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IMPORTANCE OF SEAGRASSES: A REVIEW FOR FIJI ISLANDS

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Abstract

Seagrasses form large meadows along coastlines of every continent except Antarctica and have an estimated value of 151.4 billion USD in the Melanesian region. Seagrasses provide vital functions such as preventing coastal erosion, improving water quality, capturing and storing carbon from the atmosphere. Globally, seagrasses have declined in area by approximately 29% since the beginning of the 20th century, and the rate of decline is speeding up. Scientists attribute seagrass decline to poor water quality caused by pollution in run-off, especially nutrients and sediments that are washed down rivers and into coastal habitats. Seagrass habitats are far less studied than other marine ecosystems like coral reefs, and detailed information about them in the Pacific Islands is lacking. Their nearshore location makes seagrasses highly vulnerable to human-induced disturbances, especially impacts related to human population increase such as urban expansion, water course alteration and increased loading of sediments, pollutants and algal generating nutrients. Therefore, this review wishes to highlight their functions, threats, habitat loss consequence, policy gaps, and raise awareness for seagrasses. Effectively managing seagrass ecosystems in the Fiji Islands requires: significant improvement in awareness of this natural resource and understanding issues such as ecosystem resilience, run-off, and effective catchment management strategies.

***Keywords**: Coastal; Seagrass; Run-off; Urban expansion; Catchment management*

Introduction

Seagrasses are marine flowering plants similar to terrestrial plants, and are capable of reproducing both sexually and asexually forming extensive meadows. They are the only monocot flowering plants that are found in the sea. Though they evolved from freshwater macrophytes about 100 million years ago [1-5], they do not represent the link between marine algae and terrestrial higher plants [6]. Their evolution is believed to have occurred independently 3 or 4 times within this period, resulting in the polyphyletic group recognized today. The term 'seagrass' refers to the descriptive similarity to the grass-like leaves of most of its representatives. Seagrasses are more closely related to members of the water lilies and taro family than to true land grasses (Poaceae) [7] and need to be close to the water's surface to access sunlight. Like terrestrial grasses, seagrasses can form extensive meadows in waters up to depths of 60 m [8], determined by the water clarity. Seagrass beds can be either monospecific (made up of single species) or mixed, in which instances more than one species coexist. Seagrasses possess similar organs and tissues as other flowering plants, having distinct above and below ground parts. Their leaves are above ground, however their underground roots and stems are proportionally large, hiding up to 90% of their total biomass within sediments [9].

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Above ground parts consist mainly of photosynthetic tissue, used for the uptake of nutrients and carbon from the water column. Meanwhile the below ground parts are used for absorbing nutrients, anchoring, mechanical support, clonal expansion, and storage of carbohydrate reserves [10]. Like all autotrophic plants, seagrasses are limited to growing in the photic zone, in this case in shallow and sheltered coastal waters anchored in sand or mud bottoms. In the tropics, they are often found associated with mangroves, where there is shelter from waves and strong currents. These plants have developed unique morphological, ecological, and physiological adaptations for a completely submerged existence, including internal gas transport, epidermal chloroplasts, submarine pollination, and marine dispersal (Fig. 1), which provide important ecological services to the marine environment [10].

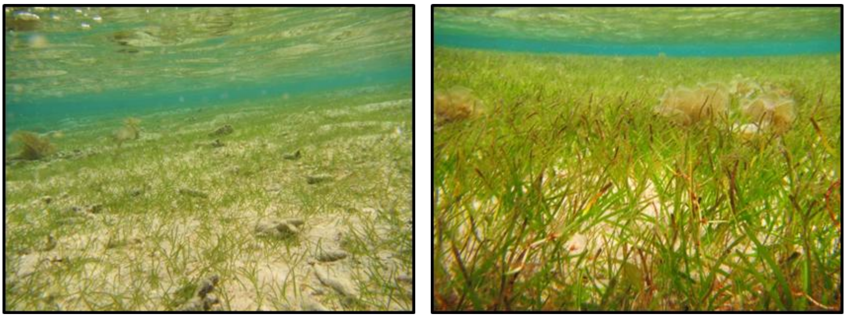

Fig. 1. Seagrass beds of *Halodule uninervis* at Makaluva Island, Suva. Photo credit S. Singh

Seagrass Ecosystem Services

Seagrasses undoubtedly provide many ecosystem services [11, 12], defined as natural processes and components that benefit human needs, directly or indirectly. Seagrasses are believed to be the third most valuable ecosystem in the world, only preceded by wetlands and estuaries. Seagrasses contribute vital ecological functions in the marine environment, many of which provide up to 25 different ecosystem services for humans including coastal protection, nursery habitats, and sediment accretion and stabilization [12, 13]. These are estimated to be worth over 19,000 USD per hectare per year [14-16]. Seagrasses support both commercial and subsistence fisheries, which in turn provide food and income generation to communities and nations. Seagrasses also serve as important habitats for a range of iconic and culturally important species such as sea turtles, and as nursery grounds for numerous economically important finfish and invertebrates such as molluscs and crustaceans [17]. Seagrass habitats also increase coastal protection by trapping and stabilizing sediments and dissipating wave energy [13, 18], allowing suspended material to settle on the bottom and increase water clarity. They are known as the “lungs of the sea”, as one square meter of seagrass can generate 10 liters of oxygen every day through photosynthesis [17]. They are considered to be “ecosystem engineers” that play key roles in ecosystem organization. Seagrasses provide conditions or resources essential for species to complete their life cycles, and help to maintain niche diversity by supporting complex habitat structures [19] on which thousands of other species depend [20]. Seagrasses are nutrient sinks, buffering or filtering excess chemicals, and also act as nutrient pumps by releasing important compounds into nutrient poor regions. This service is estimated to be worth over 29, 000 USD per hectare per year [21-23]. Additionally, seagrasses could potentially have wastewater treatment properties. It may be able to remove various disease pathogens from seawater like *Enterococcus,* which affects humans, fishes and invertebrates, and reduce coral reef diseases by 50 % [24]. Moreover, the ocean is recognized as an important carbon sink that captures and stores up to 55 % of atmospheric carbon [25], mostly in various types of seabeds, like mangroves, salt marshes and seagrass meadows. This is often referred to as “blue carbon”. Furthermore, seagrasses are estimated to be responsible for up to 18% of the total carbon storage by oceans [26-29], at a rate 35 times faster than tropical rainforests [30], which helps counteract greenhouse gas emission and climate change impacts. Seagrasses are capable of storing carbon for millennia, unlike rainforests that store carbon for decades [16, 28, 31].

Threats to Seagrass Ecosystems

Globally, seagrasses have declined in area by approximately 29% since the beginning of the twentieth century, and continue to be lost at an annual rate of 1.5% per year [ranging from 0.4 to 2.6% yr^{-1}; 32]. This is equal to about two football fields being lost each hour [17, 28, 33]. The rate is likely to increase in the future as the exploitation of coastal areas increases [34]. Scientists attribute declines to poor water quality caused by "pollutants", especially sediments and nutrients [30, 33, 35] from run-off causing turbid water that prevents sunlight penetration to seagrass plants, which then eventually die. According to R.J. Orth *et al.* [35], biological, environmental and extreme weather events have been identified as causes of seagrass losses that can interact at varying temporal and spatial scales. Furthermore, global review of the six [36] bioregions acknowledged that anthropogenic activities including urban/industrial runoff, urban/port infrastructure development, agricultural runoff, and dredging had the greatest impact on seagrasses worldwide [37]. Other anthropogenic threats or stressors include aquaculture, pollution, boating activities, coastal construction, dredging and landfill activities, and destructive fishing practices [38]. These activities have resulted in eutrophication, high trace metal levels, habitat degradation, and increased water column sediment loads, all of which negatively affect seagrass ecosystems. Likewise, in the Western Pacific, seagrass habitats face a number of threats including increasing human populations, declines in water quality, loss of biodiversity, and erosion of habitat structure [35, 39]. On the other hand, the Pacific islands of Oceania support an estimated 9 million people who are highly dependent on marine resources for food and income generation [40]. Related increases in fishing, pollution and development pressures [36] are depleting and degrading critical Melanesian regions' ocean assets, valued at 548 billion USD. The importance and value of seagrass resources in Melanesia is clear, with an estimated value of 151.4 billion USD compared to coral reefs (145.7 billion USD), marine fisheries (124.1 billion USD) and mangrove resources (109.6 billion USD) [41]. In the Pacific islands, seagrass habitat losses by the year 2100 are estimated between 5 to 35%. F.T. Short *et al*. [39] suggested from seagrass monitoring in the Western Pacific region that excess nutrients and sediments are common and significant causes of seagrass decline due to human impacts. Across the Oceania region, changing land-use practices from deforestation, agriculture, land-based mining, nutrient runoff, inappropriate land management practices also destructive fishing practices, urban expansion, poor catchment management, poor coastal infrastructure regulation, and population increases pose significant threats and challenges to coastal areas. Consequently, projected population doubling by the year 2050 in Melanesia will put additional anthropogenic pressures on already stressed coastal habitats. As stated by C.J. Brown *et al.* [42] in the Pacific Islands the management of activities on land to avoid erosion and pollution run-off to the ocean is important for the conservation of many coastal marine ecosystems. High erosion rates in other parts of the world have also been documented to substantially impact marine water quality. Furthermore, N.S. Tuivavalagi and R.J. Morrison [43] suggested adopting practices that reduce the flow of land-based effluents and sediments into the Western Pacific region and thus reduce the rate of degradation of valuable coastal assets. Therefore, actions that reduce deforestation and target catchment restoration in the most degraded watershed may prompt the greatest improvements in local coastal marine livelihoods.

Consequence of Seagrass Habitat Loss

Increasing seagrass losses reveal major environmental crises in coastal ecosystems, such as loss of the associated functions and services [35]. Seagrasses are sentinels of changes in water quality, sediment loading, eutrophication, and inputs that accumulate as a result of human modification of watersheds and receiving coastal water bodies [33]. The loss of seagrasses will also involve the loss of the oxygenation of sediment by seagrass roots, promoting anoxic benthic conditions. Additionally, seagrass loss has been shown to result in significant loss of coastal biodiversity, leading to a modification of food webs and depletion of harvestable resources [44]. Similarly, seagrass loss would result in decreased primary productivity, nutrient recycling, coastal protection, and, most importantly, carbon sequestration. J.W. Fourqurean *et* *al*. [28] and L. Pendleton *et al*. [32] argued that the deterioration of natural marine ecosystems that serve as carbon sinks (such as salt marshes, mangrove and seagrass beds) may potentially accelerate climate change through re-emissions of locked carbon dioxide (CO_2) and other greenhouse gases [16]. Specifically, if the current rates of seagrass habitat decline remain unchanged, the annual loss could result in the release of previously stored carbon of up to 299 Tg C into the atmosphere each year [16, 28].This equates 10% of all CO_2 emissions attributed to anthropogenic changes in land use [28]. K. Trumper [45] suggested that a reduction in greenhouse gases emission by 85% by the year 2050 (from levels seen in 2000) is needed if the 2^oC goal is to be achieved. Therefore, both natural and human induced disturbances, including storms, eutrophication and sedimentation, result in degradation or loss of the carbon sequestration process [46-49]. On the other hand, A. R. Armitage and J.W. Fourqurean [50] suggest that an increase in nutrient load can also promote carbon storage by supporting higher productivity and biomass growth in nutrient limited areas. Seagrass habitat loss due to land-use change was estimated to release between 0.05-0.33 Pg CO_2 yr^{-1} back into the atmosphere, based on a global annual loss rate of 0.4-2.6%; this rate is comparable to the annual rates of fossil fuel CO_2 emissions in many small countries [32]. The authors also suggested that this large discharge of CO_2 into the atmosphere could result in an economic cost of USD 1.9-13.7 billion yr^{-1} (at a C price of USD 41 per ton of CO_2). To combat further escalation of climate change, J.W. Fourqurean *et al*. [28] and L. Pendleton *et al*. [32] suggested combining reductions in anthropogenic greenhouse gas emissions and restoration and conservation of natural ecosystems that have high carbon sequestration and long-term storage. Additionally, preservation of an existing seagrass meadow retains 50 times more carbon than new sequestration into barren soil from a restoration/rehabilitation project [32].

Climate change is also part of a positive feedback cycle that may further result in increased loss of seagrasses through increasing sea level rise, temperature, storm frequency, and run-off [51-54]. In summary, seagrass degradation represents a major loss of ecological as well as economic value to the coastal ecosystems, and is therefore a major source of concern and challenge for coastal management.

Seagrass Research Effort versus Media Coverage

Seagrasses are ranked with coral reefs and mangroves as the world's most productive coastal habitat, and strong linkages among these habitats make the loss of seagrasses a contributing factor in the degradation of the world's ocean. Notably, these coastal ecosystems are often interconnected by means of migrating animals, nutrient fluxes, and organic carbon [55]. Globally, seagrasses are less studied than coral reefs, salt marshes, and mangrove forests (Fig. 2).

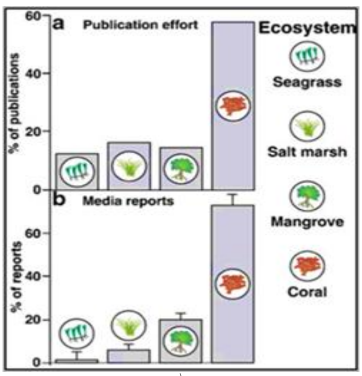

Fig. 2. Graph showing charisma gap determined by the number of media reports per scientific paper, when compared to other coastal ecosystems [15]

Despite their significance, seagrass meadows are also far less publically recognized than coral reefs, or mangrove forests, showing an imbalance or "charisma" gap. Similarly, seagrass ecosystems receive the least attention in the media (1.3%) compared to mangroves (20%), and coral reefs, which are the subject of three in every four media reports on coastal ecosystems (72.5%) [15]. For example, on average a coral reef scientific publication receives 130 media reports, whereas every seagrass scientific publication identified in this review received fewer than 13 – showing the disconnect between scientific and public awareness [15]. Furthermore, most of the research has occurred in Europe, North America and Australia [33], and there is currently no information from Oceania except for Australia and New Zealand. Therefore, a lot remains to be learned about tropical seagrasses.

Seagrass Distribution

Seagrasses are plants that grow in salty and brackish waters along coastlines of every continent except Antarctica [12, 56]. Globally, seagrass covers an area estimated at up to 600,000 km^2 [15, 30, 33], a figure derived from a global estimate of seagrass productivity. There are 72 species of seagrass worldwide and 14% of these are at risk of extinction [16, 57]. The tropical Indo-Pacific bioregion, as defined by F.T. Short *et al.* [56], has the highest seagrass diversity and is considered to be the "center of origin" of seagrasses.

Regional

M. Waycott *et al.* [58] pointed out that the Pacific islands support large areas of mangroves and seagrasses apart from coral reef habitats. However, knowledge of seagrass occurrence and area cover is poor or not documented for some Pacific Island Countries and Territories (PICTs). Table 1 below provides detail on regional seagrass species found within PICTs that are highly variable.

Table 1. Number of seagrass species recorded from PICTs, together with the estimated area of seagrass habitats [58].

PICTs	Total land area (km^2)	Species
Fiji	18,272	6
New Caledonia	19,100	11
PNG	462,243	13
Solomon Islands	27,556	10
Vanuatu	11,880	11
FSM	700	10
Guam	541	4
Kiribati	690	2
Marshall Islands	112	3
Nauru	21	0
CNMI	478	4
Palau	494	11
American Samoa	197	4
Cook Islands	240	0
French Polynesia	3,521	2
Niue	259	0
Pitcairn Islands	5	0
Samoa	2,935	5
Tokelau	10	0
Tonga	699	4
Tuvalu	26	1
Wallis & Futuna	255	5

The highest species richness of seagrasses reported from the tropical Pacific occurs in Papua New Guinea, with 14 species and a subspecies. Additionally, it has been noted that seagrass diversity declines toward the east, as they are absent or unreported from the Cook Islands, Nauru, Pitcairn Islands, Tokelau, and Tuvalu [58]. However, the discontinuity of seagrass in the Cook Islands and Tokelau may be due to limited surveys, since both have deep, sheltered lagoons and low-energy environments suitable for establishment of these plants. According to M. Waycott *et al.* [58], in some PICTs, mapping of seagrass habitats has been conducted by field surveys or by remote sensing, as most seagrasses are found in waters shallower than 10 m.

Local

In Fiji, the geographic distribution of seagrass remains to be adequately documented, however, a preliminary summary was reported by L.J. McKenzie and R.L. Yoshida [59] (Fig. 3) for seven sites monitored with an estimated area of 16.5 km^2. This was as part of Seagrass-Watch, a global scientific, non-destructive, seagrass assessment and monitoring program [7]. Nevertheless, a recent study has identified other sites along the Viti Levu shoreline where seagrass species have been found [S. Singh *et al*., unpublished]. Still, only a few sites have been studied, mostly by researchers associated with the University of the South Pacific. Seagrasses are also noted in some environmental impact assessment reports undertaken by consultants, in research by non-government organizations, as well as during coral reef monitoring works [60-66].

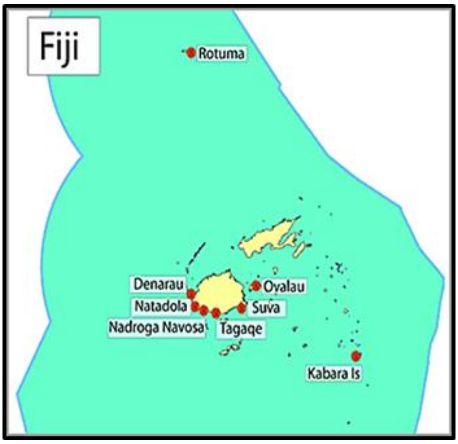

Fig. 3. Seagrass distribution in Fiji;
red points denote monitored sites by Seagrass Watch program [59]

Brief Fijian Seagrass History

The earliest account on seagrasses in Fiji was taxonomic, provided by C. den Hartog [1] as part of a global review of seagrasses, and listed five taxa (*H. ovalis* ssp. *ovalis*, *H. ovalis* ssp. *bullosa*, *Halodule pinifolia, H. uninervis*, and *Syringodium isoetifolium*). A.C. Smith [67] made another report that merged *H. ovalis* ssp. *bullosa* with *H. minor*, besides recording *H. pinifolia*, *H. uninervis*, *S. isoetifolium* and brackish-water *Ruppia maritima var. pacifica*. C. McMillan and K.W. Bridges [68] noted the distinctiveness of *Halophila ovalis* ssp. *bullosa* and suggested that it may warrant a species ranking. In 2006, P.A. Skelton and G.R. South [66] updated the nomenclature of Fiji's seagrasses, recognizing three *Halophila* taxa (*H. ovalis*, *H. ovalis* ssp. *bullosa*, *H. decipiens*), two *Halodule* species (*H. pinifolia*, *H. uninervis*), and *Syringodium isoetifolium*. Out of the 72 seagrass species recognized globally, only six are found in Fiji, all of which show a close affiliation with Indo-West Pacific distribution except for *H. ovalis* spp. *bullosa* [7]. *H. ovalis bullosa* is the only endemic seagrass species found in Fiji, Tonga and Samoa [7]. However, a recent phylogenetic study of Fijian seagrass material has revealed *H. ovalis* and the recognized endemic subspecies *H. ovalis bullosa* are in fact *H. ovalis* [S. Singh *et al*. in-press]. Moreover, it has been noted that Fiji and Tonga are the eastern most limits for *Halodule* species, whereas *S. isoetifolium* and *H. decipiens* have a Pacific-wide distribution as far east as French Polynesia and Hawaii. In Fiji, perhaps the only deep water seagrass species found is *H. decipiens,* discovered and confirmed in 2004 by P.A. Skelton and G.R. South [66] from Cakaulevu reef growing in 10-25 m water. On the other hand, *H. ovalis* ssp. *bullosa* is often found in the intertidal zones, where it is exposed during low tides, growing either in patches or intermixed with *Halodule* or *Halophila ovalis* species in the upper subtidal areas [69]. Similarly, *H. pinifolia* and *H. uninervis* are found mostly in the intertidal areas and are often exposed during low tides, growing either in patches or intermixed with *Halophila* species. In contrast, *S. isoetifolium* is mostly found in subtidal areas, usually in calm places [69]. According to L.J. McKenzie and R.L. Yoshida [59], studies on seagrasses in Fiji are limited primarily due to scientific communities and environmentalists giving low priority in seagrass ecosystem research. The only detailed studies of biological processes have been conducted at Dravuni Island for *S. isoetifolium* on nutrient dynamics of carbon and nitrogen [70]; growth and production (1); irradiance/productivity [71]; and litter production and decomposition [72]. A total of 24 studies have been conducted in Fiji on seagrasses, summarized in table 2 below.

Table 2. Fiji islands seagrass study summary (see appendix for details of the 24 studies).

Purpose	No. of studies
Biological/fauna interaction	18
Ecological mapping	2
Biogeography	1
Seagrass distribution	1
Field & identification guide	1
Current knowledge review	1

Problems Confronting Seagrass Beds in Fiji

Seagrass beds are likely to be impacted by global pressures related to climate change, such as increasing cyclone incidence, rainfall, temperature, and light levels. Similarly, sea level rise is expected to result in the loss of those seagrasses growing at their present depth limit. The Green Growth Framework for Fiji (GGFF) report [74] forecasts that such climate change issues may result in up to a 5% loss of Fiji's seagrass by the year 2035, and between 5-20% loss by 2100. Apart from the natural impacts, the report points out local threats to seagrass beds from various human impacts that are found around many coastal areas. In particular, excavation of channels and reef top pools for resort developments have destroyed and disturbed seagrass beds in Nadi, the Coral Coast and Mamanuca islands, and improper sealing of the sides of such structures continues to cause suspension of sediments, leading to longer term degradation of surviving seagrass beds. According to the report, coastal reefs, lagoons, seagrass meadows, and mangroves have been destroyed by resort construction and by excessive visitations and activities, with consequent loss of marine life and destruction of ecosystems. The report highlights beach walking, snorkeling, and recreational fishing; boat tours and anchoring have also damaged coral reefs and seagrasses and have disturbed nearshore aquatic life. Furthermore, the report also suggested that the few mines (gold and copper) operating in Fiji create a great deal of sedimentation, and in some cases toxic waste run-off into rivers and subsequently into coastal waters. H. Sykes and C. Morris [75] reported that the main impacts on seagrass beds over the past few years have been from coastal and over-water developments, mainly for tourism and residential properties that cause sedimentation from inadequately controlled construction activities, and from increased boat traffic. Similarly, H. Sykes and C. Reddy [76] reported that channel blasting, lagoon dredging, and over-water construction have destroyed some seagrass beds. Accordingly, E.R. Lovell *et al*. [77], and equivalent reports since, indicated that with declining coastal water quality already affects coral reefs, seagrass beds and other important coastal marine ecosystems in the region. A case study in Fiji by C.J. Brown *et al*. [42] indicated that, in several island catchments, land-based activities resulting in high erosion rates have a large influence on the turbidity of coastal waters, particularly where native riparian have been removed to build towns and grow sugar cane. Moreover in Fiji, the rapid increase in commercial extraction of rock, gravel and sand from rivers and streams in an unsustainable manner is causing major ecological and hydraulic changes. The economic cost of this, in the form of increased and more extreme flooding and increased dredging needs, to the nation is high and of considerable concern; [78]. V.C. Vuki [60] and V.C. Vuki *et al.*, [79] concluded that the greatest threats to seagrasses in Fiji were from development, improper methods of disposal of solid waste, sewage pollution, coral harvesting, foreshore reclamations, and high siltation of coastal areas as a result of agriculture and forestry runoff, apart from major natural disturbances such as cyclones and storms.

Globally, seagrasses are recognized as critical habitat for a number of threatened species, including dugongs, sea turtles, and sea horses, all widely perceived to have high cultural, aesthetic, or intrinsic values [56]. Likewise, in Fiji seagrass meadows are known to provide foraging habitat for green turtles in the central South Pacific [59, 79]. Previously, green turtles were hunted and sold in local markets, restaurants, and resorts as a delicacy [79]. In Fiji, there is a turtle moratorium in place under the Fisheries Act since 1997, which continues to date. The moratorium lays a total ban on the subsistence use of turtle, turtle egg, and any commercial trading of its meat and derivatives [80]. There is an exemption for traditional purposes or utilization of turtles granted on request to the Minister. These efforts have been positive for seagrasses, as well, since they play a critical part in sea turtle conservation and have been included in local awareness and protection projects to some extent.

Seagrass Policy

The Intergovernment Panel on Climate Change (IPCC) is tasked with assessing knowledge on climate change. According to P.I. Macreadie *et al.* [16], their influence over the Kyoto Protocol established the United Nations Framework Convention on Climate Change (UNFCCC), which commissioned the International Blue Carbon Scientific Working Group. This body was tasked to determine the roles of coastal ecosystems such as seagrasses, saltmarshes, and mangrove in carbon sequestration, and standardizing methods for carbon estimates. Based on these findings, activities for coastal ecosystem inclusion into assessments used by UNFCCC and Voluntary Carbon Standards (VCS) were established [16]. Unfortunately, seagrasses are currently not included in 2016 IPCC Guidelines for National GHG Inventories, although a section on coastal ecosystems is included [16]. Additionally, the Oceania region is politically and culturally complex, where independent island nations with specific regional and national laws are not yet specially designed to protect coastal habitats such as coral reefs, mangrove or seagrass beds. Despite some Oceania countries being signatories to international and regional treaties and conventions such as the Johannesburg Programme of Action, Mauritius' Strategy for the Further Implementation of the Programme of Action for the Sustainable Development of Small Island Developing States to name a few [81]. Additionally, the authors reported that these are complemented by the development of regional instruments such as the Pacific Plan and Pacific Islands Regional Ocean Policy (PIROP), along with the promotion of national instruments such as National Sustainable Development Strategies (NSDSs) or Planning Instruments, National Biodiversity Strategies and Action Plans (NBSAPs) and National Adaptation Programmes of Action (NAPAs). Finally, it is important to note that the degree of enforcement of national laws and regional and international conventions among countries and territories in Oceania is highly variable.

Surprisingly, seagrass habitat is not mentioned in key regional policy instruments as well, such as the Pacific Island Regional Ocean Policy and Framework for Integrated Strategic Action [MSWG, 2005] or the Framework for a Pacific Oceanscape [PIFS, 2010]. However, under a regional partnership-based initiative called the Pacific Mangrove Initiative (PMI), some attention may indirectly be given to seagrass, as the initiative seeks to conserve mangrove and associated coastal ecosystems to improve livelihoods and biodiversity conservation, and to reduce vulnerability to climate change in the Pacific region. Subsequently, few PICTs implement integrated coastal resource management to address/monitor all sources of pollution and contamination that impact the ocean and coasts as part of their strategic priority set in both the Pacific Island Regional Ocean Policy and Framework for Integrated Strategic Action [MSWG, 2005] and the Framework for a Pacific Oceanscape [PIFS, 2010]. However, there is a strong need to strengthen and increase reporting requirements for these actions to ensure cost effective management at provincial and national levels through policy and enforcement. Still, strategic actions to address catchment management practices in the region are lacking in both regional documents. Nevertheless, with current support from the University of the South Pacific (USP) and Office of the Pacific Ocean Commissioner (OPOC) a review is currently underway of the economic magnitude of current and past efforts made to protect seagrass habitats in the Pacific Islands.

In Fiji, there are a number of legislative measures in place, such as the Fisheries Act (1996), Environment Management Act (2005), and the Mangrove Management Plan (2013), which are administered by the Department of Fisheries, Department of Environment, and others, respectively [82]. Likewise, Fiji is a signatory to the Convention on International Trade in Endangered Species (CITES) and the Convention on Biological Diversity, Management and Planning Instruments, the Paris Accord to help meet its international obligations. Accordingly, the National Biodiversity Strategy and Action Plan form the basis for future environmental protection [74]. Moreover, there are legislative acts and impact assessment processes to control and monitor pollution from development and ports [83]. Furthermore, Fiji has made a commitment that by 2020, 30% of the marine environment within its EEZ will be included in a comprehensive and ecologically representative network of Marine Protected Areas (MPAs) that are effectively managed and enforced [74]. Nevertheless, much of the actual management of marine areas is currently implemented through Locally Managed Marine Areas (LMMAs) or community-based management, with increasing interest and growth in community-based management of marine areas in the last decade [84]. The author points out those LMMAs are not formally recognized through legislation; however, 171 have management plans that could be classed as Community Conservation Areas. Additionally, H. Sykes and C. Morris [73], indicate that government recognition of *i qoliqoli* areas (traditional fishing grounds) is limited, but many LMMAs are recognized by local councils and traditional leaders. Unfortunately, there is little formal support and integration of LMMAs into national protection measures, which is an argumentative issue. According to A. Chin *et al*. [40] there are limited resources and capacity for enforcement of fisheries and environment regulations.

Recommendations

We believe that a "seagrass crisis" in the region and country can be averted with strengthened policy implementation, fully supported and improved research efforts, enforcement of catchment management regulations, and education on the value of the resource to the general public, resources owners, and managers, since the majority of the challenges faced by seagrass meadows are from human land-based activities such as those generating increased sedimentation. We therefore recommend the following:

- Strengthened support for local and regional research and human resource capacity building on seagrass ecosystems.
- Mapping seagrass resources so that any gains, losses, or recoveries over time can be understood and can be used to facilitate informed science-based management decisions.
- Calculating regional and national estimates of coastal ecosystems based on default values from global databases.
- Developing nature- or ecosystem-based activities or coastal projects to encourage conservation and restoration, while creating disincentives to damage coastal ecosystems.
- Significantly strengthening regulation of protective and restorative measures to substantially improve water quality, monitoring and organizing measures for dredging and landfill activities, wastewater treatment and the rehabilitation of adjacent watersheds, which could radically reduce the rate of seagrass habitat loss.
- Including seagrass habitats in environmental education programs at all levels to encouraging responsible stewardship to promote conditions that will confer seagrass meadows with resistance and resilience against pressures that cannot be managed locally, such as those associated with climate change. This includes educating children at an early age and empowering resource owners to value seagrass habitats.
- Addressing and enforcing the downstream environmental impacts of poor catchment management and substantially strengthening regulation of coastal development policy by highlighting the importance of environment in national and regional governance structures.
- Supporting seagrass meadows to be specifically named and included in any new or updated ocean policy frameworks as an essential component of the Pacific Oceanscape and in achieving the targets of Sustainable Development Goals.

Conclusion

Coastal resources are important to the livelihoods and well-being of people and their communities globally, and especially for Pacific Islanders. In that light, we recognize here the importance of seagrass resources to the regional and national Oceanscape. As significant coastal habitats, seagrass meadows are providers of up to twenty-five articulated ecosystem services that are highly relevant to human livelihood quality. We wish here to raise awareness of the value of seagrass resources and promote recognition of their contribution to priority regional and national agendas. The current major threats to seagrass ecosystems also include a lack of research and knowledge of the extent of the resource, ignorance in major regional and national policy frameworks, a prevalence of unsound catchment management practices, and climate change. It is vitally important that we approach these threats by separating what elements we can and cannot mollify, and not use issues that we have little influence over as a smoke screen to hide a lack of progress in addressing issues that we do have the power to change (e.g. resource use and catchment management) at a regional, national and community level.

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Appendix

Study Title	Purpose	Author & Year
Global review of seagrass	Taxonomic	[1]
Estimation of growth & production of *S. isoetifolium* in a Fijian seagrass bed	Growth & production	[71]
Irradiance (PAR) & daily productivity, measured by productmeter & lacunal gas release of the seagrass *S. isoetifolium* in a Fijian coral sand	Irradiance/productivity	[72]
Biogeography of tropical seagrasses in Western Pacific	Biogeography & origin	[92]
Characteristics of nitrogen & carbon standing stock in a tropical seagrass bed in Fiji	Biological processes	[70]
Fate of the seagrass production as assessed by cage experiments in a monospecific seagrass bed of *S. isoetifolium* in Fiji	*S. isoetifolium* deposition & decomposition	[97]
Characteristics of the benthic communities in a Fijian seagrass bed	Faunal investigation of *S. isoetifolium*	[97]
Carbon & nitrogen budget of didemnid – algal symbiosis metabolisms	Ascidians symbiotic relation with *S. isoetifolium*	[88]
Bacterial decomposition of detritus in a tropical seagrass (*S. isoetifolium*) ecosystem, measured with (Methyl-super-^{3}H)thymidine	Litter production & decomposition	[73]
Rhizome growth & biomass of *S. isoetifolium* in Dravuni island, Fiji	Biomass & growth	[86]
Comparison in rhizome growth of the two tropical seagrass species, *Thalassia hemperichii* & *S. isoetifolium*	Biomass & growth	[85]
Decomposition process of *S. isoetifolium* with special reference to attachment of particulate matter	Decomposition process & nitrogen flow	[87]
Nitrogen fixation, a nitrogen input to a tropical seagrass bed	Decomposition process & nitrogen flow	[86]
Abundance, population structure & microhabitat use of the compound ascidians in a Fijian seagrass bed with special reference to *Didemnum molle*	Fauna – seagrass interaction	[100]
How does a compound ascidian *Didemnum molle* remain on unstable substrate?	Fauna – seagrass interaction	[100]
Nutritional diversity of symbiotic ascidians in a Fijian seagrass meadow	Fauna – seagrass interaction	[89]
Grazing effects of gammaridian amphipoda, *Ampithoe* sp., on the seagrass, *S. isoetifolium* & epiphytes in a tropical seagrass bed in Fiji	Fauna – seagrass interaction	[93]
Grazing effects of *Caltomus spinidens* on defoliation of the seagrass, *S. isoetifolium* in a Fijian seagrass bed	Fauna – seagrass interaction	[96]
Leaf production in the seagrass *S. isoetifolium*: a modified method and measurements on Suva Reef	Leaf production	[98]
An ecological & mapping study of the seagrass communities on Nukubuco Reef, Suva	Ecological & mapping	[90]
Seagrass biodiversity of the Fiji & Samoa islands, South Pacific	Nomenclature update	[66]
Mapping benthic habitats on Fijian coral reefs: Evaluating combined field & remote sensing approaches	Ecological & mapping	[99]
Seagrasses of the Fiji Islands: review of current knowledge	Seagrass distribution	[59]
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