

Original Research Article

Implications of Seagrass Ecosystem Degradation on Marine Resources and People's Livelihood: A Case Study from Komave Village, Fiji

ABSTRACT

Tropical coastal zones have rich marine ecosystems; however, they have been enduring severe environmental hazards, particularly from anthropogenic activity and the effects of climate change. Seagrass ecosystem is one of the most productive yet undervalued marine ecosystems. The residents of Komave village, located on the mainland of Fiji have witnessed marked losses in seagrass cover over the last decade. Several of the village men in Komave are unemployed and rely on the coastal resources through fishing, livestock and agricultural farming for their socioeconomic livelihood. ~~Seagrass beds are famous for their ecological role in provision of nurseries for juveniles and larvae of various fish species.~~ This research explores the impact of loss of seagrass cover on the villagers' livelihood. This paper highlights the observations and experiences of the Komave villagers, in light of the interviews and discussions carried out at the community. A random sampling method was also used over a period of two years (March, 2015 – April, 2017) to monitor the seagrass habitat. ~~The possible anthropogenic and natural factors contributing to the loss of Seagrass were gotten Based on the from the interviews and sampling physical environment; the possible anthropogenic and natural factors contributing to the loss of seagrass are also discussed.~~ This paper concludes by providing recommendations for managing seagrass to enhance fisheries productivity in this tropical coastal community.

Comment [S1]: Include the water quality parameters analysed and their results

Keywords: Seagrass, food security, fish population, random sampling, monitoring, interviews, socioeconomic

1. INTRODUCTION

Seagrass meadow is one of the most productive marine ecosystems, which provides a wide array of ecosystem support services [1]. It has significant impact on the livelihood of the people who directly or indirectly benefit from these systems. Multiple stressors including invasive species, commercial fishing, global warming and physical disturbances pose threat to the seagrass meadows, which are being degraded at a rate of approximately 7 percent of their total area per year globally [2,3]. Approximately 29 percent of seagrasses have disappeared, making it one of the most vulnerable marine habitats [3,4]. For instance, 24 percent of all seagrass species are now classified as threatened under the IUCN's Red List [5,6].

Seagrass beds form a complex ecosystem within marine coastal zones and contribute significantly to the health of mangroves and coral reefs [6-10]. In shallow coastal waters, seagrass bed provides valuable resources for juveniles in terms of food, shelter and protection from predators [1]. Majority of the ecosystem services that seagrasses provide have high economic importance, as highlighted by McCarthy [11]. In 2001, seagrasses and algae had an estimated value of approximately US\$ 3,801 billion/year worldwide, which is approximately FJ\$ 7600 billion/year [11]. Seagrass habitats serve as nurseries and feeding sites for many recreational and commercially important fish species at juvenile or larval stages [1,3]. They are the primary food source for many herbivores on coral reefs and shallow habitats, especially in the tropics, since phytoplankton biomass is reduced in these regions [12,13]. Seagrass is also the main food source of manatee, dugong, and sea turtles, all of which are classified as threatened species [6,14,15]. The additional services provided by seagrasses include filtration of water and improved water clarity, recycling of nutrients and protection of shoreline through stabilization of sediments [16,17,18,19].

In Fiji, the location of seagrass meadows or *veivutia*, as known locally is mostly in the intertidal and shallow subtidal waters [20]. There are a total of five seagrass species out of the 72 globally present species [6] and 1 subspecies reported to be present in Fiji. These include; *Halodule pinifolia*, *Halodule uninervis*, *Halophila ovalis*, *Halophila ovalis* ssp. *bullosa*, *Halophila decipiens* and *Syringodium isoetifolium* [20-22]. Seagrass beds are famous for their ecological role in provision of nurseries for juveniles and larvae of many fish species. For instance, as stated in [20], 400 square metres of seagrass bed can sustain approximately 2000 tonnes of fish per year. In addition to this, Fiji's coastal fisheries productivity relies immensely on seagrass habitats. Local juvenile species (*kawago* – *Lethrinus ethrinusnebulosus*; *sabutu*, *cabutu* - *Lethrinus atkinsoni*; *kabatia*, *kabatiko* - *Lethrinus harak*) live in the shallow and inshore regions such as seagrass and mangrove before they move to deeper waters as adults [20,23].

Nutrient profiling of the water source typically helps to identify the health of the aquatic environment. Various analyses are used to make conclusions in regards to the health of the water source and the possible sources of contamination. Current applications of Total Dissolved Oxygen (TDO), nitrate levels, phosphates, pH, Total Dissolved Solids (TDS) and heavy metal analysis are used to depict the possible environmental impacts on the water resource. As for the anthropogenic causes, this study focuses more on how nutrients, such as nitrate run-offs affects seagrass growth and survival rate. Cheimonopoulou [24] reported values of NO₂-N (0.002 and 0.025 mg/L), NO₃-N (0.90 and 0.91 mg/L) and NH₄-N (1.66 and 1.58 mg/L) during the winter season and it slightly varies in summer as higher temperatures enhance more microbial activity. These values are slightly higher when considering the marine organisms or the aquatic environment due to dilution and tolerance behavior of many fish and crustacean species. As mentioned previously, nutrient rich waters will induces algal bloom and this affects the growth or coverage of sea grass. Runoffs from farms, industrial effluents and household activities are some of the sources of this contamination. Nitrates are not only toxic to marine organisms in high quantities but they are also indicators of anthropogenic pollution especially in amalgamation with other metals and organic compounds.

The degradation of seagrass habitat adversely affects the economic and ecological value of coastal ecosystems [6]. Seagrass loss rates are considerably high and can be compared with those of coral reefs and mangroves [7]. However, seagrass ecosystems are often neglected, which explains the basis of this research and the need to enhance community awareness and facilitate development of community management plans [6]. Local marine protected areas (MPAs) are being implemented throughout the world to protect seagrass

resources from current and future degradation, as it is important to emphasize legal frameworks to protect and maintain seagrasses for restoration [2]. On the other hand, the efficiency of MPAs are variable [25,26] and a crucial factor that is contributing to this inefficacy in Fiji is the oversight of socioeconomic factors in management and planning [27,28]. Nevertheless, to improve the efficiency of MPA strategy; there is a need for the practitioners to understand completely the role of seagrass ecosystems in the coastal marine environment. Also, taking into account the socioeconomic factors is a key aspect for attaining social benefits from conserving and generating stakeholders' support for management [25].

Seagrass ecosystems endure serious threat mostly from anthropogenic activities such as solid waste disposal, eutrophication, reclamation of land for coastal development and dredging. Introduction of invasive species, spread of disease by epiphytes, over-fishing and chemical or nutrient run-offs from agriculture also pose threat to sea grass meadows [1,5,6,29,30,31,32,33]. Additionally, seagrass ecosystems are at an extended risk from climate change through thermal pollution, ocean acidification, increased frequency of storms and changes in water flows [34,35,36].

The focus of this research is the case study of Komave village situated in Sigatoka, Fiji. Most of the villagers rely on fishing, livestock rearing and farming for their livelihood. The purpose of this paper is to examine the seagrass ecosystem at Komave village and to provide a baseline data that shows the current status of the seagrass meadows and the potential threats. In addressing this objective, the study as exemplified by testimonies and series of in-depth semi structured interviews from the people of Komave village provide an insight to the changes in the seagrass ecosystem over the past two decades.

2. MATERIAL AND METHODS

2.1 Sampling site

A two-year study was conducted to monitor the multi-species (four species) seagrass population changes in Komave village, located (latitude 18°13'26.96"S, longitude 177°46'5.92"E), Viti Levu, Fiji Islands as shown in Fig. 1. Sampling was conducted twice a year from March 2015 - April 2017 to monitor the seagrass habitat. Coral reef ecosystem and algal habitat was also observed at the site to examine their relationship with seagrass ecosystem.

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1. current state of problem
2. problem
3. gap your research will fill
4. objectives

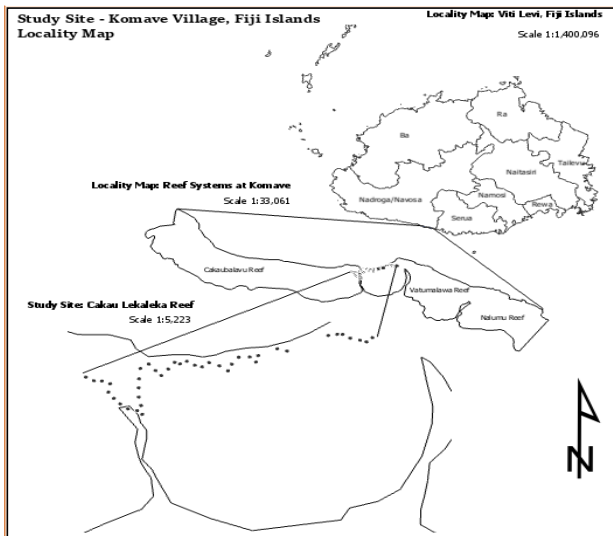


Fig. 1. Overview of the study area (~~Komave village, latitude 18°13'26.96"S, longitude 177°46'5.92"E~~) and locations of the investigated seagrass habitats.

2.2 Random sampling and quadrant estimation method

The study was conducted during low tide as the low tide area is mainly at risk due to various anthropogenic activities. For the first monitoring, random sampling method was used to monitor the different seagrass populations at different points. A total of 50 points were considered, whereby, a 50cm by 50cm quadrant was placed randomly at each point for detailed observation. The quadrant was laid at 3 – 4 meter intervals and without harming any habitat, small posts were driven into 50 different substrates acting as a permanent marker to be used as a reference. For the other three monitoring periods, the markers were used to specifically identify any changes. Within each quadrant, evaluation of different species of seagrasses present was estimated as a percentage. At each point, the coral reefs and algal habitats present were observed thoroughly and photographs were taken to compare the different monitoring data obtained. The observations were recorded in the data sheet. After each observation, the quadrant was moved on to the next point until 50 points had been reached. The abundance of seagrass populations were specifically compared near the shore, in the middle of the intertidal zone and at the end of the reef flat near the surf. Any evident damages to the seagrass beds were also noted.

2.3 Individual interviews

An interview questionnaire was also used to generate data that provided better insights into peoples' perception of coastal resources and their associated benefits. A total of 30 individuals were interviewed and each interview was conducted for a period of 30 minutes. Since the villagers visited the site frequently for fishing and leisure purposes, they had comprehensive knowledge of the site including the status of the seagrass. This method enhanced data richness.

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2.4 Nitrate analysis

For the purpose of this study, water samples were collected in sampling bottles from the littoral zone of the Komave coastal shore during the early morning low tide. The samples were collected from 50 different locations using random sampling method with a 50 cm by 50 cm quadrant which was laid at 3 – 4 meter intervals. All samples were analyzed in triplicates. The triplicates were randomly obtained from the quadrant. Chemical analysis was carried out by measuring the amount of nitrates (mg/L) in situ in triplicates using a Vernier Nitrate – ion selective electrode, which was calibrated 30 minutes prior.

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3. RESULTS AND DISCUSSION

4.1 General significance of seagrass beds in the marine ecosystem

There is no doubt that seagrass beds employ highly productive marine ecosystems, ranking them as one of the most prolific biomes on earth [37,38]. Besides their increased primary production, seagrasses perform many other functions in the ecosystem. Seagrass meadows are the main source of food for many grazing animals, such as the dugong (*Dugong dugon*) and the green turtle (*Chelonia mydas*). For instance, on the approximate an adult sea turtle consumes 2 kilograms of seagrass per day. Also, decomposing seagrasses provide food for benthic dwellers, such as many fish, mollusk, crab and prawn species [39]. The photons from the sunlight induce the photosynthetic process in seagrasses, causing it to fix carbon dioxide and convert it into organic carbon to endorse seagrass growth and distribution to adjacent ecosystems. Elevated rates of biomass synthesis enhances high rate of oxygen production, a byproduct of photosynthesis that is released to the surrounding waters and sediments [38,40]. The leaves of seagrass favor the retention of suspended particles in the water column, behaving like a filter for the coastal waters giving some level of transparency to the water [11]. In addition, it is important to understand whether seagrass ecosystems can play central roles in climate change mitigation process, since (18-60 × 10⁶ ha) seagrass meadows globally are responsible for 3-20 % of carbon sequestration in sediments and store 10% of the total buried organic carbon [5,41,42].

Moreover, the extensive rhizome system, roots and leaf canopy stabilizes the sediment over which seagrasses grow, minimizing the re-suspension of the sediment by the wave and current actions. The reduced water motion is due to the friction created by the canopy and the framework that rhizomes and roots offer to the sediments. Thus, more vegetated sediments are less likely to be disturbed by wave and current actions and can reduce coastal erosion as well [40]. Seagrasses also offer the benefit of being nutrient sinks, filtering and buffering the chemicals and nutrients being run-off into the coastal waters. For example, seagrasses would absorb the nitrogen and phosphorous from the run-offs, but if the nutrient is in excess this would lead to algal bloom, which would most likely impair water quality [38,39]. Finally, seagrass meadows are key feeding and nursery habitat for many organisms (such as commercially important fisheries), in terms of primary productivity and protection from predators [20,40]. Due to the various function offered by seagrass meadows, they are classified as the unique and economically valuable ecosystems in the biosphere [38,43].

4.2 Ecosystem flows and habitat connectivity supporting coastal fisheries

Many habitats depend on the intact and healthy seagrass meadow that is responsible for the maintenance and regeneration of fish populations. For instance, fish and other marine

organisms depend on various coral reef habitats for different things including feeding, protection and shelter. Seagrass meadows provide habitat for juvenile fishes that later migrate to coral reefs upon maturity [11]. The filtering mechanism of seagrasses keeps the water column clean and sustains coral reef growth [38]. This in turn supports fish population growth, as coral reefs play an important role in rearing matured fish populations.

Fig. 2 shows the seagrass cover for each quadrant and different replicates over the study period and Fig. 3 shows the abundance of four seagrass species present in the study area over four sampling periods. Seagrass beds support many juvenile reef fish, providing protection against predators and food resources. They later relocate to coral reefs and increase the ocean's fish population. Seagrasses filter the tiny particles, sediments, and contaminants and by doing this, they keep the water clear, which supports coral reef growth. However, if there are losses in seagrass density then water would not be filtered and there would be decline in coral reef growth and the coral reef fish population would deteriorate. This will also affect local and commercial fishermen. Thus, loss of seagrass leads to loss of corals, which would have deteriorating effect on the entire coral ecosystem. On the other hand, the role of mangroves includes featuring as a coastal bio-filter. If mangroves are deforested or absent, there will be severe consequences for seagrasses as it will lead to reduced water quality, increased pollution, increased nutrient load, and increased fresh water input as well. Fig. 4 shows the significant inverse relationship of nitrate concentration with seagrass abundance in the study area. Juvenile reef fish also utilize mangroves for food, shelter, and protection against predators. Mangroves are resource rich habitat, having the capacity to support juveniles and maintaining the fish population. Therefore, as depicted in Fig. 5, these three habitats are interdependent and offer support to each other in various ways.

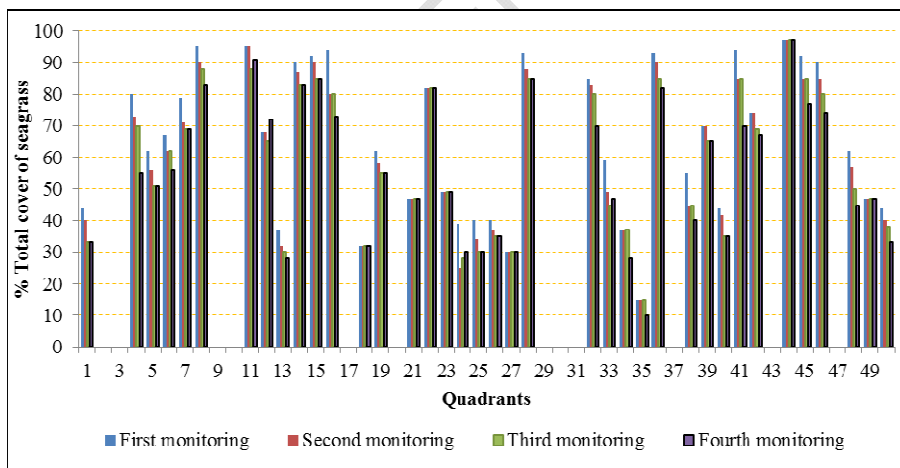


Fig. 2.Total cover of seagrass species (%) for the 50 quadrants over different monitoring periods.

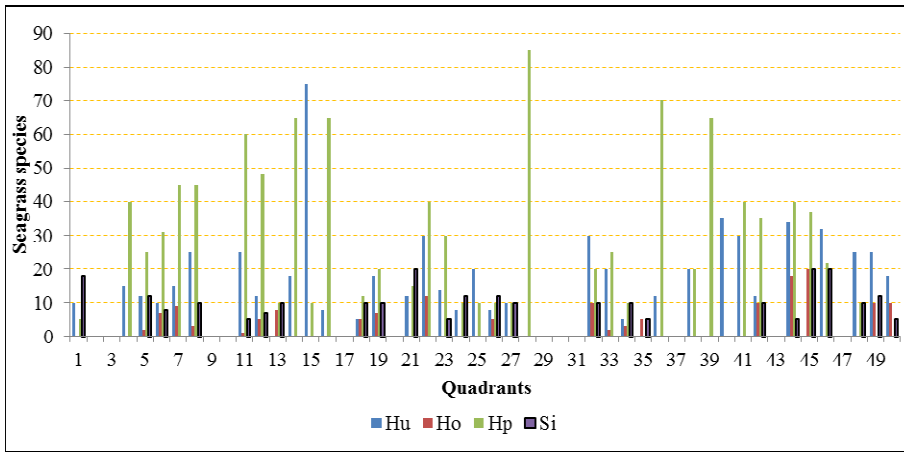


Fig. 3. Showing the percentage abundance of different seagrass species (%) observed under 50 quadrants over different monitoring periods. Seagrass species include *Halodule uninervis* (Hu), *Halophila ovalis* (Ho), *Halodule pinifolia* (Hp) and *Syringodium isoetifolium* (Si).

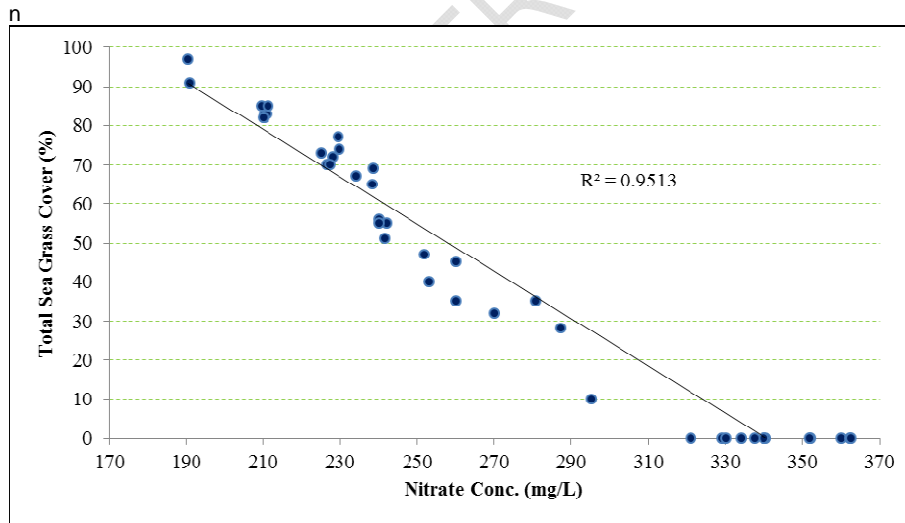


Fig. 4. Regression correlation between levels of Nitrate in Komave with the total sea grass cover.

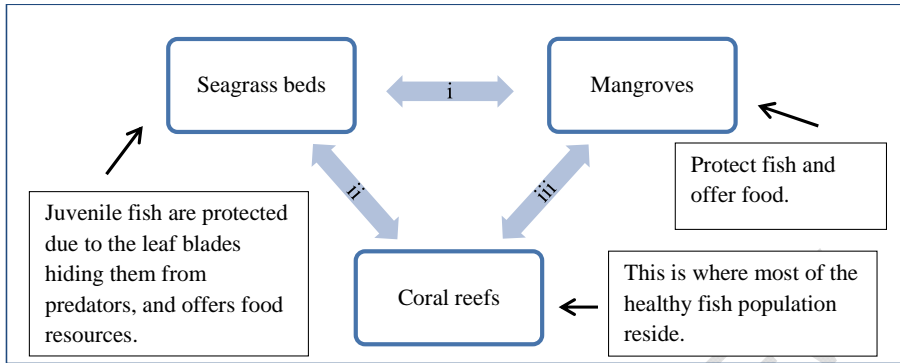


Fig. 5. The interrelationship between three different habitats. These three habitats are interdependent and support maximum fish production. Excerpted from Di Carlo and McKenzie [44].

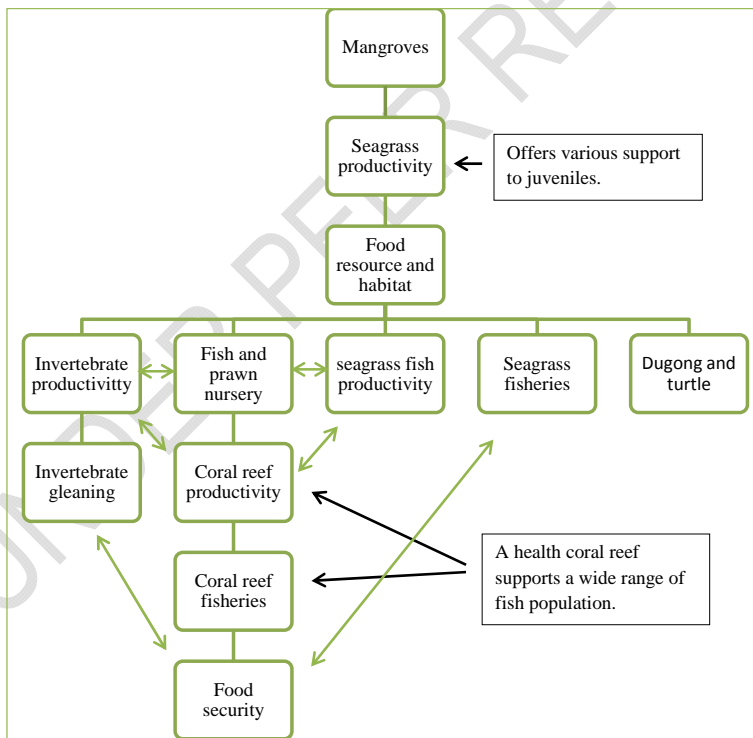


Fig. 6. Mangroves and seagrasses are the key foundation responsible for the maintenance and maximized productivity of fish population that enhances food security. Adapted from Di Carlo and McKenzie [44].

The flow chart depicted in Fig. 6 shows how different habitats are linked to support food security. It emphasizes the considerable role of mangroves in maintaining seagrass productivity, which in turn provides food resource and a convenient habitat for different marine organisms.

4.3 Komave villagers' dependence on fisheries as the major source of protein

Fiji's coastal fisheries productivity is greatly dependent on seagrass habitat, for instance, about 400 square metres of seagrass can support approximately 2000 tonnes of fish a year [20]. The larvae grow in the nursery site (seagrass meadows) for about 5 months and then move into deeper waters where they develop into adults. The mating and spawning period is between October – November [20,45].

When interviewed, majority of locals stated that fish is the main source of protein in their diet. The villagers' are also involved in livestock and poultry rearing. However, while they prefer consuming fish on a daily basis, livestock and poultry rearing is done mainly for sales purpose and is to be only consumed during special occasions, such as church activities, traditional *Sevusevu*¹, weddings, and feasts. According to some of the villagers, fish is a continuous resource and can be attained easily. However, some villagers do not realize that fisheries productivity could decline with seagrass habitat under threat. For example, the equipment used for fishing includes big nets, spears, fishing lines, and bottom trawl method is also practiced at times. In addition, boats are also used during high tides to catch fish while chemicals and dynamite fishing is not being practiced at this village. Moreover, many families cook fish for dinner every evening. This indicates the serious dependency on fish by the villagers.

4.4 Anthropogenic impacts on seagrass meadows in Komave

Seagrass habitats in the coastal region face myriad threats [2,6]. The coastal environment is under pressure due to the direct impacts resulting from anthropogenic activities as well as the indirect impacts rising from natural disturbances. The direct impacts include Duarte [38]: mechanical damage to the seagrass meadows, for instance, destructive fishing practices, anchoring of boats, dredging and etcetera. Shoreline development, land reclamation, and salinity changes are other direct impacts. Also, eutrophication occurs when there is discharge of agricultural and domestic waste and when nutrients run into water during rainy season and reduces the clarity of water. Increased nutrients can lead to algal bloom and growth of epiphytes. Algae will compete with seagrass for food whereby epiphytes attach themselves on the blades of seagrass preventing light to reach seagrass, hindering the photosynthesis process [38,11]. Therefore, tourists walking over the seagrass beds while exploring the site and solid waste disposal such as plastic bags and bottles could result in the loss of seagrass meadows.

The threshold value of nitrate is reported as 25 mg/L [46]. The samples analyzed in this study, reported values above the threshold; 190 mg/L to a maximum of 362.8 mg/L. These values demonstrate that the shores are impacted directly through nitrate runoffs. This could possibly be sourced from the farm area which makes use of fertilizers and organophosphate pesticides by the villagers. Secondly, there could be mixing of ground water through the sewerage discharge and waste from the domesticated animals in the village that dwell around the shores. These levels of nitrates are harmful in the long term to the marine

¹*Sevusevu* is an i-Taukei term used to define a traditional ceremony organized to accept outsiders, such as tourists into a Fijian village.

organisms as there should be no efflux of the nutrients. Since the villagers are highly reliant on the ocean for their livelihood,

there is very high possibilities that the toxic products will bio-accumulate and cause severe health implications. Nitrates enhance the growth of algae and hence decrease sea grass cover. This is clearly seen in Fig. 4. In areas where nitrate concentrations were greater than 300 mg/L, there was 0% sea grass cover in total. Fig. 4 also shows a very high correlation (0.98) with the values of nitrates to sea grass cover, which confirms that if high levels of nitrates are present, sea grass cover is highly impacted. Previous studies by Jiang [47] have also shown that increase in nitrates and salinity greatly impacts the growth of sea grass. Therefore, the nutrient (nitrate) analysis carried out shows that there is concern in terms of anthropogenic activity in Komave.

Moreover, indirect impacts from climate changing events include increase in sea surface temperature and this affects seagrass survival as seagrass species require optimum temperatures for respiration, photosynthesis, and growth [1,11], increased carbon dioxide concentration leads to enhanced algae and epiphyte growth, which affects seagrass growth as well. Also, other impacts are sea level rise, which reduces light penetration to meet the photosynthetic needs of seagrasses due to increased water depth, shoreline erosion, and elevated frequency and intensity of storms that can lead to increased wave actions and sediment deposition on grass beds [1]. Therefore, in Komave, the common direct impacts include destructive fishing practices such as using of nets and anchorage damages, agricultural and domestic waste discharge enhancing the growth rate of epiphytes and macroalgae, villagers walking over seagrass beds to harvest sea cucumbers, octopuses, crabs, lobsters, prawns, and fish for food. Lastly, indirect influences from climate change as discussed in this section are also of concern.

4.5 Limitations

The main limitation of this study is lack of data. No study on seagrass meadow has been done at this site previously, so we had to just rely on the two years data collected as shown in Fig. 2 and Fig. 3 during the field work. The data collated is not sufficient to firmly assert that seagrass populations are declining under stressed environmental factors. Thus, more research needs to be done in this area to monitor the changes taking place in the seagrass meadows. In addition, the villagers are not well-educated and it was slightly difficult to explain to them about the research being conducted. Some of the locals did not understand the difference between seagrass and algae and they combined both as the same class. When asked, "What do you think is happening to seagrass population over the year"? Few people replied, "I think it is increasing because nutrient run-offs enhance their growth rate", which is not true as increased nutrient enhances algae and seaweed growth that competes with seagrass species, declining their percentage density in the coastal environment. Interview process was quite time consuming as some locals had to be explained more than once before asking them questions. Another important factor observed is during the study, researchers had to walk on the seagrass beds to observe the population density and take pictures of the quadrants. This disturbs many habitats, including the juveniles that seek protection and shelter in seagrass beds.

4.6 Recommendations

For enhanced productivity of fisheries, and to contribute towards food security the importance of seagrass habitat and the role it plays is evident. It is quite obvious that the locals did not have much information on the various importance of seagrass beds. It is often thought that loss of seagrass would not be a serious concern, not realizing the different roles

it plays in the coastal environment [5]. The two years monitoring shows that the seagrass population is declining and it will affect the food security if this continues. To prevent a further reduction of the population density, some steps need to be considered. Marine protected areas (MPAs) are being implemented throughout the World to protect seagrass resources from current and future commination. There is a MPA in Komave as well but to improve the efficiency of MPA strategy, there is a need for practitioners to be well-versed on the role of seagrass ecosystems in the coastal marine environment. The key stakeholders involved in Komave are local community members, The University of Fiji (PACAM and Department of Science unit), and tourists as well (involved in the plantation of mangroves in 2015). Increased education and awareness is crucial to inform the locals and the managers about the essence of seagrasses. More MPAs needs to be established by the locality to address many of the threats faced by seagrass habitats.

Moreover, few steps that can be taken to manage the seagrass habitats at Komave includes afforestation of mangrove trees as they are efficient ecosystem engineers and reduce soil and run-offs from being leached into the sea. Extending the traditional 'Taboo' from 5-10 years will allow many species to mature and allow the marine ecosystems to recover from the damages made. To reduce solid waste disposal, waste management programs need to be established in the region, proper sewage system must be in place to minimize on the sewage outfall [11]. Fish – farming operations need to be regulated by the village head to ensure no destructive fishing practices are being utilized. Fixed moorings need to be implemented for boats to lower the impacts of anchor damage [38]. In addition, the major priority is to initiate research at local level, considering the significant value seagrass meadows have on food security of the villagers [48,49]. The University of Fiji has developed a base map for the abundance of corals, algae, and seagrass present on the coastal regions of Komave in association with the provision of USAID fund (PACAM). This will help the researchers to monitor changes taking place over the years. The undergraduate science students also visit the site each year to monitor the changes taking place for their practical sessions. This interaction of UniFiji with the locals of Komave is very useful in building awareness towards the coastal resources in terms of education. For instance, lack of knowledge in the community leads to poor management of seagrass population and this issue can only be resolved through educating the villagers on the importance of seagrass meadows. This research with the two years monitoring done will feature as a baseline for the students and other researchers. Although two years data may not be enough to prove the changes taking place, but it can still be used to predict the future trend of seagrass loss at Komave.

Most importantly, it will help and motivate the villagers to take part in the conservation of seagrass meadows as their food security relies upon it. Finally, if more research work is conducted then it would be easier to get more research grant from overseas or the Government of Fiji to create awareness in Komave and help protect the seagrass habitats and food security of the villagers.

5.0 CONCLUSION

Fish population owes their maintenance and productivity to seagrass beds that offer shelter, protection, and food to juveniles. It is no doubt that many villagers in Fiji depend on fish as the main source of protein, this is portrayed by using the case study of Komave Village as an example. Globally, it is evident through various researches that seagrass populations are declining. The main aim of this research was to initiate monitoring of seagrass beds in Komave village to see the population change of seagrass species. The changes in the population would be used to describe how it might affect food security. The two years monitoring done using 50 points each time showed signs of decline in the population.

However, a two-year period is not sufficient to monitor the population change but this research is just a starter to the other researches and monitoring that will be done in years to come to see whether the population is really declining or just for a short period of time. Moreover, if the population of seagrass declines, there would be a greater probability of fish population declining in that area. Since the village people rely majorly on fish, this would be a threatening factor to food security in Komave. Therefore, to utilize the MPA set in Komave effectively the locals needs to be well informed through awareness programs being held at Komave and more MPAs needs to be set up.

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