project. Using their skills, knowledge and expertise, they will be able to effectively collaborate with the other stakeholders to create a robust conservation project, and be able to shed light on the best way to implement it. They hold knowledge on the best way to involve local and indigenous communities to create an equitable plan, taking into account human wellbeing of locals in the area.

### Decisions, Opportunities, Sideboards, and Constraints

One potential constraint for the proposed Great Sea Reef (GSR) conservation plan is that portions of the reef are designated Marine Protected Areas (MPAs) which fall under government jurisdiction. In 2019 Fiji declared they would meet a 30% offshore MPA commitment by 2030 to be able to improve and increase sustainable fisheries management and MPAs for food security. (Oceans5, n.d.). Another constraint might be local or national laws that govern development of coastal areas and interactions/modification of habitats for endangered species. In order to implement our conservation plan and not interfere with Fiji's MPA goals and local/national laws we will work closely and coordinate conservation efforts with local and national governments.

Currently there is another project working on the coral reef system in Fiji called the Coral Reef Resiliency Program. This conservation plan was proposed by the World Wildlife Fund and the Green Climate Fund (GCF) in January of 2023 and it is currently preparing a funding application. The plan aims to “implement ecosystem-based adaptation within Fiji's Great Sea Reef and connect coastal ecosystems to enhance the resilience of coastal ecosystems and communities to climate change by reducing local scale impacts such as ecosystem destruction, overfishing, unsustainable production and solid and chemical waste.” (Green Climate Fund, 2023). Based on similar outcome goals for the Coral Reef Resiliency Program and our proposed conservation plan for the GSR, by combining some of the proposed strategies would save money and resources.

### **Situation Analysis**

The primary conservation targets in the Great Sea Reef regard the fish populations and coral coverage, both of which are key species in the ecosystem. There are many endangered fish species such as the Humphead Wrasse, Camouflage Grouper, and Parrotfish. The corals are the most important organism in the reef as they provide habitats for these fish species and many other marine organisms. Both the corals and the fish are being threatened by various climate and human caused threats. *Figure 1* conceptualizes the various threats contributing to the decline in fish populations and coral coverage, as well as threats to the livelihoods of local communities as shown by the included human wellbeing target.



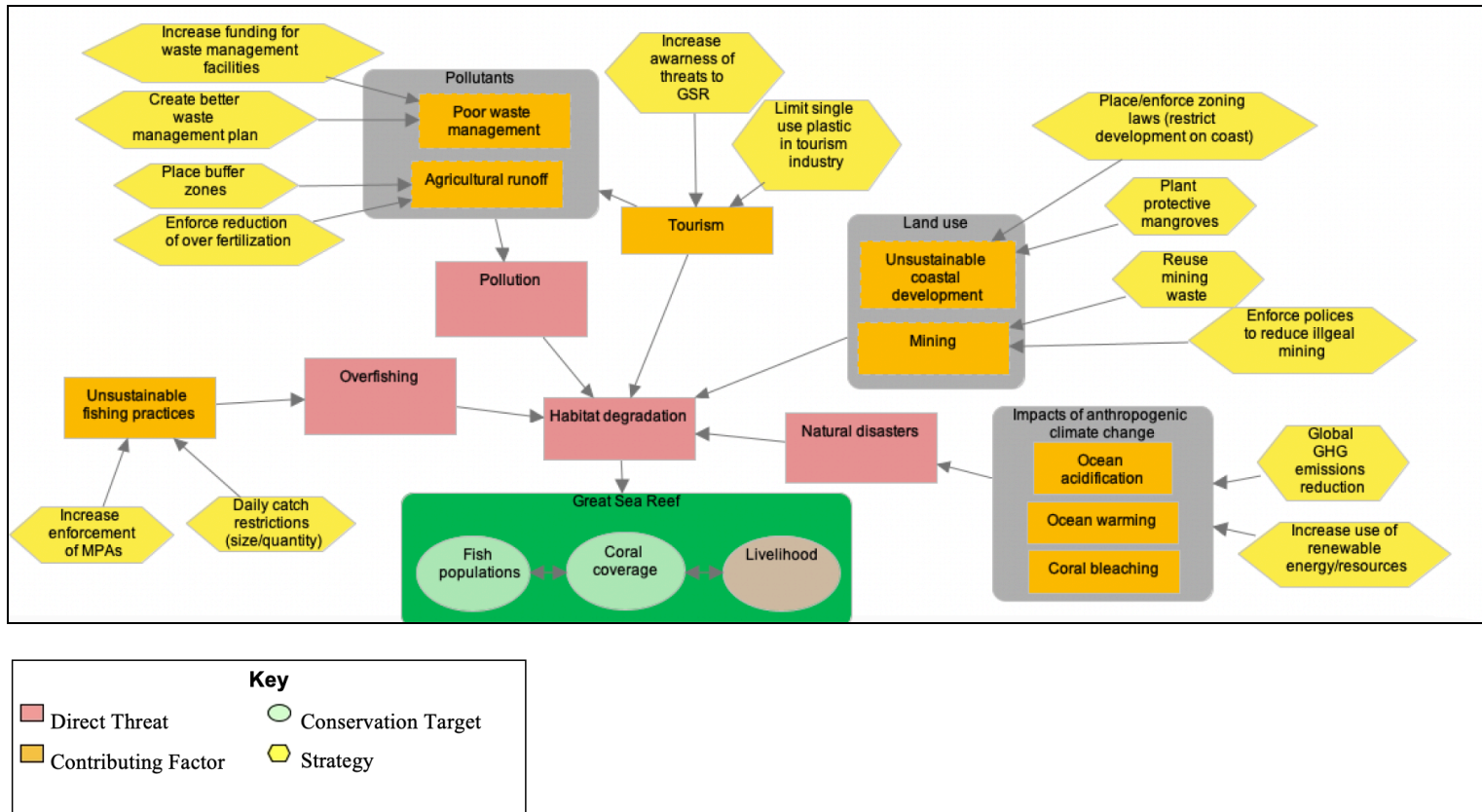


Figure 1: Miradi Conceptual Model

### Direct and Indirect Threats

The most significant threats to the Great Sea Reef, specifically to the fish populations and coral coverage, include overfishing, pollution, habitat degradation, natural disasters, as well as ocean warming and acidification which causes coral bleaching. These overarching threats can be further specified into contributing factors that have exacerbated these issues.

Overfishing stems from the issue of the use of unsustainable fishing practices and insufficient regulation due to a lack of cohesive decision making. Pollution in the waters of the Great Sea Reef has been caused by poor waste management and agricultural runoff, including chemical pesticides as well as soil erosion. (Madigibuli, 2020) Plastic pollution has also posed a threat to fish populations, has negatively impacted coral health, and can indirectly cause economic issues such as decreased tourism and fishing revenue losses. (Mitempergher et al. 2022) Increasing tourism, specifically for water sports, intensifies stresses on the reef.

Habitat degradation has been caused by urban expansion and coastal construction which involves the clearing of mangroves and other vegetation, weakening the reef ecosystem and making the coast more vulnerable to the storm surge caused by natural disasters, such as hurricanes. (Madigibuli, 2020) Major hurricanes - of which Fiji has been hit by three within the last 20 years - alongside ocean warming and acidification are threats caused by anthropogenic climate change. As the planet continues to warm, natural disasters have become more frequent and more deadly. The rising ocean temperatures are making the water uninhabitable for some marine species and with increased carbon dioxide emissions, the ocean takes up more carbon dioxide causing it to become acidic. This acidification slows the growth of coral skeletons, negatively impacting the reef's health. (NOAA, n.d.)

## **Project Scope**

### Spatial, Temporal, and Strategic

The conservation plan is focused on the Great Sea Reef in Fiji. This reef is located on the northern shore of Vanua Levu island. Stretching over 450 km, it is the third longest continuous barrier reef in the world. The reef is home to a diverse range of species including over 1000 fish species and 300 coral species. This includes 12 endangered IUCN red-listed marine species. (WWF, n.d.). The reef ecosystem also supports coastal mangroves. The conservation plan focuses on the entire reef ecosystem, as the coral reef itself as well as the the species that inhabit it are threatened by human activity.

The desired timeline of this conservation plan is to reach our proposed goals for coral coverage, mangrove coverage, and fish populations within 10-15 years, our targets for sustainable fisheries and clarity of water within 5 years, and see our livelihood of local communities objective - household income - reach its increase by 2030.

The success of this project is dependent on efficient and effective decision making by our planning team, discussion and cooperation with the stakeholders involved, as well as evaluation and reevaluation of the conservation plan as progress is made and the plan is implemented.

## Fundamental Objectives and Desired Outcomes

Table 3 outlines the fundamental objectives of our conservation plan which highlights the primary goals this project hopes to achieve. These fundamental objectives cover environmental concerns including biodiversity, ecological processes, and ecosystem services. Additional economic and social fundamental objectives are focused on in order to preserve human wellbeing in local communities. In order to determine these fundamental objectives we met with various stakeholders in order to understand how this issue impacts them, what they value protecting, and what areas of focus will create the most effective long lasting conservation plan. The stakeholders' perspectives and concerns were essential in creating a list of steps laying out how this conservation plan will address the consequences connected to the degradation of the Great Sea Reef in Fiji. These fundamental objectives aim to increase health of the GSR in order to decrease risk of inundation of coastal settlements, social and economic hardships, and loss of biodiversity. Additionally human well being is prioritized in order to make sure the conservation plan addresses the needs of local communities which will lead to longevity in protection of the GSR.

Great Sea Reef Ecoregion	6. Fundamental Obj	7. Features	8. Indicators	9. Targets
	<i>What &amp; Direction</i>	<i>What can be measured</i>	<i>How will 'what' be measured</i>	<i>Goal/time</i>
Environmental-Biodiversity	Increase coral coverage	Coral coverage	Ha of coral coverage	Increase coral coverage by 20% in 15 years
	Increase key fish populations (Parrotfish, Humphead Wrasse,	Fish biomass	Fish biomass grams per square meter	Increase fish biomass by 30% in 10 years

	Camouflage Grouper)			
<b>Environmental –Ecological Processes</b>	Increase clarity of water	Turbidity	Depth (meters) Secchi disc is visible	Increase depth Secchi disc is visible for by 1 meter every year for 5 years
<b>Environmental –Ecosystem Services</b>	Increase buffers for natural disasters	Mangrove coverage in buffer areas	Kilometers squared of mangrove coverage in buffer area	Increase mangrove coverage by 5 Kilometers Squared over 10 years
<b>Economic</b>	Increase local sustainable fisheries	Illegal fishing	Rate of illegal fishing	Reduce illegal fishing rates to 0% in five years
<b>Social</b>	Increase livelihood of local communities	Household income	Average household income	Increase average household income by 10% by 2030

*Table 3- Fundamental Objectives and Desired Outcomes for the Great Sea Reef in Fiji*

## **Fundamental Objectives: Environmental**

Environmental objectives are broken up into three categories; biodiversity, ecological processes, and ecosystem services. These objectives aim to protect and enhance the diversity and functionality of the Giant Sea Reef in Fiji.

### *Biodiversity:*

The first fundamental objective working to improve biodiversity is increasing coral coverage in the GSR. This is a main focus identified by stakeholders for this conservation plan because the health of the whole marine ecosystem and livelihood of surrounding communities rely on healthy corals. Healthy coral reefs in GSR provide habitat for many marine species, protect local communities from storms and flooding, and provide economic benefits through tourism (Vierus, 2020). Increasing coral coverage will help increase the abundance of fish, turtle, shark, and bird species, will increase climate change resilience, and will allow for economic and cultural prosperity in local communities.

The second fundamental objective is focusing on increasing key fish populations. This was identified as a fundamental objective by stakeholders because fisheries play an essential economic and cultural role in Fijian society. It is seen that fisheries were worth over 64 million USD in 2014 (Gillett et al. 2014). Increasing fish populations will allow for communities whose cultural practices and food security are dependent on fish populations to thrive. Additionally declining fish populations have a negative top down effect on the whole marine ecosystems putting many other species at risk of decline.

### *Ecological processes:*

Increased water pollution surrounding the GSR caused by agricultural runoff, poor waste management, and tourist practices is detrimental to the survival of coral reefs. As water turbidity, cloudiness of water, decreases due to this pollution less light is able to get through to zooxanthellae which provide coral with 90% of their energy (“How Does the Water Quality Affect Coral Reefs”, n.d.). This is why the fundamental objective for ecological processes is to increase turbidity in order to allow more sunlight to reach coral which will foster a productive and healthy coral reef.

### *Ecosystem service:*

Communication with stakeholders made it clear that a main concern is protection from climate change and climate related disasters. It is seen that Fiji is extremely vulnerable to tropical cyclones, rising sea levels, floods and landslides. (“Fiji- Vulnerability”, n.d.). Protecting mangroves is essential in this conservation project because they sequester and store carbon, along with protecting coastal communities from tropical cyclones, rising sea levels and flooding (Cameron, 2020). Increasing buffers, such as mangroves, for natural disasters is an important step in climate change mitigation and adaptation making it a fundamental objective.

### **Fundamental Objectives: Economic**

Economic objectives are focused on increasing profits made in communities near the location of the conservation plan. Local stakeholders made it clear that increasing local sustainable fisheries needed to be a fundamental objective. This is because unsustainable fishing practices such as illegal fishing leads to overfishing and the depletion of key fish species. Not only does this have top down effects on the coral reef ecosystem it also prevents local fisheries from having access to enough fish to support local economies and food security (NOAA, n.d.). Eliminating illegal fishing practices will create more room for sustainable fishing that will allow fish populations to recover and local communities having access to necessary fish quotas.

### **Fundamental Objectives: Social**

Our social fundamental objective is focused on increasing the overall livelihood of local communities. This is an area of focus because the wellbeing of communities surrounding the GSR will determine if protection of local ecosystems will continue once this conservation plan is implemented. If surrounding communities are unsafe, food insecure, and economically struggling they will be unable to put energy or resources towards protecting the GSR. Additionally failure to support and consider local communities and stakeholders would make this a weak and inadequate conservation plan.

### **Conservation Features**

Within *Table 3* every fundamental objective is connected to a “feature”. Each “feature” demonstrates how that fundamental objective can be measured. Next the “indicators” are how the

22

feature will be measured. Indicators can be broken down into natural, proxy or constructed categories. Natural indicators are used when the desired feature can be directly measured to reflect the effectiveness of the objective. When the indicator is not measurable, therefore a natural indicator can not be utilized, a proxy indicator is effective. Proxy indicators measure something that there is data for that can then reflect changes in the desired feature. Constructed indicators can be used to understand the feature on a scale of excellent to terrible. Lastly the targets are the changes in features the conservation aims to achieve within a certain time frame in order to address each fundamental objective.

### Features, Indicators, and Targets

For the first environmental-biodiversity fundamental objective to increase coral coverage, the feature that will be measured is coral coverage, and the indicator is to measure the Ha of coral coverage. Our goal is to increase coral coverage by 20% in 15 years. The second fundamental objective is to increase key fish populations, the feature is fish biomass, and the indicator is fish biomass with the unit grams per square meter. The target is to increase fish biomass by 30% in 10 years.

The environmental- ecological processes fundamental objective is to increase clarity of water. The feature used here is turbidity, and the indicator is depth in meters, the Secchi disc is visible. The target is to increase depth, the Secchi disc is visible for, by 1 meter every year for 5 years.

The environmental- ecosystem services fundamental objective is to increase buffers for natural disasters. The feature used is mangrove coverage in buffer areas and the indicator is kilometers squared of mangrove coverage in buffer areas. Our target is to increase mangrove coverage by 5 kilometers squared over 10 years.

The economic fundamental objective is to increase local sustainable fisheries. The feature here is illegal fishing and the indicator is rate of illegal fishing. The target is to reduce illegal fishing rates to 0% in five years.

Lastly the social fundamental objective is to increase the livelihood of local communities. The feature is household income with the indicator being average household income. The target is to increase average household income by 10% by 2030.

## **Range of Strategies**

### Waste management

Pollution poses a significant threat to coral reefs. A large source of this pollution comes from mismanaged waste including sewage, agricultural, mining, and coastal development waste. When mismanaged waste from these activities end up in the ocean this increases chemicals, nutrients, oil, debris, and sediments present (NOAA, n.d.). In order to protect water quality our team is working with local stakeholders to increase funding for waste management plans. This will allow for more resources to be put towards incorporating sustainable practices. Also some faulty waste management systems will be rethought to avoid the runoff currently occurring. One area of focus will be relocating waste disposal facilities further from the coast to prevent any possible contamination.

### Buffer Zones

Buffer zones composed of mangrove forests and seagrass beds have the potential to protect the coast line as well as the coral reef itself. These species are vital to their surrounding ecosystems as mangroves can trap pollutants, such as nitrates and phosphates, and keep them from flowing into the ocean, thus filtering the water. Seagrass beds block silt that could smother and damage corals. This coastal ecosystem also protects the local residents from coastal erosion and storm surge from natural disasters. The fallen leaves from the mangroves are also useful as they are eaten by many organisms and support a large food system. (AMNH, n.d.)

### Reduce over fertilization

Excess use of fertilizers increases the chance of nutrient runoff into the ocean. This process is known as eutrophication. The increase in nutrients present leads to algae blooms which decreases available oxygen in the water causing fish populations to rapidly decline. Declining fish populations economically and culturally harms surrounding communities who rely on fisheries for income, food, and tradition. Along with human wellbeing consequences declining fish populations will have top down negative effects on coral reefs. Fish help clean algae off corals, reduce pests, and provide nutrients for corals (NOAA, n.d.). With less fish present, coral reefs will also suffer. This is why we are going to implement laws that restrict



fertilizer use in areas with high risk of runoff. Additionally strict enforcement including fines will be utilized to encourage proper sustainable fertilization. This means using the right amount, at the right time of the year, in the right locations, using the right method (“Threats to Coral Reefs”, 2013). Educational resources will be provided to the agricultural industry to help aid the switch to fertilization methods that does not harm the GSR,

### Increase awareness on GSR

The team wants to focus on increasing awareness of threats to the GSR and the consequences this has on marine ecosystems and local communities. This will encourage more people to be engaged in the protection of the GSR and eager to support other strategies in our conservation plan. We will focus on educating local communities by targeting elementary school students. This will foster awareness of the importance of conservation from a young age and will allow students to relay information to their families. We will also target the tourist industry and make sure there are informational resources for people coming to visit Fiji to help them understand how their actions can harm the GSR if they are not careful. The more people educated on this issue the more people will be passionate about protecting the GSR and able to have informed discussions about conservation strategies.

### MPA enforcement

Marine Protected Areas are designated areas of the ocean in which fishing is prohibited. This is done to protect the species living there and conserve their habitat. Currently in Fiji, less than 1% of the total marine area is fully or highly protected from fishing. (MPAtlas, n.d.) This has allowed for overfishing to occur and led to the decline of key fish populations. With the creation and enforcement of more MPAs, the health of the reef ecosystem would increase and the fish populations would be able to stabilize. Enforcement of these zones would help to limit illegal fishing and promote more sustainable fishing practices.

### Daily catch restrictions

Limiting the number of fish that one is allowed to catch in a day would help to regulate and maintain fish populations and reduce the possibility of overfishing. The United Nations Food and Agriculture Organization estimates that there are around 30,000 subsistence fishers in Fiji. In

a recent study on the spawning potential of 129 fish species in the waters of Fiji, it was found that over half of 34 assessed species were below the benchmark level and greater than 57% of future reef fish yields could be lost without the implementation of improved management and policies (Chanel and Singh, n.d.). By imposing daily catch limits, it would conserve endangered fish species and key fish species which in turn would improve coral health and help to stabilize the reef ecosystem.

#### Limit single use plastic

Research shows that the likelihood of disease in coral increases from 4 percent to 89 percent once plastic is present/tangled in the coral (Lamb, n.d.). Additionally many marine organisms mistake plastic as prey. This increases risk of death due to starvation and infection caused by plastic full stomachs (“Marine Plastic Pollution”, n.d.). The tourism industry is the latest culprit to production of plastic waste harming the GSR. This is why the team is committed to working with the tourist industry to start plastic free initiatives. This will mean eliminating many common single use items associated with tourism that end up in the ocean harming marine ecosystems. The main targets will be plastic water bottles, utensils, disposable toiletries, and food packaging. Resorts, airlines, and other tourism sectors that comply with eliminating these items will receive a plastic free certificate as an incentive. This will elevate coral reefs and marine organisms from the harm caused by plastic pollution.

#### Reduce illegal mining/reduce mining waste

The gold mining industry has been active in Fiji for many years, and more recently there has been an increase in black sand mining. The gold mines have been found to be responsible for large amounts of toxic chemicals present in the rivers and the ocean surrounding Fiji’s coastline. (Kumar, S. *et al.* 2022) Exposure to chemicals not only negatively impacts marine life, but the local communities as well as it results in declines in their fisheries and their own health. Many of the black salt mines are owned and operated by foreign companies who disregard the livelihoods of the local communities. They have gone forward with projects without properly informing the residents who will be affected and in some cases have even falsified or left out information in order to receive consent for the implementation of the mines. (Wiseman, 2021) These black sand

mines on the coast line will also damage mangrove buffers. Government intervention is needed to regulate the various forms of mining and to mitigate the impacts.

### No action

If no action is taken, the Great Sea Reef will be greatly affected by unregulated threats from overfishing, pollution, and climate change. Poor farming practices and coastal development have led to toxic run off into the ocean, damaging the reef. If not addressed, this will only continue to occur and the reef health and coral coverage will continue to decline to critical levels. (WWF, n.d.) Overfishing has also been a rampant issue, and given the current trajectory many fish species may become endangered and those that already are may reach incredibly low population sizes. This not only harms the reef ecosystem but the local economy as well that relies heavily on fishing and ocean and reef related tourism.

## Strategy Selection

### Consequence Table

The consequence table (*Table 4*) analyzes some of the main strategies listed in the situational analysis (*Figure 1*) by rating whether each strategy has a positive (+), negative (-) or no impact (/) on the corresponding fundamental objectives. By having a consequence table we can easily analyze which strategies will be most effective based on their net impact score. The net impact score is calculated by adding up all the (+) and subtracting the (-) in a row to get the net impact value, we don't include the (/) because it does not include any change to the net impact score.

Fundamental objectives		Increase coral coverage	Increase key fish populations	Increase clarity of water	Increase buffers for natural disasters	Increase local sustainable fisheries	Increase livelihood of local communities	
Strategies	Indicators	Ha of coral coverage	Fish biomass grams per square meter	Depth (meters) Secchi disc is visible	Kilometers squared of mangrove coverage	Rate of illegal fishing	Average household income	Net impact

					in buffer area			
Create better waste management plan/ increase funding		+	+	+	+	/	+	5
Place buffer zones (mangroves)		/	/	+	+	/	+	3
Enforce reduction of over fertilization		+	+	+	+	/	-	3
Increase awareness of threats to GSR		+	+	+	/	+	/	3
Increase enforcement of MPAs		+	+	+	+	+	-	5
Daily catch restrictions		+	+	+	+	+	-	5
Limit single use plastic in tourism industry		+	+	+	/	+	-	3
Place/enforce zoning laws (restrict development on coast)		+	/	+	+	/	-	3
Enforce policies to reduce illegal mining/reuse mining waste		+	+	+	+	/	-	4
No action		-	-	-	-	-	-	-6

*Table 4 - Consequence Table*

### Multiple Criteria Decision Analysis

The Multiple Criteria Decision Analysis (Table 5) looks at the fundamental objectives (FO) and strategies and weighs them on a scale of 1 to 5 with 1 being the lowest and 5 being the

highest priority for (FO) and 1 to 10 with 1 being the lowest and 10 being the highest for strategies. These ratings are based on stakeholder preference and what planners find most important for conservation of the Great Reef System (GRS) in Fiji. To calculate the total scores, the weight (1-5) of (FO) was multiplied by the score (1-10) given to each of the strategies options then adding up the row.

<b>Fundamental objectives</b> Weight (1-5)	Increase coral coverage (5)	Increase key fish populations (5)	Increase clarity of water (3)	Increase buffers for natural disasters (4)	Increase local sustainable fisheries (4)	Increase livelihood of local communities (5)	
<b>Strategies</b> Weight (1-10)							<b>Total</b>
Create better waste management plan/ increase funding	8 (40)	8 (40)	10 (30)	2 (8)	4 (16)	6 (30)	164
Place buffer zones (mangroves)	8 (40)	7 (35)	7 (21)	10 (40)	4 (16)	7 (35)	187
Enforce reduction of over fertilization	8 (40)	6 (30)	10 (30)	1 (4)	2 (8)	5 (35)	147
Increase awareness of threats to GSR	7 (35)	6 (30)	7 (21)	7 (28)	7 (28)	8 (40)	182
Increase enforcement of MPAs	7 (35)	9 (45)	8 (24)	7 (28)	7 (28)	7 (35)	195
Daily catch restrictions	6 (30)	10 (50)	6 (18)	3 (12)	8 (32)	5 (35)	177
Limit single use plastic in tourism industry	7 (35)	8 (40)	8 (24)	4 (16)	3 (12)	4 (20)	147
Place/enforce zoning laws (restrict	10 (50)	8 (40)	9 (27)	10 (40)	7 (28)	7 (35)	220

development on coast)							
Enforce policies to reduce illegal mining/reuse mining waste	10 (50)	9 (45)	10 (30)	7 (28)	8 (32)	8 (40)	225
No action	1 (5)	1 (5)	1 (3)	1 (4)	1 (4)	1 (5)	26

*Table 5 - x Multiple Criteria Decision Analysis*

We took the fundamental objectives (FO) and strategies from the consequence table (*Table 4*) and incorporated them into the multiple criteria decision analysis table (*Table 5*). We did this in order to determine which strategy would be most effective once implemented. Looking at *Table 5* we see that the most effective strategy would be enforcing policies to reduce illegal mining/reusing mining waste, followed by place/enforce zoning laws and increasing enforcement of Marine Protected Areas (MPAs).

The implementation of the reducing illegal mining and reuse of mining waste would allow for less pollution of waterways and land areas. Reducing illegal mining would allow for the government and other organizations to keep track of sites being used, and potentially who is responsible for certain runoff or mining waste. Reusing mining waste could take on many forms, some of the ones we would incorporate include but are not limited to: construction materials, and mine water can be treated and used for particulate suppression, agricultural use or as a coolant. (ITRC, n.d.). This strategy would allow for an increase in water quality which would allow for different species of fish to populate the area while also allowing for an increase in coral cover.

Zoning laws place prohibitions on specific land uses that are deemed harmful to the environment and public health. By having these laws enforced more strictly we can limit the development of coastal areas for uses that cause air and water pollution. For example, zoning laws can encourage the building of homes and businesses that meet renewable energy standards.

The development and enforcement of MPAs would allow for growth of biodiversity of marine species in the Great Reef System. The addition and enforcement of MPAs would see a decline in overfishing, allowing for certain species of fish to reach healthy population levels.

This strategy would help the Fiji national government in meeting their goal of 30% of their ocean becoming MPAs.

These three strategies are the most effective in meeting our fundamental objectives due to ranking the highest among stakeholder interests. By prioritizing the enforcement of policies to reduce illegal mining/reusing mining waste, place/enforce zoning laws and increasing enforcement of Marine Protected Areas we will address biodiversity loss, coral coverage, and provide community members with a higher standard of living. These strategies will be implemented through partnerships with residents of Fiji, non government organizations and local/municipal and national government.

## **Data and Knowledge**

The data that needs to be used in the planning should incorporate the local Fijian knowledge, data on the threats to the reef, and data on the biotic and abiotic factors of the reef.

Local Fijian knowledge would aid in identifying the services that the reef provides to local communities. The Great Sea Reef (GSR) provides fish, income from tourists, and cultural significance to the local communities. Taking qualitative reports of the community and their needs is important to maintaining a fair living environment when conserving an ecosystem. The locations of local communities along the coast of Fiji could also give insight on where creating buffer zones can benefit the GSR as well as the communities.

Data on the threats that impact the reef are crucial to identifying causes and how to mitigate them. An example of one of the threats is that of ocean warming and acidification. This threat envelopes a large scope as multiple international factors cause ocean warming and acidification. It is important to have the information of how much the ocean is warming and acidifying to plan ahead in the case CO<sub>2</sub> emissions goals set by climate treaties aren't met. Data on ocean water temperature and pH levels of the water in the GSR could be used to identify how great the impact these factors have on the GSR.

An example from our plan that is at a smaller scope is that of pollution. Pollution is generally created locally. In the case of Fiji, mining operations and plastic pollution are a threat to the health of the GSR. Data on the mining runoff and who is producing it is important to mitigate the impact of harmful metals and chemicals being released into the GSR. The data can be used to implement taxes and caps to mining companies that are dumping waste into the GSR.

Knowing which biotic species live in the GSR and which are endangered due to threats to the ecosystem is crucial to focusing conservation efforts on specific species. Decreases in population can serve as a marker to which species need focus. Knowing the abiotic feature of the environment and the changes that threats have on it can also serve as an indicator of how changes in the environment impacts natural processes and species. An example of an abiotic feature that can be tracked that is known to cause negative impacts on aquatic ecosystems is agricultural runoff which can cause dead zones and algae blooms from the increase of nutrients in the water. The data that can be monitored to increase conservation accuracy is that of nutrient composition at river mouths.

## **Risks and Uncertainties**

Conservation planning and management projects are subject to a multiplicity of risks and uncertainties. The Great Sea Reef (GSR) in Fiji faces numerous threats and pressures that can be difficult to predict and monitor and that contribute to increasing uncertainty surrounding conservation efforts. Acknowledging the presence of risks and uncertainties helps us build a more resilient conservation plan which takes into account the possible unpredictable hazards in the area. This enables us to think about solutions ahead of the problems and thus ensure the welfare of restoration efforts. Risks and uncertainties regarding the GSR are listed below from severe to moderate.

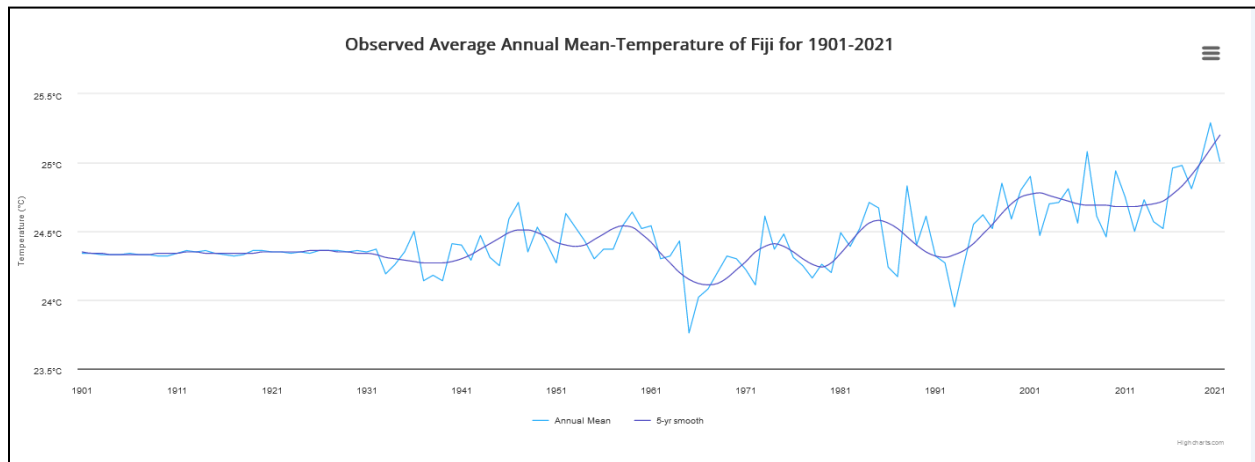
### Risk 1: Global Climate Change - severe

Uncertainties in regards to the effects of climate change on the area are severe. Indeed, not only hurricanes are particularly detrimental to the GSR, but also, sudden changes in weather conditions can affect the ecosystem. As an example, coral bleaching is caused by rising sea temperatures and exposure to sunlight. So far fortunately, high temperatures have only happened during cyclone season, when the sky is cloudy (Bhattacharyya, 2020). But a slight change in weather conditions or the deregulation of weather cycles because of climate change could change the trend and cause corals to drive out algae.

Rising sea temperature is caused by the heat trapping effect that CO<sub>2</sub> and other greenhouse gasses as well as the radiative force of the sun being increased due to the melting of



permafrost ice, glaciers, and icebergs. These two forces aid in the increasing rate of coral bleaching. As seen in figure two, the local annual mean temperature in Fiji has increased since 1901. These issues can't be dealt with directly through a conservation plan but rather through public



*Figure 2: Graph of Average Annual Mean-Temperature for Fiji*  
Source: Fiji's Great Sea Reef: The first marine biodiversity survey

### Risk 2: Lack of stakeholder engagement : Industries Opposition and Government Enforcement - moderate

The fishing and tourism industries both have detrimental impacts on the GSR ecosystems and organisms. However, while the tourism and agricultural industries are the backbone of Fiji's economy, the fishing sectors contribute around 2.8 percent to Fiji's GDP with most of their products being exported to Japan, China, and Thailand. Since those fishing, agricultural, and tourism companies rely on the reef to make profit and often do not comply with regulations, their willingness to cooperate with conservation efforts is very uncertain. But, in order to ensure the success of conservation initiatives, the engagement and compliance of every stakeholder is necessary. Planners need to find common interests and advantages between all parties involved in the exploitation of the GSR to guarantee the favorable outcomes of the conservation initiatives. The aid of the government is also needed to enforce regulations and stop illegal fishing, agricultural, and tourism activities. Taking into account the interests and benefits of the different stakeholders and offering alternatives to unsustainable practices would greatly diminish the uncertainties regarding stakeholders engagement in conservation efforts.

### Risk 3: Insufficient Data & knowledge

Data about the GSR in Fiji is limited compared to other more famous barrier reefs. The “first ever systematic effort to document the marine biodiversity of the Great Sea Reef” (WWF, 2007) was a survey conducted in December 2004. This survey expedition lasted 12 days and resulted in finding that the GSR has 55% of the known coral reef fish in Fiji, 74% of the known coral species, and 40% of all known marine flora, and 44% of Fiji’s endemic reef species. Before this there was limited data on the biodiversity of the GSR. This survey is currently the main source of information many government organizations, non-government organizations, and researchers use to base environmental policy and conservation efforts on.

### Responding to risks and uncertainties

- Conducting more marine observation surveys
- Regular monitoring of important abiotic factors (salinity, temperature, nutrients, etc.)
- Public engagement surveys
- Enforcing laws and regulations on marine protected areas (MPAs)

## **Conclusion**

Although resilient, the Great Sea Reef needs protection, as it is threatened by a variety of factors. A conservation plan supporting the sustainable management of coastal ecosystems in the Great Sea Reef is integral in order to maintain and restore its crucial biological diversity. The habitats provided by the reef support many populations of important reef fish and other species, many of which have become threatened or endangered. The reef, as well as the coastal ecosystems it supports, are vital not only to the surrounding environment, but to local and indigenous communities whose livelihoods are dependent on the health of this vast barrier reef. By conserving populations of marine species, mangroves, and corals, this will stabilize this ecosystem, boosting its health, productivity, quality, and resilience, especially in the wake of climate change, a great threat to our oceans and reefs.

## **Bibliography**

- Vierus, T. (2020). *The Great Wall of Fiji: Expeditions to the Island Nation's Barrier Reef*.
- Gillett, R., Lewis, A., & Cartwright, I. (n.d.). *Coastal fisheries in Fiji resources, issues, and enhancement of the role of the Fisheries Department. A review supported by the David and Lucile Packard Foundation*. Suva, Fiji.
- *How Does the Water Quality Affect Coral Reefs?*” Encounter Edu, [encounteredu.com/cpd/subject-updates/learn-more-how-does-water-quality-affect-the-coral-reefs](https://encounteredu.com/cpd/subject-updates/learn-more-how-does-water-quality-affect-the-coral-reefs). (n.d.).
- Fiji- Vulnerability. (n.d.). *Climate Change Knowledge Portal*, [climateknowledgeportal.worldbank.org/country/fiji/vulnerability](https://climateknowledgeportal.worldbank.org/country/fiji/vulnerability).
- Cameron, C. (2020). Land Cover Change in Mangroves of Fiji: Implications for Climate Change Mitigation and Adaptation in the Pacific. *Environmental Challenges*.
- *How Does Overfishing Threaten Coral Reefs?*” NOAA's National Ocean Service. (2016).
- *As Warming Threatens Reefs, Fragile Fiji Explores Inland Tourism*.” Reuters. (2018).
- Sanctuary, F. (2011). Coral Bleaching and Ocean Acidification Are Two Climate-Related Impacts to Coral Reefs.” How Is Climate Change Affecting Coral Reefs? In [gov/corals/climatethreat.html#:~:text=Ocean acidification slows the rate,storms; and altered ocean circulation](https://www.noaa.gov/corals/climatethreat.html#:~:text=Ocean acidification slows the rate,storms; and altered ocean circulation).
- Madigibuli, A. (n.d.). *The Importance of the Great Sea Reef*.” FijiTimes, [www.fijitimes.com/the-importance-of-the-great-sea-reef](https://www.fijitimes.com/the-importance-of-the-great-sea-reef).
- *Summary on the Marine Plastic Pollution in Fiji, Samoa, and Vanuatu*. (n.d.).
- Conservation International. (n.d.). Retrieved 2 June 2023, from <https://www.conservation.org/>

- Fund, G. C. (n.d.). Green climate fund. Retrieved 2 June 2023, from Green Climate Fund website: <https://www.greenclimate.fund/>
- Fiji. (n.d.). *WWF Study Shows Fish Decline on Fiji's Great Sea Reef - Islands Business*". [islandsbusiness.com/news-break/fiji-great-sea-reef](https://islandsbusiness.com/news-break/fiji-great-sea-reef).
- *Fiji-strong tourism recovery boosts growth prospects*. Export Finance Australia. (n.d.). [https://www.exportfinance.gov.au/resources/world-risk-developments/2022/july/fiji-strong-tourism-recovery-boosts-growth-prospects/#:~:text=Tourism%20is%20important%20to%20Fiji,\(up%200.7%20percentage%20points\)](https://www.exportfinance.gov.au/resources/world-risk-developments/2022/july/fiji-strong-tourism-recovery-boosts-growth-prospects/#:~:text=Tourism%20is%20important%20to%20Fiji,(up%200.7%20percentage%20points)).
- New Insights into the Incredible Animals of Fiji's Great Sea Reef | Stories | WWF." World Wildlife Fund, [www.worldwildlife.org/stories/new-insights-into-the-incredible-animals-of-fiji-s-great-sea-reef](https://www.worldwildlife.org/stories/new-insights-into-the-incredible-animals-of-fiji-s-great-sea-reef). (n.d.).
- *The Great Sea Reef*. WWF. (n.d.). [http://www.wwfpacific.org/what\\_we\\_do/freshwater/the\\_great\\_sea\\_reef/](http://www.wwfpacific.org/what_we_do/freshwater/the_great_sea_reef/)
- Coastal Care. (2011, August 16). *Cakaulevu Reef, Fiji*. Coastal Care. <https://coastalcare.org/2011/08/cakaulevu-reef-fiji/>
- Sullivan, M. (2019, December 31). *Great Sea Reef Resilience Programme: A financially sustainable model for growth and regeneration*. Medium. <https://medium.com/from-the-land/great-sea-reef-resilience-programme-a-financially-sustainable-model-for-growth-and-regeneration-ed504fb47d49>
- Mpatlas.org. (n.d.). MPAtlas " great sea reef of fiji. <https://old.mpatlas.org/campaign/great-sea-reef-of-fiji/>

- *The Great Wall of Fiji: Expeditions to the island nation's Barrier Reef*. Oceanographic. (2020, September 8). <https://oceanographicmagazine.com/features/fiji-great-reef/>
- Fisheries, N. (2023, January 5). *How are fisheries and coral reefs connected?*. NOAA. <http://www.fisheries.noaa.gov/feature-story/how-are-fisheries-and-coral-reefs-connected#:~:text=Fish%20help%20to%20clean%20algae,and%20keep%20pests%20in%20check>
- Environmental Protection Agency. (n.d.). EPA. <http://www.epa.gov/nutrientpollution/sources-and-solutions-agriculture#:~:text=Applying%20fertilizers%20in%20the%20proper,water%20and%20protects%20stream%20banks>
- Plastic waste associated with disease on coral reefs | science. (n.d.). <https://www.science.org/doi/10.1126/science.aar3320>
- *Marine plastic pollution*. IUCN. (n.d.). <http://www.iucn.org/resources/issues-brief/marine-plastic-pollution#:~:text=Marine%20wildlife%20such%20as%20seabirds,to%20swim%2C%20and%20internal%20injuries>
- US Department of Commerce, N. O. and A. A. (2013, June 1). *Anthropogenic threats to corals - corals: NOAA's National Ocean Service Education*. Anthropogenic (Human) Threats to Corals: Corals Tutorial. [https://oceanservice.noaa.gov/education/tutorial\\_corals/coral09\\_humanthreats.html](https://oceanservice.noaa.gov/education/tutorial_corals/coral09_humanthreats.html)
- *Fiji*. Earth Journalism Network. (n.d.). <https://earthjournalism.net/tags/fiji>
- . Kumar, S., Islam, A. R., Hasanuzzaman, Md., Salam, R., Islam, Md. S., Khan, R., Rahman, M. S., Pal, S. C., Ali, M. M., Idris, A. M., Gustave, W., & Elbeltagi, A. (2022). Potentially toxic elemental contamination in Wainivesi River, Fiji impacted by gold-mining activities using chemometric tools and SOM analysis. *Environmental*

*Science and Pollution Research*, 29(28), 42742–42767.

<https://doi.org/10.1007/s11356-022-18734-w>

- Wiseman, D. (2021, May 31). *Black sand mining pushes Fiji's boundaries*. RNZ.  
<http://www.rnz.co.nz/international/pacific-news/443746/black-sand-mining-pushes-fiji-s-boundaries>
- *The importance of mangrove forests: Diverse ecosystems: AMNH*. American Museum of Natural History. (n.d.).  
<http://www.amnh.org/explore/videos/biodiversity/mangroves-the-roots-of-the-sea/why-mangroves-matter>
- Green Climate Fund. (2023, January 30). *Coral Reef Resiliency Program*. Green Climate Fund. <https://www.greenclimate.fund/document/coral-reef-resiliency-program>
- *Supporting sustainable fisheries and protected areas in Fiji*. Oceans 5. (n.d.).  
<https://www.oceans5.org/project/supporting-sustainable-fisheries-and-protected-areas-in-fiji/>
- Mining Waste Treatment Technology Selection. (n.d.).  
<https://projects.itrcweb.org/miningwaste-guidance/#:~:text=Additionally%2C%20solid%20mine%20wastes%20have,and%20in%20numerous%20other%20ways.>
- The Great Sea Reef Weaving Together Conservation. (n.d.-b).  
[https://wwfint.awsassets.panda.org/downloads/great\\_sea\\_reef\\_case\\_study.pdf](https://wwfint.awsassets.panda.org/downloads/great_sea_reef_case_study.pdf)
- Institute for Marine Remote Sensing, University of South Florida (IMaRS/USF), Institut de Recherche pour le Développement (IRD), UNEP-WCMC, The WorldFish Center, and WRI, 2011. Global Coral Reefs composite dataset compiled from multiple sources for

use in the Reefs at Risk Revisited project incorporating products from the Millennium Coral Reef Mapping Project prepared by IMaRS/USF and IRD.

- *Fiji's Great Sea Reef: The first marine biodiversity survey*. WWF. (n.d.-a).

<https://www.wwf.eu/?102860%2FFijis-Great-Sea-Reef-The-first-marine-biodiversity-survey>