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Understanding human impacts on the marine environment in Fiji: insights from an ODEMM conceptual model and semi-structured interviews

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UNDERSTANDING HUMAN IMPACTS ON THE MARINE ENVIRONMENT IN FIJI, INSIGHTS FROM AN ODEMM CONCEPTUAL MODEL, AND SEMI-STRUCTURED INTERVIEWS

By

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Fiji

A dissertation submitted to the World Maritime University in partial fulfillment of the requirements for the reward of the degree of

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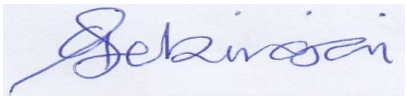
Declaration

I certify that all the material in this dissertation that is not my work has been identified and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views and are not necessarily endorsed by the University.

(Signature): 

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additionally data to this study in Fiji's marine ecosystem (see list of participants in Appendix D: Stakeholder Participant List).

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Abstract

Title of Dissertation: **Understanding Human Impacts on the Marine Environment in Fiji, Insights from an ODEMM Conceptual Model and Semi-structured Interviews.**

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Fiji's marine environment has been subjected to a lot of human activities that impact marine habitats as well as livelihoods for local communities. Conceptual models such as ODEMM are vital in trying to detect the sources of human pressures within the marine ecosystem and find ways for policy and decision-making processes. The purpose of this research is to identify the human activities and their impacts on the ecosystem services and marine environment in Fiji from its main sectors so that it can form be more easily overviewed for potential future use by scientists, communities, industries, and ministries.

In this study, interviews were carried out within expert groups in Fiji with background on the three different sectors Tourism, Fisheries, and Shipping. A workshop was also conducted with the following experts to score these human pressures within Fiji's EEZ formulating this first ODEMM model in Fiji. These expert groups are from the government, NGOs, researchers, and academic departments. These experts then scored the different human pressures outlined in this study with the impacts from different sectors (tourism, fisheries, and shipping) into the marine habitats.

Based on the experts' analysis, it was found that the shipping sector has contributed to the highest amount of impacts within the marine environment. The highest number of human pressures involved within the marine ecosystem is the organic matter/Nitrogen and Phosphorus. These pressures from different sectors pose a lot of threats to coral reefs when marine habitats are analyzed from the results. However, the least pressure that was obtained from the result was the EMF with Radionuclides not present within Fiji's EEZ but are planned for future events from Japan nuclear waste into the Pacific Ocean. Tourism sectors are seen as the least contributing factor within the human pressures where beaches tend to have the least impact on marine habitats within this assessment. Therefore, it is crucial to have effective law enforcement programs on the activities carried out within our marine environment. Also, more support should be given to communities, industries, and partners that contribute more to the management of the marine environment.

KEYWORDS: ODEMM, Conceptual Model, Shipping, Fisheries, Tourism, Human Pressures, Marine Habitats.

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List of Abbreviations

EEZ - Exclusive Economic Zone

FAO - Food and Agriculture Organization

ILO - International Labour Organization

FFA - Pacific Islands Forum Fisheries Agency

NGO - Non-Government Organisation

EIA - Environment Impact Assessment

MPA - Marine Protected Area

MSP - Marine Spatial Planning

ODEMM - Options for Delivering Ecosystem-based Marine Management

ADB - Asian Development Bank

RNZ - Radio New Zealand

GDP - Gross Domestic Product

IFC - International Finance Corporation

IEA - Integrated Ecosystem Assessment

WMU- World Maritime University

REC - Research and Ethics Committee

SDG - Sustainable Development Goals

GOI - Global Ocean Institute

COVID-19 - Coronavirus Disease of 2019

COP 23 -Conference of the Parties 23rd session

WHO - World Health Organization

USP - The University of the South Pacific

IMR - Institute of Marine Resources

MACBIO - Marine and Coastal Biodiversity Management in Pacific Island Countries

PhD - Doctor of Philosophy

IUCN - International Union for Conservation of Nature

FLMMA - Fiji Locally Managed Marine Area

EMF - Electric and magnetic fields

IR - Impact Rank

MES - Mamanuca Environment Society

PAFCO - Pacific Fishing Company Pte Limited

WCS - World Conservation Society

CI - Conservation International, Fiji

WWF - World Wide Fund for Nature

SIDS - Small Island Developing States

CSV – Comma-separated Values

1. Introduction

1.1. Ecosystem services and their impacts on Fiji's marine ecosystem

Marine habitats play an important role in sustaining the marine environment by providing shelter and food to the marine organisms within the marine ecosystem. However, these habitats are also under threat by human activities including climate change. Fiji is located in the South Pacific with its estimated Exclusive Economic Zone (EEZ) of around 1,290,000 km2 (Fandom, 2020). Fiji's marine environment provides many valuable ecosystem services. Some of these services include cultural, regulating, provisioning, and supporting services (Atkinson et al., 2016). These are currently under threat from human activities, some of which are under Fiji's control, while others are less so. Some of the threats are the increase in pollution, overfishing, coastal developments from sectors such as fisheries, tourism, and shipping within Fiji.

Fiji's Mangroves, coral reefs, seagrasses, estuaries, and beaches are some of the habitats affected by human pressures. Mangroves are said to be a vital source of terrestrial and marine ecosystem services in Fiji and are an important habitat for several marine species, functioning as fish nurseries (Sheaves, 2017). In the Pacific, Fiji harbors the third largest mangrove area with a region totaling 435 km2 of mangrove, home to eight different mangrove species and one hybrid mangrove species (Pearson, McNamara, & Nunn, 2019). Ecosystem services provided by mangroves assist humans in various ways from coastal protection to fisheries, biodiversity, and carbon storage (Olson et al., 2010). Some other benefits of mangroves include an increase in fish diversity by acting as nursery grounds for fish species which produces more biomass for commercial and subsistence fisheries (Ellison & Fiu, 2010).

Furthermore, Fiji's coral reef environment is extensive in the South Pacific and gives fisheries and the tourism industry opportunities that are essential to the contribution of the nation's GDP and vital to the prosperity, culture, and endurance of coastal communities in Fiji (Reef Resilience Network, 2019). These coral reefs are under stress in Fiji with direct climate change effects from induced human activities with increased sediment loading, organic and inorganic pollution, and overexploitation (Ellison & Fiu, 2010). The coral coast on the western side of Viti Levu is the longest fringing reef in Fiji which is also the most populated area as it is being used for tourists. These reefs are affected by the overfishing within the region, coastal developments due to tourism, and also climate change impacts undermining the foundation of the nation's economy and the business and food security within coastal communities (Reef Resilience Network, 2019).

Other marine habitats in Fiji that are under stress are beaches, seagrasses, and estuaries. In Fiji, seagrasses are mainly found in intertidal and shallow subtidal marine waters contributing more to the fisheries sector and livelihoods of the local communities (McKenzie & Yoshida, 2020). They also act as coastal protection, contribute to nutrient cycling as well as carbon sequestration within the marine ecosystem. They are considered the most economically valuable ecosystem in the world in which most of the marine organisms and local communities depend on a source of income, food, and habitats (Reynolds, 2018). However, due to urbanization and civilization, these habitats are affected by most anthropogenic activities. Some of these impacts are from industry's runoff, coastal development, discharge of wastes (litter pollution) and sewage wastes, cyclones, and temperature (McKenzie & Yoshida, 2020).

Additionally, estuaries provide a lot of support to marine organisms within freshwater and seawater species. Estuaries are majorly impacted by tourism developments, which impact biodiversity in these vulnerable ecosystems. Major impacts arise from the number of dredging activities done within the area with

digging up the underlying sediment that can negatively affect all the plants and animals that live in and around estuaries (Silaitoga, 2020).
They are also seen as vital habitats for ray species and juvenile sharks in Fiji (Silaitoga, 2020). Hence, it is important to protect marine habitats for sustaining the nation's future through healthy marine biodiversity.

Finally, beaches are seen as a way of attracting tourists in Fiji with their nice and sandy beaches. They are often used for recreational activities and also acts as habitats for most organisms and plants (EPA, 2021). They also act as coastal protection from sea-level rise and saltwater inundation. However, they are more vulnerable to pollution and coastal developments impacting marine biodiversity destroying the habitats of marine organisms leading to a decrease in the local economic benefits.

All these marine habitats described above provide habitats and nursery grounds to many marine organisms. Thus, it is crucial to protect the marine habitats as it provides important ecosystem services to humankind who are the major contributors of impacts onto the marine ecosystem. This study will focus on three major sectors which exert pressure on Fiji's marine environment. These pressures are based on the human activities from the three main sectors (tourism, fisheries, and shipping) within Fiji's EEZ.

1.2. Conceptual Overview with Linkages Between Human Pressures, Habitats and Sectors in Fiji.

A conceptual overview of the linkages between human activities and impacts or pressures and ecosystem components (e.g. habitats) and their services can help to provide a holistic picture for ecosystem-based management of Fiji's EEZ. Different sectors have different approaches in trying to sustain livelihoods and generate revenue/profit which contributes to the impacts of the marine environment from human pressures. The decreasing supply of fish stocks due to overfishing impacts the economic base of the coastal communities that depend on this marine environment

(Bernal, et al., 2016). Shipping has contributed to both ballast water and anti-fouling systems where invasive species are found underwater noise, and oil pollution that leads to the death of marine organisms in the marine environment (RNZ, 2019). Fiji has confirmed a recent invasive species due to this ballast water and anti-fouling system which is the red swamp crayfish also known as the vormers (RNZ, 2019). These invasive species cause serious biological and financial effects, for example, by feeding on local plants and creatures, and competing with other oceanic species for space, harming dykes and waterways in rice fields because of its tunneling movement (Goldberg & Wilkinson, 2004) (Oficialdegui, 2020) which will heavily impact the different trophic levels within the ecosystem.

Moreover, tourism has impacted the marine environment. Tourism activities such as snorkeling, game fishing, direct pressures such as touching/tripping over with diving, or (mainly) destructive fishing practices and pollution have impacts on the marine ecosystem in Fiji (Hooper, 2005). Therefore, it has also been seen as a major contributor to the loss of biodiversity in the marine environment (Tyllianakis et al., 2019). Thus, generating money from these industries will increase impacts on the environment and biodiversity as a whole if not managed to be used sustainably.

These sectors contribute to most of the economic impacts in the region. Tourism is the main revenue creator in Fiji generating about 38 percent of the country's GDP (IFC, 2020). Due to the increase in demand from tourists, land developments and coastal developments have been a major priority for Fiji. These include the building of hotels, marinas, roads, bridges, and other tourist attraction sites. In these, it creates businesses locally and also employment opportunities (Harrison & Prasad, 2013).

Likewise, the fisheries sector is important in Fiji’s economy as it creates employment, food & livelihoods which it also associates with the tourism sector due to the management of MPA and fisheries resources in a way forward for sustainable tourism (Kitolelei, Torii, & Bideshi, 2011). In these, fish and fishing activities

contribute to the food consumption of residents (FAO, 2016). Fishing ships in Fiji are also there to create businesses and employment where enforcement in regulations and governance are essential for the protection of fisheries and their resources. Fiji is for instance also a member of the Pacific Islands Forum Fisheries Agency (FFA) (FAO & ILO, 2016).

Moreover, shipping industries interlink with fisheries and tourism in the transportation of fisheries and tourism activities within the ocean. As maritime trade increases in exporting and importing goods, the shipping industry also increases in providing job opportunities and businesses across the region which mainly serves as the backbone of Fiji's economy (ADB, 2019). Therefore, shipping is very critical in terms of revenue when it comes to the increase in the export market due to the vast area of ocean Fiji has and the small population within the country.

Furthermore, dredging has been one of the common anthropogenic activities when it comes to land developments in Fiji. It has been claimed that there is an increase in sedimentation that leads to the loss of seagrass vegetation in the marine environment in Fiji (Erftemeijer & Robin Lewis, 2006). The release of sediment-bound metals from these dredging activities into the water can heavily impact many marine organisms within the marine ecosystem in which there is a lot of sediments, corals die and when marine habitats die, organisms die as well. (Guerra, Pasteris, & Ponti, 2009). This shows the need to focus on the amount of these activities which needs to be managed properly with different instruments to protect the marine ecosystem.

Moreover, pollution from land-based sources is a major pressure on the marine ecosystem. Pollution impacting the waters around Fiji includes wastes from industries and also land runoffs that lead to eutrophication into the marine environment destroying coral reef health (Sykes & Lovell, 2009). Other pollution source contributors are food waste from people and plastic pollution which is now a serious concern in Fiji. Due to the increased population, tourism, and related food

consumption within Fiji, plastics tend to be found in most of the marine environments in Fiji. These plastic wastes then disintegrate into microplastics that fish feed on, leading to more effects on higher levels of the food chain (Galloway, Cole, & Lewis, 2017). Microplastics bio-accumulate and thus move up the food chain, microplastics are in most of the fish consumed by humans, consequences of eating microplastics are still largely uncertain (Thiele & Hudson, 2021), but there are some indications fish that consume microplastics have fewer offspring (Martins & Guilhermino, 2018).

The impacts of these anthropogenic activities on the marine environment and ecosystem services within Fiji also impact the social and economic aspects of the marine environment (Bernal, et al., 2016). In these, it is very important to protect our marine environment and to understand the value it has for the nation. A conceptual overview of the linkages between human activities and impacts or pressures on the ecosystem components (e.g. habitats, species) and their services would help to provide a holistic picture for management.

1.3. Importance of Conceptual Model (ODEMM)

ODEMM (Options for Delivering Ecosystem-Based Marine Management) is a conceptual model of human activities and pressures and it has been applied in the integrated ecosystem analysis in Irish waters (Pedreschi et al., 2019). ODEMM approach is a tool that conceptualizes ecosystem components and helps in the management of the impacts in human activities on the marine environment and ecosystem services. The ODEMM approach supports the development of an integrated ecosystem assessment that is flexible, cost-efficient, and expert-based (Pedreschi et al., 2019). By scoping and helping to overview the major human activities impacts, an ODEMM approach could help to support marine spatial planning (MSP), marine protected areas (MPA), and environmental impact assessment (EIA) in Fiji.

ODEMM approach is a tool that conceptualizes ecosystem components and helps in the management of the impacts in human activities on the marine environment and ecosystem services. Such a conceptual model does not yet exist for Fiji's marine environment but could support marine spatial planning (MSP), marine protected areas (MPA), and environmental impact assessment (EIA) in Fiji. Here, I develop an ODEMM model to scope out the human activities that mainly affect the marine environment and its ecosystem services, with the three sectors (shipping, fishing, and tourism) in Fiji. It detects simply the different sectors that affect the marine environment with pressures and the ecological characteristics that are then impacted by the identified pressures. Also, it offers an extensive and versatile material to direct the management of ecosystems towards policymakers by showing sectors with a disproportionate amount of impact or ecosystem components most at risk. These are obvious needs for the decision-making processes towards management options and research within the marine environment (Pedreschi et al., 2019).

This research aims to identify the human activities and their impacts on the ecosystem services and marine environment in Fiji from its main sectors so that it can be more easily overviewed for potential future use by scientists, communities, industries, and ministries.

More specifically, this research will address the following questions:

- How do tourism, fisheries & shipping sectors benefit from the habitats, and which challenges do these sectors get from those habitats?
- How are ecosystems and their ecosystem services impacted by human activities in Fiji?
- What activities are happening currently and where? Can share and show pictures of maps e.g. of habitats, coral reefs, mangrove, seagrass, saltmarsh, beaches/dunes, estuaries, etc.
- Which activities and impacts could happen in the future, where are they concentrated, and possibly when?

- How could ODEMM be used for conceptualizing human impacts on ecosystems?

Anthropogenic activities gradually increased over the past years due to urbanization and industrialization. These activities have caused many challenges to the marine ecosystem. These include pollution activities from humans, overfishing, dredging, land reclamation, and other land developments. Further developments need to be done in a way that is more sustainable to the marine environment. Further, it would be very useful to know what pressures may be on the way (future threats) on Fiji's marine environment. This dissertation will therefore interview key stakeholders' experts about the potential development or trajectories for human activities in the Fiji marine environment. A workshop will also be carried out in scoring the appropriate linkages between the different sectors, pressures, and marine habitats within Fiji's EEZ. Hence, the vital role of experts on the marine ecosystem in Fiji for constructing this first ODEMM model in the country for future management and decision making within our marine ecosystem.

2.0 Methodology

In this thesis, I used a combination of two qualitative approaches. First, I conducted interviews with a set of participants, and second, I conducted an ODEMM analysis/risk assessment for the Fijian marine ecosystem. The interview approach was to have a background idea of the current human activities and future activities within Fiji's EEZ for shipping, fishing, and tourism. The second approach developed an ODEMM analysis based on a literature review, interview responses, an expert workshop, and subsequent analyses.

2.1. Semi-structured Interview Analysis

2.1.1. Interview Questions

I conducted semi-structured interviews with 9 expert panelists from the three different sectors in Fiji. These experts are from academia & research, government, private backgrounds with their different expert backgrounds on Fiji's marine ecosystem. Interviews were done within an hour using Zoom, I recorded each interview. During the interview, experts were asked open-ended questions which enabled experts to interpret the current and future planned human pressures within Fiji's marine ecosystem. The interview questions are as follows:

1. What human activities are happening currently and where?
2. How do tourism, fisheries & shipping sectors benefit from the habitats, and which challenges do these sectors get from those habitats?
3. Are you aware of any human activities (tourism, fishing, shipping) that interfere with the benefits you receive from these habitats? Are the habitats threatened in any way?
4. Are you aware of any future activities planned for tourism, shipping, and fishing in this area? Where are they located?
5. Is there anything else you would like to share with me relating to the research topic?

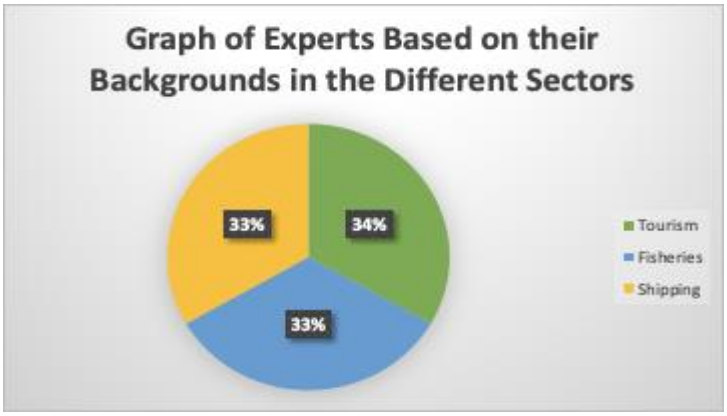


Figure 1: The percentage of the 9 different experts with their backgrounds on the tourism, fisheries and shipping sectors.

2.1.2. Ethics Approval

I presented the interview questions to World Maritime University (WMU) for ethics clearance. In these, information sheets, consent forms, and interview questions were submitted to the Research and Ethics Committee (REC) in the WMU, expert panelists were guaranteed anonymity. Consent forms were provided to the experts and signed by them before starting the interview sessions. Furthermore, participants were informed that information obtained from this interview would be anonymous and only shared with approval from respective experts. Hence, experts are entitled E1, E2, E3 in the results section in answering the different questions provided.

2.1.3 Interview Participants

This research was carried out by using expert interviewees with expertise in the marine ecosystem in Fiji on tourism, shipping, and fisheries activities. Semi-structured interviews were carried out by using zoom with recorded sessions. Experts from Fiji's marine ecosystem were chosen based on their different projects and background. Their backgrounds are from governments, private, research, and academia which is outlined in the table below.

Table 1: List of Interview Participants.

Expert	Background
1	School of Marine Studies, USP Professor
2	School of Marine Studies, USP Professor
3	IUCN, NGO
4	Researcher, IMR
5	Ministry of Fisheries, Government
6	Faculty of Tourism, USP Professor
7	Research Fellow, USP
8	FLMMA, NGO
9	Maritime Administration, Government

2.1.4 Transcribing, Coding of Themes for Answers

In this study, zoom sessions' video and audio were recorded. The recordings were then stored in different files with separate questions addressed. I then transcribed the video and audio recordings with the use of the otter application (https://otter.ai/) with edited transcription. I then carried out the coding of these transcriptions into themes, specifically related to different habitats' benefits and the major human activities that impact Fiji's marine environment.

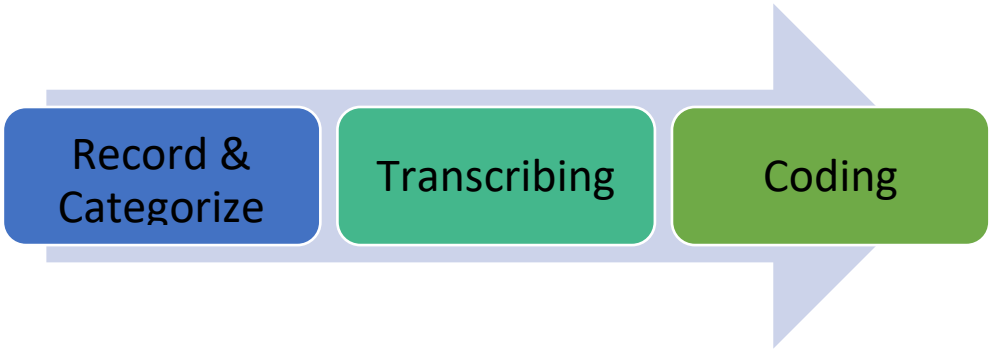


Figure 2: Stages of transcribing and coding in analyzing interviews.

2.1.5 Analysis of interviews

Interview analysis was done on recorded sessions from zoom (see appendix D for the experts' names). These questions were then analyzed based on the current activities and future activities planned within the marine environment in Fiji. I have also analyzed the interviews based on the common themes, new topics addressed and the different issues within the marine ecosystem based on human pressures from the main sectors.

2.2. ODEMM Expert Workshop and Analysis

I also carried out an ODEMM analysis supported by information from the interviews, a literature review, an expert workshop, and are analysis in R to develop an ODEMM conceptual model for Fiji. The methods are explained below. The first step in the ODEMM process was that I carried out a literature review (inspired in part by the interview results) to populate ODEMM pressure scoring sheets to be used in the expert workshop, (described below). The second step was to develop a linkage framework (described below). The third step was that I carried out an expert workshop that discussed and adjusted the scores in the pressure scoring sheets. The last step was the development of the ODEMM conceptual model diagrams using an R script.

2.2.1 Pressure Literature Review

Following (Pedreschi et al., 2019) I carried out a literature review to identify human pressures on the marine environment that could be relevant to Fiji. This literature review included pressures identified during the interviews and those listed in Pedreschi et al., 2019.

Table 2 : List of Human Pressures.

Human Pressures	
Agreed	**Definition**
Sealing	Sealing by permanent construction (e.g. coastal defenses, wind turbines) or change in substrate type due to loss of key characteristic features (physical and/ or biological). Natural substrate loss and replacement by a different kind of substrate. Loss of seal haul-out sites. Exclusion of species from areas due to disturbance (e.g. shipping and marine mammal). Loss of roosting/nesting/foraging areas of the bird. Loss of nursery grounds for fish.
Changes in siltation/ Smothering	Change in the concentration and/or distribution of suspended sediments in the water column from runoff, dredging, etc., or smothering by man-made structures or disposal of materials to the seafloor.
Abrasion	Physical interaction of human activities with the seafloor and with seabed fauna/flora causing physical damage and/or mortality (e.g. from trawling or anchoring), excluding death or injury due to collision. Abrasion may cause damage to spawning grounds.
Non-living Resources	Sand & gravel (aggregates) extraction, or removal of surface substrates for exploration of subsoil.
Noise	Underwater sound from anthropogenic sources (e.g. shipping, fishing, geological investigations, harbor operations).
Litter	Marine litter originates from numerous sources and consists of different materials including metal, glass, rubber, wood, cloth, and plastics (including microparticles of plastics).
Thermal Regime	Change in temperature (average, range, and variability) due to outfalls/industry
Salinity Regime	Change in salinity (average, range, and variability) due to constructions affecting water flow.
Introduction of Contaminating compounds	Introduction of pesticides, antifoulants, pharmaceuticals, heavy metals, hydrocarbons, and radionuclides into marine waters.
Introduction of Radionuclides	Radioactive effluents from nuclear power stations and nuclear fuel reprocessing sites
The input of Organic Matter (including N&P)	Organic enrichment e.g. from industrial and sewage effluent input and/or fertilizers, and other nitrogen & phosphorus rich substances into rivers and coastal areas. Include organic discards e.g. from aquaculture or fishing discards.
Invasive species	Introduction of non-indigenous species and translocations of species by the activities of a particular sector (e.g. through shipping or aquaculture)
Species Extraction	Targeted extraction of species
Bycatch	By-catch of non-target marine fauna as a result of directed species extraction
Incidental Loss of spp.	Ghost Fishing and loss of individuals due to collisions.
Barriers	Preventing the natural movement of motile marine fauna along a key route of travel (e.g. migration or foraging routes) due to barrages, causeways, wind turbines, weirs, and other man-made installations and structures. Preventing the natural movement of motile marine fauna along a key route of travel (e.g. migration or foraging routes) due to barrages, causeways, wind turbines, weirs, and other man-made installations and structures
Change in wave exposure	Changes to the natural sea-level regime (average, range, and variability) due to barrages or other structures. Change in the size, number, distribution, and/or periodicity of waves along a coast due to installation of structures.
Current Changes	Change in currents (speed, direction, and variability) due to barrages or other man-made structures.
pH changes	Change in pH (average, range, or variability) due to runoff from land-based industry and agriculture, aquaculture activities, or point-source discharges. Here, pH changes exclude ocean acidification (i.e. the reduction in pH of the ocean over an extended period, typically decades or longer, caused primarily by the uptake of anthropogenic carbon dioxide from the atmosphere)
Electromagnetic (EMF)	Change in the amount and/or distribution and/or periodicity of electromagnetic energy emitted in a marine area (e.g. from electrical sources such as underwater cables).

2.2.2 Linkage Framework

The second step was I developed a linkage framework. The linkage framework is the approach in which it assesses all impact chains of the pressures, marine habitats, and sectors within the marine ecosystem in Fiji.

From the linkage framework, a metric called proportional connectance is derived. This is all possible(number) linkages (connectance) of different sectors, pressures, and ecological components (habitats). It is calculated as the number of linkages associated with the sector, divided by the total number of linkages in the ecosystem model. A sector/ecosystem component associated with many different pressures will have a high proportional connectance. Likewise, a pressure associated with many different sectors/ecosystem components will have a high proportional connectance.

2.2.3 Filling Out the Pressure Sheets before the workshop.

Following recommendations in Pedreschi et al., 2019, to provide a “straw man” score to the experts in the workshop I developed preliminary scores for the pressure sheets based on the literature review. These would later be shared with experts for further work during the workshop (see below).

Table 3: Pressure Assessment Scoring Categories.

Source: (Pedreschi et al., 2019).

Spatial Overlap	Frequency	Degree of Impact/Severity
Spatial overlap of each activity-pressure combination with an ecosystem component	**Temporal overlap of each activity-pressure combination with an ecosystem component**	**the severity (in terms of likely degree of impact) of any sector/pressure interaction with the ecological component**
No Overlap	**If there is No Overlap, the pressure is linage chain is not considered further in the framework.**	
No overlap between Sector and Ecological Characteristic		
Exogenous	**Rare**	**Low**
The activity occurs outside of the area occupied by the ecosystem component, but one or more of its pressures would reach the ecosystem component through dispersal	A pressure is introduced up to 1 months of the year	Never causes high levels of mortality or habitat loss/ never causes a noticeable effect for the ecosystem component of interest in the area of interaction
Site	**Occasional**	**Chronic**
Sector overlaps an ecological component, but less than 5%	A pressure is introduced up to 4 months of the year	An impact that could have detrimental consequences if it occurs often enough or at high enough levels
Local	**Common**	**Acute**
Sector overlaps an ecological component by more than 5% but less than 50%	A pressure is introduced up to 8 months of the year	A severe impact over a short duration. An interaction that kills a large proportion of individuals and causes an immediate change in the Ecological Characteristic
Widespread	**Persistent**	
Sector overlaps an ecological component by 50% or more with a widespread distribution	A pressure is introduced throughout the year	

2.2.4 ODEMM Expert Workshop Methods

Participants in the workshop were chosen based on the experience they have with the government and other stakeholders within Fiji's marine ecosystem. Most of the work they've carried out is based on the human pressures mentioned in Table 2. The focused group of experts in this workshop was chosen from the interview groups with the highest experience with the marine sector in Fiji. The list of these experts is mentioned in the table below.

Table 4: List of expert groups with background during the ODEMM Workshop.

Expert	Background
1	Faculty of Marine, USP Professor
2	Researcher, USP
3	IUCN, NGO
4	FLMMA, NGO

At the start of the workshop, I provided the experts with my preliminary "straw man" scores and asked them to discuss and adjust as needed during the workshop. During the workshop, the experts adjusted scores and pressures on each ecosystem component based on criteria for spatial overlap of pressures, their frequency, and degree of impact (see table 3 for criteria in scoring the pressure assessment).

Spatial overlap refers to the overlap of the different pressures with certain activities from specific sectors in this research relative to the marine habitats within Fiji's EEZ whereas frequency relates to the consistency (sectors-pressures & marine habitats) of these overlaps within a month or years in the marine ecosystem. However, the degree of impact is the intensity of these overlaps/interactions of the sectors, pressures, and habitats within Fiji's EEZ.

In the workshop, I asked experts to score all possible interactions that are relevant to different pressures, habitats, and sectors in which most of these pressures are not relevant to impact the marine habitats from different activities within the sectors (tourism, fisheries, and shipping) in this study.

2.2.5 Exclusion of Climate Change in ODEMM The Pressure Assessment.

Following the recommendations of Pedreschi et al., 2019, I did not include climate change as a pressure in the IIIODEMM pressure assessment. As with implementations of ODEMM elsewhere, the focus of the ODEMM analysis was pressures that could be managed at a Fijian scale. Climate change impacts would require global-scale management.

2.2.6 Analysis in R

During this analysis in R, the pressure sheet scores obtained from the workshop excel sheets were then downloaded into a CSV file and uploaded into R to map out the different linkages between the sectors, pressures, and marine habitats. R studio was used in the creation of the Horrendogram graphs and box plots graphs.

In addition to the Horrendogram plots, the pressure sheet scores were used to compute several metrics which (in a qualitative manner) indicate the risks associated with the sectors, pressures, and ecosystem components. These metrics are impact rank and impact risk. They are identified as follows:

1) Impact risk: which is the combination of scores from the spatial extent, frequency, and severity criteria (See table 3 for a detailed description of each of the elements), and where the greater the Impact Risk Score, the greater the threat to that component or combination of components.
2) Impact rank: ranking of sectors by impact risk (which is the combination of scores from the spatial extent, frequency, and severity criteria).

2.3. Qualitatively Interpretation of the ODEMM Horrendogram

In this research, scores from the ODEMM Pressure assessments linking all of the sectors, pressures, and habitats were analyzed using R to produce an ODEMM diagram/ typology. Linkages framework were then mapped out into a Horrendogram to provide a high-level overview of what services may be at risk from the existing pressures and to provide a context for consideration of trade-offs in decision-making. Horrendogram graphs were then created for each of the different sectors with each habitat separately but with all the different pressures associated with it.

3.0 Results

3.1 Interview Results

In this study, 9 experts on the marine ecosystem in Fiji were interviewed (Table 1) based on the questions reflected in Appendix A. Based on the interview conducted, experts' panelists outlined some of the activities that affect the marine ecosystem with the future planned activities. Some of the current activities within the marine ecosystem outlined by the different experts are mentioned in Table 5 with the planned activities for the future in Table 6.

Table 5: Some of the current activities that affect the marine environment within the marine ecosystem outlined by the different experts in Fiji.

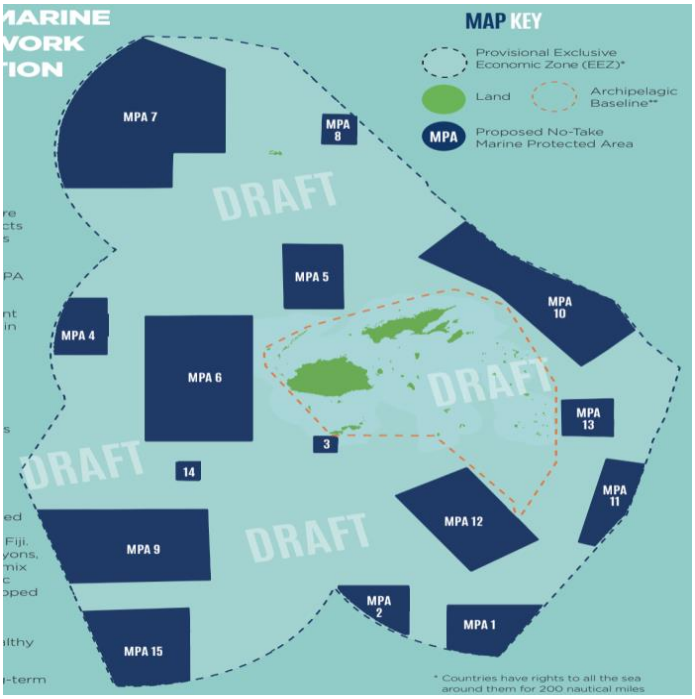
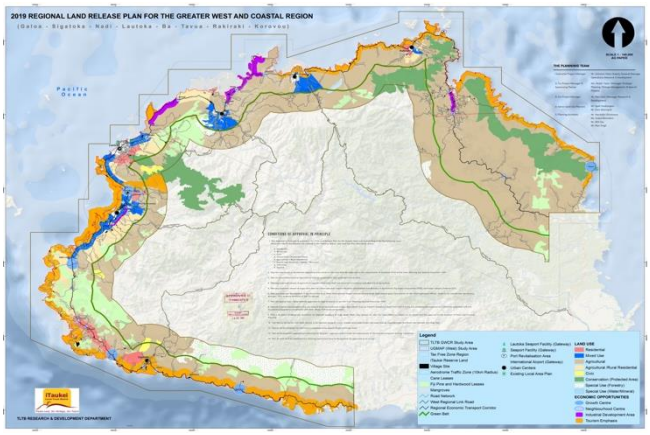
Activity	Picture/Map
1. Fantasy Island development (Man-made Island on the western side of Viti Levu, Fiji)	 Source : (Fantasy Island, 2021)
2. Amex Sand Extraction (Dredging) - Ba River Delta	

	Source :(GREENPAC, 2011)
3. Road constructions (sand extraction)	 Source: (Fiji Roads Authority, 2019)
4. Nasese Bridge Development	 Source: (Chand, 2021)
5. Blue Lane Initiative (Denarau) - VIP yacht COVID-19 travels safely into Denarau, Fiji to assist in the recovery of the ailing tourism industry.,	 Source: (Bains, 2021)
6. Fiji Mangrove salt ponds (Lomawai village)	 Source: (UNDP, 2010)

7. Seaweed farming (Blue economy)	 Source: (Doviverata, 2020)
8. Floating dock for ship repairs (Two floating docks - Suva & Lautoka)	 Source: (Tuimaisala, 2019)

Table 6: List of future planned activities in Fiji that affect the marine ecosystem.

Activity	Picture/Map
1. Blue Town Model (Savusavu)	 i Government, 2020)

2. MPA 30% Offshore Implementation	 Source: (Fiji Government, 2020)
3. Greater West and Coastal Regional Plan	 Source: (TLTB, 2019)

The 9 expert panelists agreed upon having coastal and land developments as a major impact on the marine ecosystem. Academic experts (E1, E2 &E6) in Table 1 highlighted the importance of having a thorough Environmental Impact Assessment before having land developments along with coastal areas. Environmental NGO experts (E3 & E8) also agreed that tourism activities have a greater impact when it comes to developing land and coastal developments. In these, government experts (E5 & E9) suggested that business operators must follow regulations and laws when implementing such developments within the coastal areas.

Furthermore, research experts (E4 & E7) stated the use of road constructions with sand extraction from the beach which is a current activity in Fiji now. They also stated the importance of marine habitats (coral reefs, estuaries, mangroves, seagrass, and beaches) as nursery ground and habitats for marine organisms on which Fiji's fisheries sectors depend. Moreover, most of the experts stated the importance of these habitats for local communities sustaining them with income and livelihoods.

However, most of the experts agreed that due to the increase in urbanization, these habitats are threatened by human pressures. The most commonly noted pressure from hotels and industries was the discharge of sewage wastes that resulted in the growth of unwanted weeds or seaweeds into the marine environment. Another commonly noted pressure is the issue of litter, mainly plastic pollution, into the marine environment. Environmental NGO experts explained the use of MPAs within the coastal areas, shipping activities (fiberglass boats) have a way of damaging the MPAs with the right of freeway passage. All the experts emphasized the importance of the enforcement of laws and regulations when it comes to different human activities within the marine ecosystem in Fiji. All of the experts also agreed that the ODEMM conceptual model will support ecosystem-based management such as EIA, MSP, and MPA, and could be used as a guide to support enforcement.

3.2 ODEMM Workshop

3.2.1 Sectors

Shipping has a higher proportional connectance than tourism and fisheries, meaning that this sector has proportionally the most links to the different pressures. Based on the 20 lists of pressures in Table 2, only 18 pressures were associated with the Shipping sector excluding the introduction of radionuclides and bycatch (Figure 4). Most of these shipping activities are associated with the five different categories mentioned in this research. Hence, the highest rank average, Average Impact Rank (IR), and rank-sum with sum IR are in Table 7. Also, the impact rank is then considered due to the greater overlap of these pressures and habitats with its spatial extent and frequency of occurrence. Fisheries were ranked the second where it associates with the 19 different pressures without the introduction of radionuclides (Figure 5). These pressures were then associated with the 5 categories of marine habitats. Tourism was ranked the lowest sector as it associates with 18 pressures excluding EMF and radionuclides (Figure 6). Thus, the lowest rank average and average IR. As stated in Table 7 below, Total Average Impact Risk (AvgIR) shows the median impact risk scores of the different sectors from pressures and habitats into different variables due to variations in the frequency and overlap from different sectors. The total sum Impact risk score (SumIR) shows the total sum of the frequency and overlap scores in the different sectors mentioned below based on the different activities within the marine habitats in this study. Therefore, the rank average and the rank sum of the different sectors are in the same order from highest to lowest (Shipping, Fisheries, and Tourism).

Table 7: List of sectors with impact average rank and sum rank in Fiji's Marine Environment.

Sector	Rank Average-AvgIR (Total Average Impact Risk)	Rank Sum-SumIR (Total Sum Impact Risk)
Shipping	1	1
Fisheries	2	2
Tourism	3	3

3.2.2 Pressures

From all the pressures scored during the workshop Organic matter/Nitrogen and Phosphorus obtained the highest rank average and Average IR from the 20 pressures included in this study. This is because organic matter has a greater spatial extent and frequency of occurrence within the different sectors and marine habitats resulting in a greater impact on the marine environment. Electric and magnetic fields (EMF) were considered the lowest rank average with average IR within these pressures. This shows the lowest spatial extent and frequency of occurrence for EMF within the different sectors and habitats in this study. The categories on the rank average and average IR of the different pressures are listed in Table 8 and Figure 3 under Pressures. In the top 5 order on Table 8 below based on the average total risk score from highest to lowest (Organic Matter/Nitrogen and Phosphorus (NP), Siltation/ Smothering, Noise, Contaminants, and Non-living resources) whereas in total sum risk scores remain the same order with the inclusion of litter as the 5th highest impact risk (Organic Matter/Nitrogen and Phosphorus (NP), Siltation/ Smothering, Noise, Non-living resources, and litter) based on the frequency and overlap of different activities from different sectors and habitats in this study.

Table 8: List of pressures with its average ranks and sum ranks in Fiji's Marine Ecosystem.

Pressure	Rank Average - AvgIR (Average Total Risk Score)	Rank Sum -SumIR (Total Sum Risk Score)
Organic Matter/Nitrogen and Phosphorus (NP)	1	1
Siltation/ Smothering	2	2
Noise	3	3
Contaminants	4	6
Non-living Resources	5	4
Abrasion	6	7
Litter	7	5
Salinity Regime	8.5	8.5
Thermal Regime	8.5	8.5
Bycatch	10	18
Species Extraction	11	10
Barriers	13.5	11.5
Current Changes	13.5	11.5
pH Changes	13.5	14
Wave Exposure	13.5	13
Invasive Species	16	15
Sealing	17	16
Incidental Loss	18	17
EMF	19	19

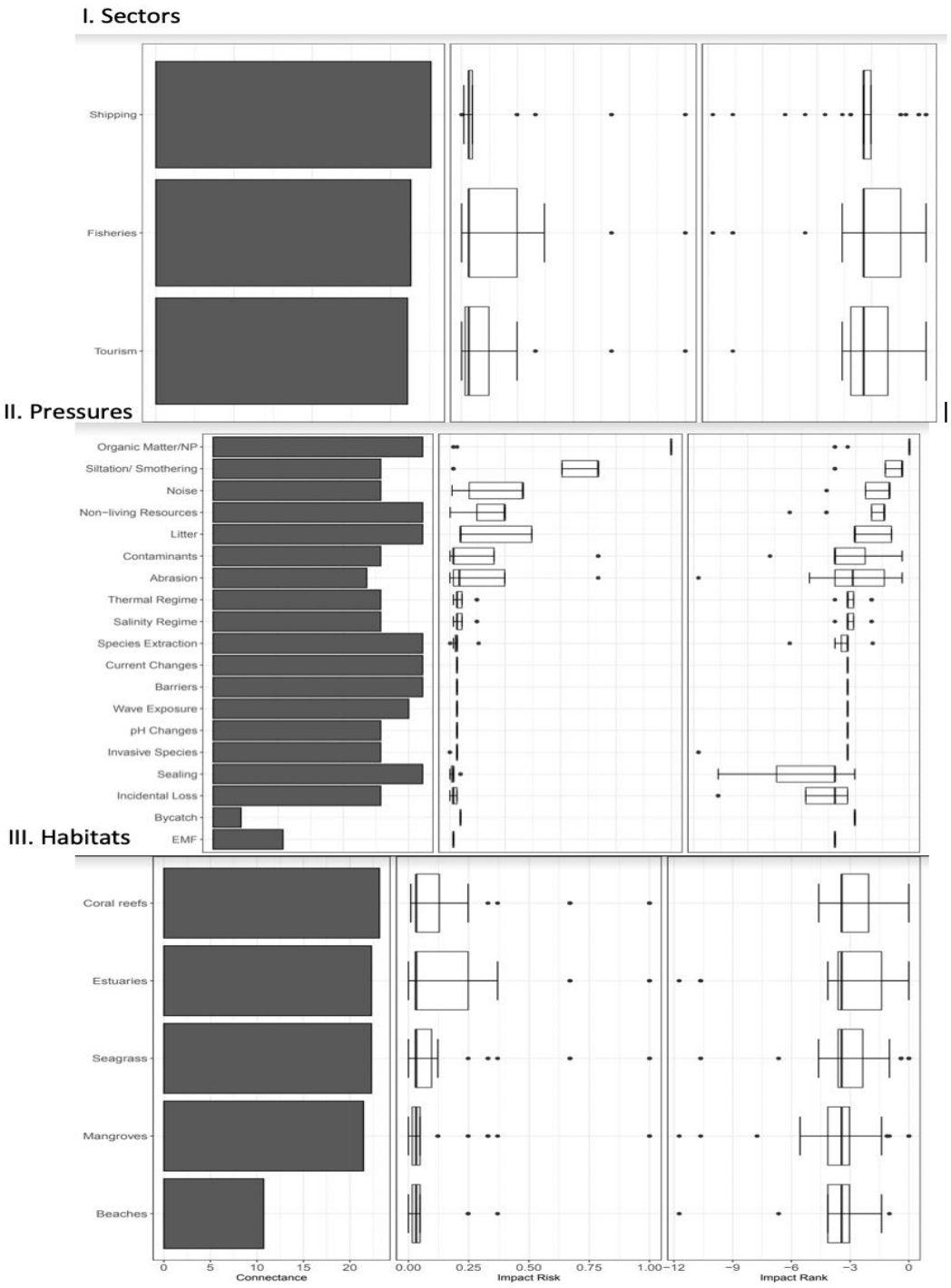


Figure 3: The boxplot graphs of Proportional Connectance, Impact Risk and Impact Rank of I) the different sectors, II) human pressures, and III) marine habitats in Fiji's Marine Ecosystem.

3.2.3 Marine Habitats

There are five marine habitats chosen in this study. Based on the ODEMM scoring by the experts, coral reefs were seen as the highest rank in regards to the different pressures from the different sectors in this study resulting in a higher rank average and average IR. Most of the spatial extent and frequency of occurrence of pressures in this study received higher scores for the coral reefs, resulting in a greater impact rank. Beaches on the other hand tend to be the lowest rank average and average IR associated with the different pressures from the different sectors within the marine environment in Fiji. Hence, the lowest impact rank results from the lower scores for spatial extent and frequency of occurrence for the beaches. Other habitats included and their different impact ranks are summarized in Table 9 and Figure 3. In table 9 below the order is the same from highest to lowest (coral reefs, estuaries, seagrass, mangroves, and beaches) in the total average impact risk and total sum impact risk within the marine habitats.

Table 9: Different ranks (Average and Sum) of the marine habitats in Fiji's Marine Ecosystem.

Marine Habitats	Rank Average- AvgIR (Total average Impact Risk)	Rank Sum- SumIR (Total Sum Impact Risk)
Coral reefs	1	1
Estuaries	2	2
Seagrass	3	3
Mangroves	4	4
Beaches	5	5

3.3 ODEMM Horrendogram

The Horrendogram graphs were divided into different sectors to showcase the overlap of the different pressures with marine habits within these sectors. As shown in Figure 4 under shipping (pink lines) it associates mostly with the 5 categories of marine habitats and 18 pressures without by-catch and radionuclides throughout the scoring. Fisheries and tourism also associate with 18 pressures excluding EMF and radionuclides. Furthermore, Beaches are seen to have the lowest impact from the pressures on the shipping, tourism, and fisheries sectors.

3.3.1 Shipping

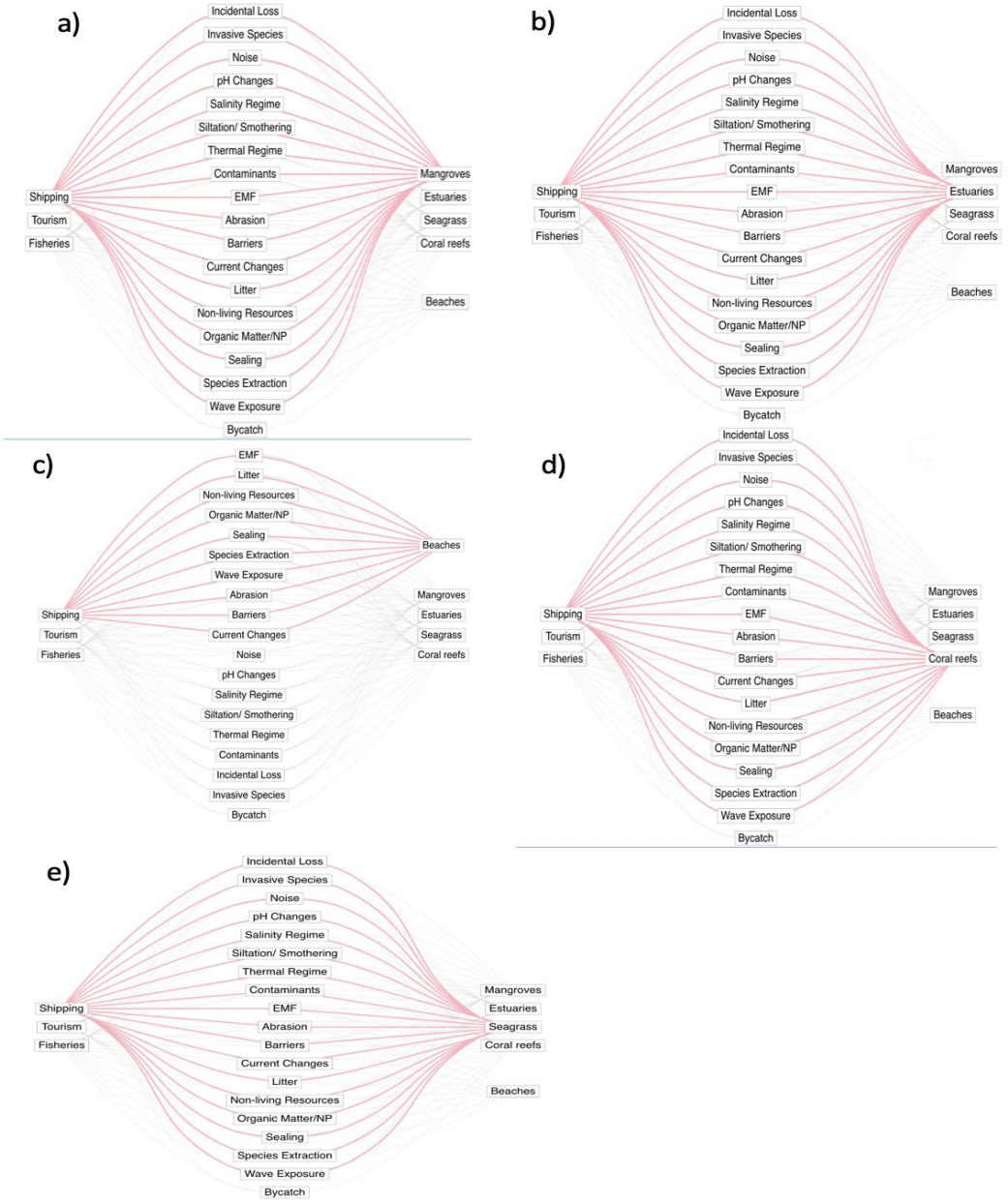


Figure 4: Horrendogram graphs showing the different linkages (pink lines) between shipping sector, pressures, and marine habitats in Fiji's marine ecosystem. For: a) shipping, pressures and mangroves b) shipping, pressures and estuaries c) Shipping, pressures and beaches d) shipping, pressures and coral reefs e) shipping, pressures and seagrass.

3.3.2 Fisheries

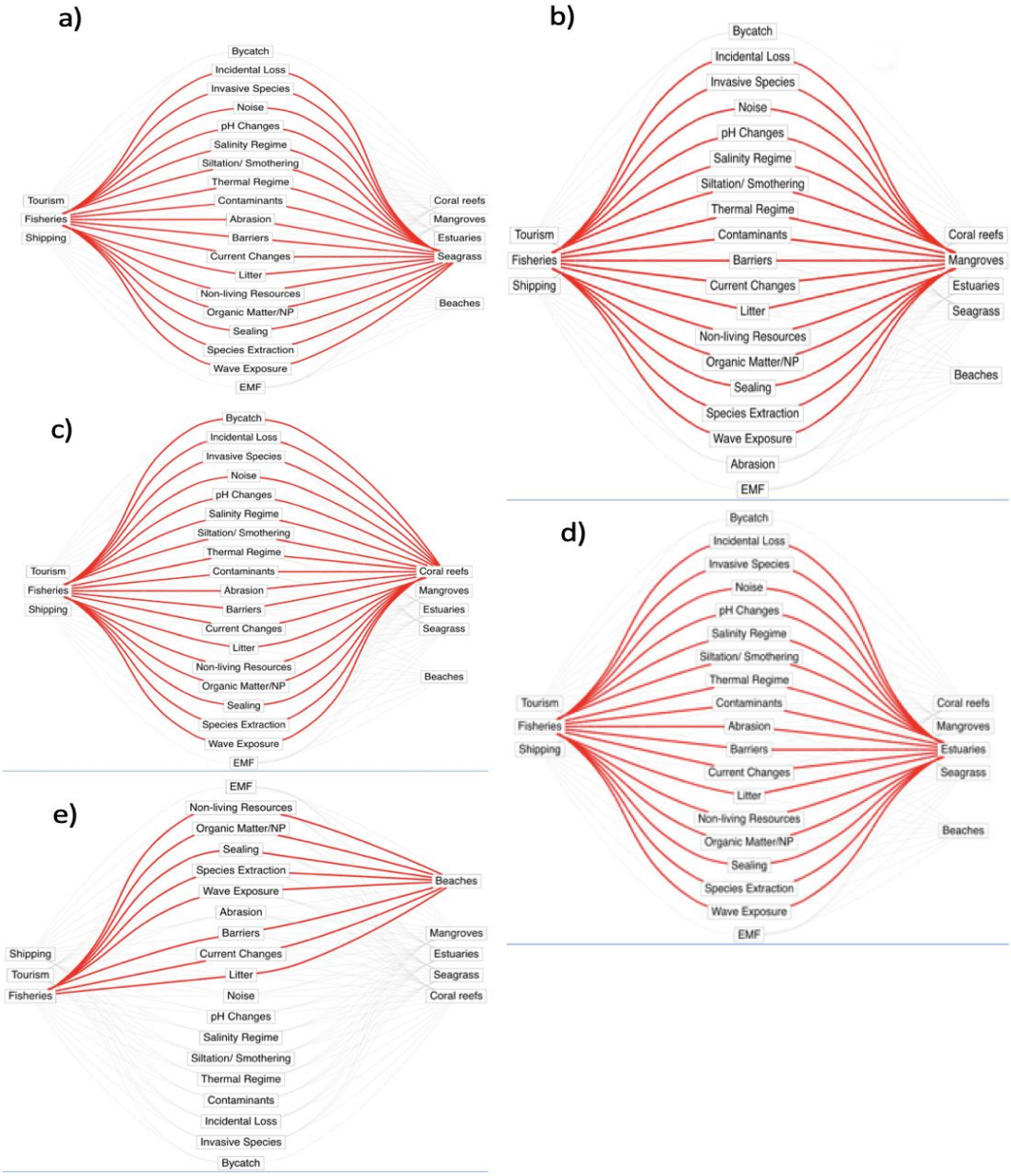


Figure 5: Horrendogram graphs showing the different linkages (red lines) between fisheries sector, pressures and marine habitats in Fiji's marine ecosystem. For: a) Fisheries, pressures and seagrass b) Fisheries, pressures and mangroves c) Fisheries, pressures and coral reefs d) Fisheries, pressures and coral estuaries e) fisheries, pressures and beaches.

3.3.3 Tourism

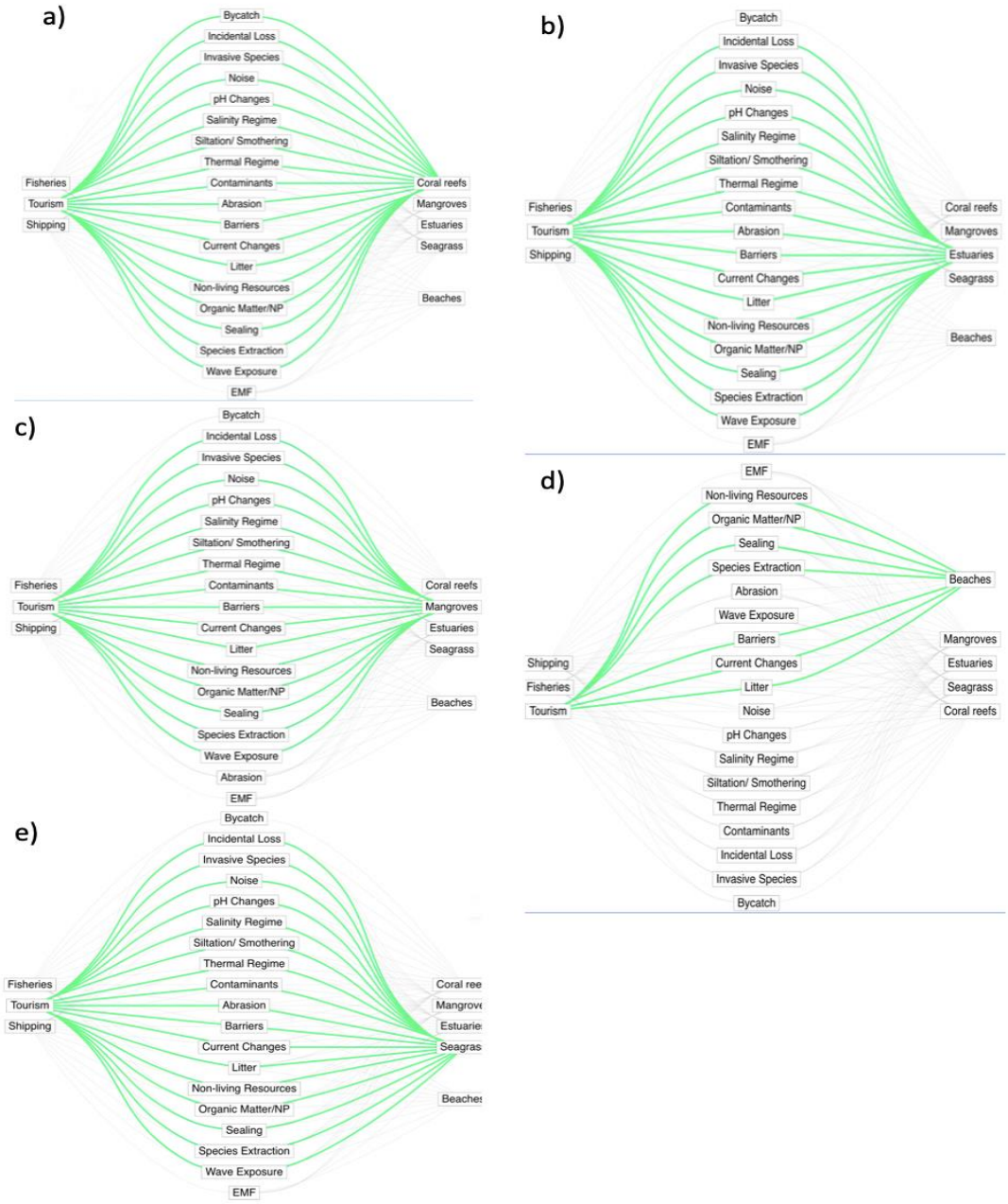


Figure 6: Horrendogram graphs showing the different linkages (green lines) between tourism sector, pressures and marine habitats in Fiji's marine ecosystem. For: a) Tourism, pressures and coral reefs b) Tourism, pressures and estuaries c) Tourism, pressures and mangroves d) Tourism, pressures and beaches e) Tourism, pressures and seagrass.

4.0 Discussion

4.1 Fiji's Marine Ecosystem in ODEMM Approach

Based on the analysis of the three sectors in this study, it was shown that fisheries are linked with the largest number of human pressures on Fiji's marine environment. However, surprisingly, after scoring and grading the pressures associated with marine habitats, the shipping sector was seen as having the highest impact risk from the three sectors assessed in this study as shown in Table 7 and Figure 3. This shows that shipping activities pose a lot of risks to the marine environment with the inclusion of fishing vessels. Some of the activities that pose threats to the marine environment are the development of ports, jetties, and marinas as shipping is a major source of transportation to maritime islands within Fiji. These developments not only benefit the community but also pose threats to the marine habitats and organisms around it.

Moreover, when it comes to scoring the activities during the workshop within Fiji's marine environment, experts show that most of the future developments lead to shipping activities due to this COVID-19 pandemic as a source of transportation locally, regionally, and internationally. In these, the most impact risk and rank is from the shipping industry. They also stated the lack of enforcement strategies within the shipping sector in regards to dumping wastes and pollution into the ecosystem. In the tourism industry, most of the developments are with the use of artificial man-made islands such as Footprint Island (Vuda Landing) and Fantasy Island (Nadi). Other pressures result from the construction of hotels, marinas, etc. Those kinds of creations disturb the natural environment and the consequences are large. Most of the communities are not well aware of the events occurring underneath the sea. An example of an impact underneath the surface during coastal development is a Giant Clam in Gau Island, Fiji after a port construction where it was seen on its side because of all the sediments being exposed into it. Not to mention the other marine organisms that are affected by this as well. Certainly, we know that wherever there is

sediment, corals die. Therefore, it contributes to the domination of seagrass and algae destroying coral reefs. As for fisheries sectors, most of the developments are with the use of fisheries industries such as Pacific Fishing Company Pte Limited (PAFCO) in Levuka which processes Tuna loin and Tuna canning for local and overseas markets. Others are Fiji fish company, Golden Ocean Fish Ltd, Solander, and Seaquest Fiji Limited. Most of these fishing companies are located in coastal areas for easy loading and unloading of fish for processing. In these, most of the industries discharge their wastes into the marine environment elevating the amount of organic matter/Nitrogen and Phosphorus as shown in Table 8 & Figure 3.

Additionally, when it comes to tourism, guests complain about the treatment of wastes being dumped into the sea at night by resorts. Hotels rely heavily on having a nice environment to attract guests, but they have no choice but to dispose of their waste where they are carrying out their operations as the cost of waste management is very high in developing countries such as Fiji. In these, most of the island resorts have challenges with seaweeds or weeds that grow up as a result of enriched nutrients in the water which is a direct indication that the water is polluted because it's from sewage.

Out of the multitude of activities that are set up and bound to occur in Fiji's marine environment, Free soul real estate resort development in Malolo, Fiji was more emphasized by the experts. In these, they state the importance of enforcing the law on coastal developments due to the massive destruction of the marine environment. Freesoul resort development was proposed to be the largest hotel in Fiji with 350 bures with the first casino to be established in the country (Lyons, 2021). It was later found that during the development, the company stopped diggers on top of the pristine reef, burrowed a channel 100 meters in length and 20 meters wide through the reef to permit barges to bring supplies onto land, unloaded the coral they uncovered onto the beachfront of their neighbors' territory, obliterated immense wraps of mangrove and funneled sewage straightforwardly from their laborers'

latrine block into the sea (Lyons, 2021). Therefore, the importance of EIA in coastal development should be enforced by the government before carrying out such activities as stated by the expert groups in this research.

Figure 7: The impacts of the Freesoul Resort development in Fiji's marine environment. Source: (Silaitoga, 2019).

NGO partnerships are well recognized when trying to limit such activities within the tourism, shipping, and fisheries sectors into the marine ecosystem. One of these NGOs is the Mamanuca Environment Society (MES) that helps the tourism industry with the management of the marine environment by planting corals, turtle nesting sites, and other restoration activities. Others are WWF, IUCN, WCS, CI, and FLMMA.

Government experts (E5 & E9) in Table 1 elaborated on the importance of Fiji's presidency in the COP 23 in Bonn, Germany in the year 2017 for the fisheries sector in implementing the sustainability goals promoting the blue economy. Some of this includes the use of MPA, planting mangroves, restoring coral reefs, Kawakawa and Donu (Grouper fish species) ban for harvesting during the breeding season, ban for harvesting and sale of turtle, trochus shell, triton trumpet shell, pearl oyster shell, giant clams, and sea cucumbers (4FJ Movement, 2021). EMF was considered in this study as the lowest-ranked human pressure on Fiji's EEZ (Table 6 & Figure 6). Within Fiji's seafloor, there is a well-established submarine cable hub with connections to several cable networks (Southern Cross trans-Pacific) which connects to Australia and Hawaii (Gassner et al.,2019). These cables are disrupted by the

movement of ships in which most ships drag the cables with them disturbing the marine environment. Also, Fiji has not allowed nuclear energy (radionuclides) to be exposed into our marine environment which poses no threat to Fiji's EEZ. However, experts elaborated that Japan is planning to release the Fukushima nuclear plant into the Pacific Ocean which will be a big issue within our EEZ (Conca, 2021).

4.2 Limitations arising from the Workshop & Interview Assessments and Recommendations.

In this study, there were several challenges faced while collecting the data in which it is mostly through online data collection with interviews and workshop. During the interview, trying to get experts for the interview was challenging in a way where there have been frequent emails and no response from participants. However, during the workshop, Fiji was in a devastating COVID-19 pandemic impact with the presence of the delta variant in the country in which it was categorized under WHO as one of the highest spread infections in the world (Ruggiero, 2021). This has led to a decrease in the number of experts during the workshop and interview. Most of the experts are working from home and are unable to access resources from home as they usually have a shared drive only accessible within the office premises. The difference in time zone is also a challenge when it comes to creating the workshop. Some of my experts are in Samoa & New Zealand making it so difficult to arrange an appropriate time for the workshop. In these, it is advisable if the workshop can be done with experts with the same time zone for better communication processes. Zoom was the main platform for carrying out interviews and workshops. In these, the challenges faced were the technical problems in internet connection where most of the information was not recorded.

All in all, experts were chosen on their involvement in projects on the marine environment in Fiji in which most of the experts chosen have interlinked in certain projects on the development, management, and activities within the marine

ecosystem making it easy for them to understand each other's perspective on the human pressures within this study. Therefore, with this study, it is trusted that it addresses some verifiable and target positions on some basic issues true to form and meets the necessities of the study however much as could be expected.

4.3 Challenges of Not Including Climate Change

Small island developing states (SIDS) like Fiji are particularly vulnerable to the impacts of climate change. For the past years, we have been facing devastating cyclone seasons (November to April) with up to category 5 damaging most of our livelihoods and livestock. Sea level rise is also common within the country and in this, it is a big challenge not to include climate change within this study in Fiji's EEZ.

When speaking with experts, most of them described how many management efforts are destroyed with the impacts of climate change. Some elaborate on the importance of addressing climate change as Fiji's future depends on it. Climate change impacts occur every year with cyclone seasons from November to April following floods and sea-level rise. In these, most of the coastal communities find it difficult to adapt to these changes and need immediate attention on this issue.

The effects of climate change interact with other human pressures and exacerbate them. Although the ODEMM approach did not include climate change (the effects of which are beyond Fiji's control) it does highlight the human activities and pressures that Fiji has more control over. Thus, ODEMM highlights opportunities where Fiji can reduce pressures that would otherwise interact with and exacerbate the effects of climate change. Management of human activities that are under Fiji's control will help to reduce the cumulative effects of pressures on Fiji's marine environment.

5.0 Conclusions and Recommendations

Ultimately, this research demonstrates the importance of understanding the human pressures within our marine environment that are under Fiji's control for decision-making processes and policy development within Fiji's EEZ. Using conceptual models such as ODEMM helps in identifying the priority areas in limiting the human activities from different sectors towards ecosystem services in the marine ecosystem. This model provides an evaluation useful to guiding and supporting IEA, MSP, and other decision-making processes of the marine ecosystem. The ODEMM approach involving experts is very useful when data is limited. ODEMM can help to indicate where risks of human pressures exist so that they can be prioritized for management and improvements for future research, development of indicators, and monitoring.

Different sectors serve different purposes within the livelihoods of people within the communities in Fiji. In these, the tourism sector outlines the need for land and coastal developments to attract tourists into the country as a major contributor to our economy. The tourism industry provides job opportunities to most local communities such as tour guides, hotel workers, and even boat trips for tourists. However, in the shipping industry, it involves trade and transport locally and internationally providing goods and services to meet people's needs. In these, it contributes to ballast water, invasive species, waste discards from ships, and oil pollution. In the fisheries sector, fish and fishing is the main contributing factor to Fiji's economy. Communities depend on the fisheries resources for income and livelihoods. These include the use of bill nets, overfishing, destructive fishing methods, and fishing discards in the marine environment.

Therefore, management of these human pressures is vital in conserving the marine ecosystem within Fiji's EEZ, especially to avoid exacerbating the effects of climate change, which are largely out of Fiji's control. Hence, experts emphasized, prioritizing the importance of supporting communities and industries (hotel operators

& agents) with the resources needed in committing to the management of the marine environment. As well as protecting the marine protected areas from boaters, because there's a lot of that going around at night trying to harvest marine resources from MPA.

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Appendices

A. Interview Questions

Title: "Understanding human impacts on the marine environment in Fiji, insights from an ODEMM conceptual model and semi-structured interviews"

Specialization: Ocean Sustainability, Governance and Management

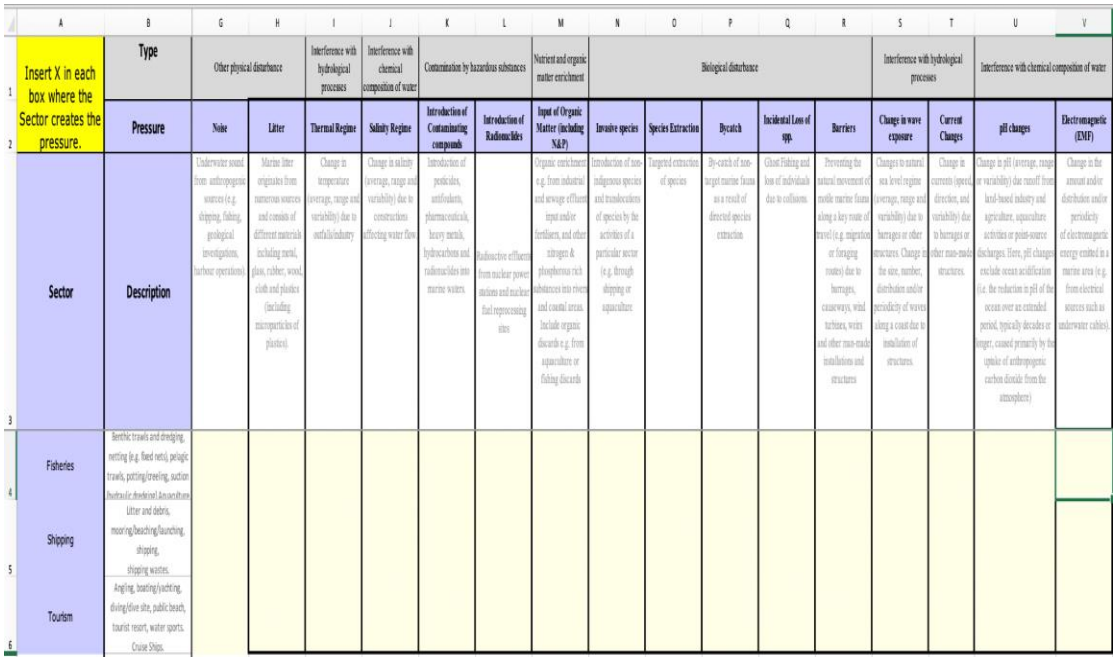
Year: 2021

INTERVIEW QUESTIONS

1. What activities are happening currently and where? Can share and show pictures of maps e.g. of habitats, coral reefs, mangrove, seagrass, saltmarsh, beaches/dunes, estuaries, etc.
2. How does tourism, fisheries & shipping sectors benefit from the habitats, and which challenges do these sectors get from those habitats?
3. Are you aware of any human activities (tourism, fishing, shipping) that interfere with the benefits you receive from these habitats? Are the habitats threatened in any way?
4. Here are some maps of Fiji's coastal areas. Are you aware of any future activities planned for tourism, shipping, and fishing in this area?
5. Is there anything else you would like to share with me relating to the research topic?

B. Workshop Score Sheets Template

i. Pressure with Sectors



Insert X in each box where the Sector creates the pressure.	Type	Other physical disturbance		Interference with hydrological processes	Interference with chemical composition of water	Contamination by hazardous substances		Nutrient and organic matter enrichment	Biological disturbance					Interference with hydrological processes		Interference with chemical composition of water	
	Pressure	Noise	Litter	Thermal Regime	Salinity Regime	Introduction of Contaminating compounds	Introduction of Radionuclides	Input of Organic Matter (including N&P)	Invasive species	Species Extraction	Bycatch	Incidental Loss of spp.	Barriers	Change in wave exposure	Current Changes	pH changes	Electromagnetic (EMF)
Sector	Description	Underwater sound from anthropogenic sources (e.g. shipping, fishing, geological investigations, harbour operations).	Marine litter originates from numerous sources and consists of different materials including metal, glass, rubber, wood, cloth and plastics (including microparticles of plastics).	Change in temperature (average, range and variability) due to outfalls/industry	Change in salinity (average, range and variability) due to constructions affecting water flow	Introduction of pesticides, antifoulants, pharmaceuticals, heavy metals, hydrocarbons and radionuclides into marine waters.	Radioactive effluents from nuclear power stations and nuclear fuel reprocessing sites	Organic enrichment e.g. from industrial and sewage effluent input and/or fertilisers, and other nitrogen & phosphorus rich substances into rivers and coastal areas. Include organic discards e.g. from aquaculture or fishing discards	Introduction of non-indigenous species and translocations of species by the activities of a particular sector (e.g. through shipping or aquaculture	Targeted extraction of species	By-catch of non-target marine fauna as a result of directed species extraction	Ghost Fishing and loss of individuals due to collisions	Preventing the natural movement of motile marine fauna along a key route of travel (e.g. migration or foraging routes) due to barriers, causeways, wind turbines, weirs and other man-made installations and structures	Changes to natural sea level regime (average, range and variability) due to barrages or other structures. Change in the size, number, distribution and/or periodicity of waves along a coast due to installation of structures.	Change in currents (speed, direction, and variability) due to barrages or other man-made structures.	Change in pH (average, range or variability) due runoff from land-based industry and agriculture, aquaculture activities or point-source discharges. Here, pH changes exclude ocean acidification (i.e. the reduction in pH of the ocean over an extended period, typically decades or longer, caused primarily by the uptake of anthropogenic carbon dioxide from the atmosphere)	Change in the annual and/or distribution and/or periodicity of electromagnetic energy emitted in a marine area (e.g. from electrical sources such as underwater cables).
Fisheries	Benthic trawls and dredging, netting (e.g. fixed nets), pelagic trawls, potting/creeling, suction (hydraulic dredging) & anchoring																
Shipping	Litter and debris, mooring/beaching/launching, shipping, shipping wastes.																
Tourism	Angling, boating/yachting, diving/dive site, public beach, tourist resort, water sports. Cruise Ships.																

ii. Pressure with Habitats

Insert X where there is an interaction		Habitats	Coral reefs	Estuaries	Seagrass	Beaches	Mangroves
Type	Pressure	Description					
Physical Loss	Sealing	Sealing by permanent construction (e.g. coastal defences, wind turbines) or change in substrate type due to loss of key characteristic features (physical and/ or biological). Natural substrate loss and replacement by a different kind of substrate. Loss of seal haul-out sites. Exclusion of species from areas due to disturbance (e.g. shipping and marine mammal). Loss of roosting/nesting/foraging areas of bird. Loss of nursery grounds for fish.					
Physical damage	Changes in siltation/ Smothering	Change in the concentration and/or distribution of suspended sediments in the water column from runoff, dredging etc. or smothering by man-made structures or disposal of materials to the seafloor.					
	Abrasion	Physical interaction of human activities with the seafloor and with seabed fauna/flora causing physical damage and/or mortality (e.g. from trawling or anchoring), excluding death or injury due to collision. Abrasion may cause damage to spawning grounds.					
	Non-living Resources	Sand & gravel (aggregates) extraction, or removal of surface substrates for exploration of subsoil.					
Other physical disturbance	Noise	Underwater sound from anthropogenic sources (e.g. shipping, fishing, geological investigations, harbour operations).					
	Litter	Marine litter originates from numerous sources and consists of different materials including metal, glass, rubber, wood, cloth and plastics (including microparticles of plastics).					
Interference with hydrological processes	Thermal Regime	Change in temperature (average, range and variability) due to outfalls/industry					
Interference with chemical composition of water	Salinity Regime	Change in salinity (average, range and variability) due to constructions affecting water flow.					
Contamination by hazardous substances	Introduction of Contaminating compounds	Introduction of pesticides, antifoulants, pharmaceuticals, heavy metals, hydrocarbons and radionuclides into marine waters.					
	Introduction of Radionuclides	Radioactive effluents from nuclear power stations and nuclear fuel reprocessing sites					
Nutrient and organic matter enrichment	Input of Organic Matter (including N&P)	Organic enrichment e.g. from industrial and sewage effluent input and/or fertilisers, and other nitrogen & phosphorous rich substances into rivers and coastal areas. Include organic discards e.g. from aquaculture or fishing discards					
	Invasive species	Introduction of non-indigenous species and translocations of species by the activities of a particular sector (e.g. through shipping or aquaculture					
	Species Extraction	Targeted extraction of species					

iii. Sectors with Habitats

	A	B	C	D	E	F	G
1	**INSERT X's FOR EACH CO-OCCURENCE**	**Habitats**	**Coral reefs**	**Estuaries**	**Seagrass**	**Beaches**	**Mangroves**
2	**Sector**	**Description**					
3	Fisheries	Benthic trawls and dredging, netting (e.g. fixed nets), pelagic trawls, potting/creeling, suction (hydraulic dredging),Aquaculture					
4	Shipping	Litter and debris, mooring/beaching/launching, shipping, shipping wastes.					
5	Tourism	Angling, boating/yachting, diving/dive site, public beach, tourist resort, water sports. Cruise Ships					

iv. Pressure Assessment

	A	B	C	D	E	F	J
1	Sector	Pressure	Habitats	Overlap	Frequency	Degree of Impact	Comments
2	Fisheries	Abrasion	Coral reefs				
3	Fisheries	Abrasion	Estuaries				
4	Fisheries	Abrasion	Seagrass				
5	Fisheries	Abrasion	Beaches				
6	Fisheries	Abrasion	Mangroves				
7	Fisheries	Barriers	Coral reefs				
8	Fisheries	Barriers	Estuaries				
9	Fisheries	Barriers	Seagrass				
10	Fisheries	Barriers	Beaches				
11	Fisheries	Barriers	Mangroves				
12	Fisheries	Bycatch	Coral reefs				
13	Fisheries	Bycatch	Estuaries				
14	Fisheries	Bycatch	Seagrass				
	Fisheries	Bycatch	Beaches				

C. Consent Form

Dear Participant,

Thank you for agreeing to participate in this research survey, which is carried out in connection with a Dissertation which will be written by the interviewer, in partial fulfilment of the requirements for the degree of Master of Science in Maritime Affairs at the World Maritime University in Malmo, Sweden.

The topic of the Dissertation is **"Understanding human impacts on the marine environment in Fiji, insights from an ODEMM conceptual model and semi-structured interviews"**

The information provided by you in this interview will be used for research purposes and the results will form part of a dissertation, which will be published online and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your personal data will be immediately deleted.

Anonymised research data will be archived on a secure virtual drive linked to a World Maritime University email address. All the data will be deleted as soon as the degree is awarded.

Your participation in the interview is highly appreciated.

Student's name	Alumita Talei Sekinairai
Specialization	Ocean Sustainability, Governance and Management
Email address	w1904606@wmu.se

* * *

I consent to my personal data, as outlined above, being used for this study. I understand that all personal data relating to participants is held and processed in the strictest confidence, and will be deleted at the end of the researcher's enrolment.

Name: .....

Signature: .....

Date: .....

D. Stakeholder Participants List

Workshop and interviews were carried out online with the following expert groups with helpful experiences, direction, thoughts, policies, data as well as information for this study.

I.	**Ministry of Fisheries**	Epeli Maisema, Fisheries Investigation Officer.
II.	**Maritime Safety Authority of Fiji**	Penaia Votadroka, Senior Engineer Examiner.
III.	**International Union for Conservation of Nature (IUCN), Fiji**	Alisi Rabukawaqa, Project Liaison Officer.
IV.	**University of the South Pacific**	Dr. Peter Nutall, Scientific and Technical Advisor for the Micronesian Center for Sustainable Transport. Dr. Joeli Veitayaki, Associate Professor at the School of Marine Studies & Director for the International Ocean Institute Pacific Islands. Dr. Stephen Pratt, Professor & Deputy Head of School (Research, Innovation, and Post Graduate Affairs) at the School of Business & Management. Andrew Irvin, Project Officer at the Micronesian Center for Sustainable Transport, USP.
V.	**Institute of Marine Resources, USP**	Dr. Rusila Savou, Research Fellow
VI.	**Fiji Locally Managed Marine Area (FLMMA)**	Dr. Alifereti Tawake, Council Chair & Technical Advisor at LMMA International Network.