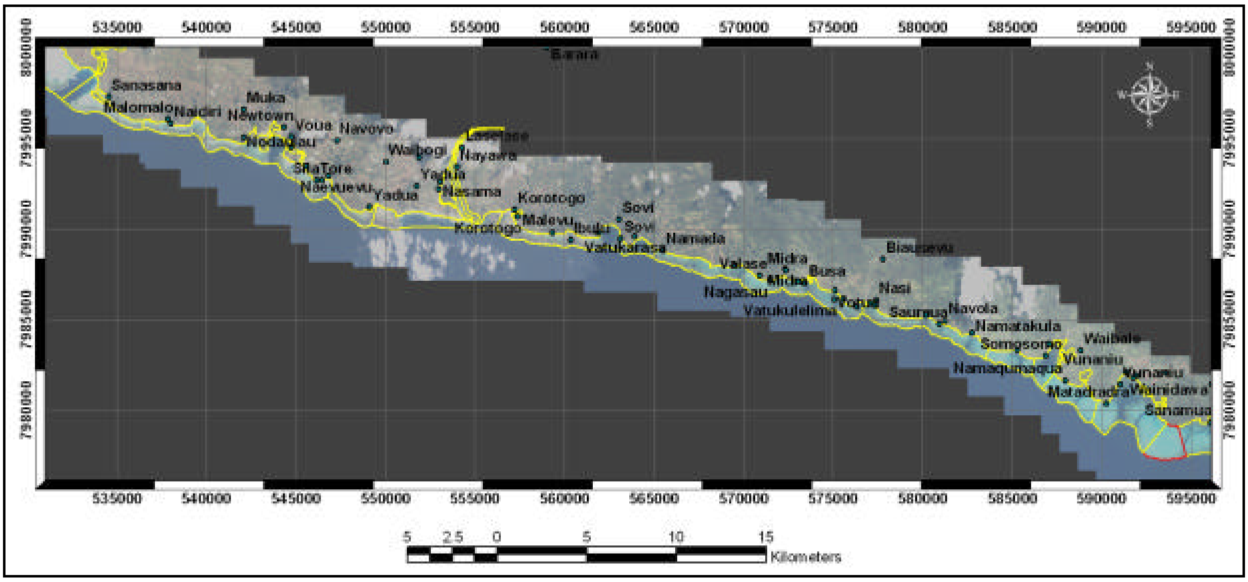
The Coral Coast,

Viti Levu, Fiji.

A Marine Resource Assessment



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Executive Summary

- Much of Fiji's wealth is generated by its extensive marine resources, which provide both an important source of protein-based food in the form of fishing and an income through tourism. A range of factors currently threatens the ecological balance and health of Fiji's reef systems.
- Biological surveys have been carried out along the Coral Coast on the southern coast of Viti Levu, Fiji by the British NGO Coral Cay Conservation.
- These surveys assess the status of marine resources on the back reef area fringing the district. These provide valuable information for use by traditional fishing right owners, Government, and Non-Government Organisations in the decision-making process relating to the management of the area.
- Areas of high coral cover tend to contain high levels of important food fish and invertebrate species. As such, they are of high management concern.
- The effectiveness of current Marine Protected or Tabu areas and other management is considered. While the position of most Tabu areas appears to satisfy the desired scientific criteria, it will require a dedicated and long-term approach to increase and safeguard the future of the coral reef resources of the area. Other fisheries management options are also discussed.
- Through the use of point intercept and belt transects, the assessment provides information on the benthic, fish and invertebrate communities of the Coral Coast.
- Using Geographic Information System (GIS) derived images and other forms of analyses; results have served to highlight the specific concerns over nutrient enrichment and reversion of the system to algal dominated reef platform. Algal dominance over coral generally reduces the abundance of fish and invertebrate communities.
- Recommendations towards the reduction of detrimental impacts, the employment of more sustainable management practices, and the relevant information still required is presented.

1. Introduction

Coral Reefs and their associated habitats are recognised as an extremely important resource throughout the South Pacific region. Fiji is one of the wealthiest countries in the region. This is in part attributable to its biodiverse and productive reef ecosystems, which provide valuable fishery resources, important tourism attractions, as well as protection from storms and coastal erosion. Over recent decades, there has been a growing realisation of the degradation caused to coral reef environments due to increased coastal development and resource over-utilisation (Hodgeson, 1999). These threats may manifest themselves as increased nutrient enrichment, erosion, siltation, over fishing, destructive fishing, marine pollution, and well as harvest for the aquarium trade. Such impacts, often acting synergistically with natural impacts, can result in a decline in ecosystem productivity and stability. Left unchecked, this will ultimately lead to a reduction in income and resources for coastal communities and other stakeholders that rely on fishing and the marine environment.

1.1 Coral Cay Conservation (CCC)

Effective coastal zone management, including conservation of coral reefs, requires a holistic and multi-sectoral approach, which is often a highly technical and costly process and one that many developing countries cannot adequately afford. With appropriate training, non-scientifically trained, self-financing volunteer divers have been shown to be able to provide useful data for coastal zone management at little or no cost to the host country (Hunter and Maragos, 1992; Mumby *et al.*, 1995; Wells, 1995; Darwall and Dulvy, 1996; Erdmann *et al.*, 1997; Harding *et al.*, 2000; Harborne *et al.*, In press). This technique has been pioneered and successfully applied by Coral Cay Conservation (hereafter referred to in this report as CCC), a British not-for-profit organisation.

Founded in 1986, CCC is dedicated to '*providing resources to protect livelihoods and alleviate poverty through the protection, restoration and sustainable use of coral reefs and tropical forests*' in collaboration with government and non-governmental organisations within a host country. CCC does not charge the host country for the services it provides and is primarily self-financed through a pioneering volunteer participatory scheme whereby international volunteers are given the opportunity to join a phase of each project in return for a financial contribution towards the project costs. Upon arrival at a project site, volunteers undergo a training programme in marine life identification and underwater survey techniques, under the guidance of qualified project scientists, prior to assisting in the acquisition of data. Finances generated from the volunteer programme allow CCC to provide a range of services, including data acquisition, assimilation and synthesis, conservation education, technical skills training and other capacity building programmes. CCC is associated with the CCC Trust (the only British-based charity dedicated to protecting coral reefs) and the USA-based CCC Foundation.

During 2000, CCC was invited to the Mamanuca Islands in the west of Fiji by local tourism operators, the Ministry of Tourism and Transport and the Fiji Visitors Bureau to determine the current status of the coral reefs and threats to their integrity and suggest possible conservation initiatives. This ultimately led to the setting up of the Fiji Coral Reef Conservation Project (FCRCP). A three-year Memorandum of Agreement was signed between CCC and The Ministry for Tourism (formerly the Ministry of Tourism and Transport) of Fiji in March, 2002 and renewed in April 2005. Over this period additional projects, including a project in the Coral Coast region (figure 1), were set up.

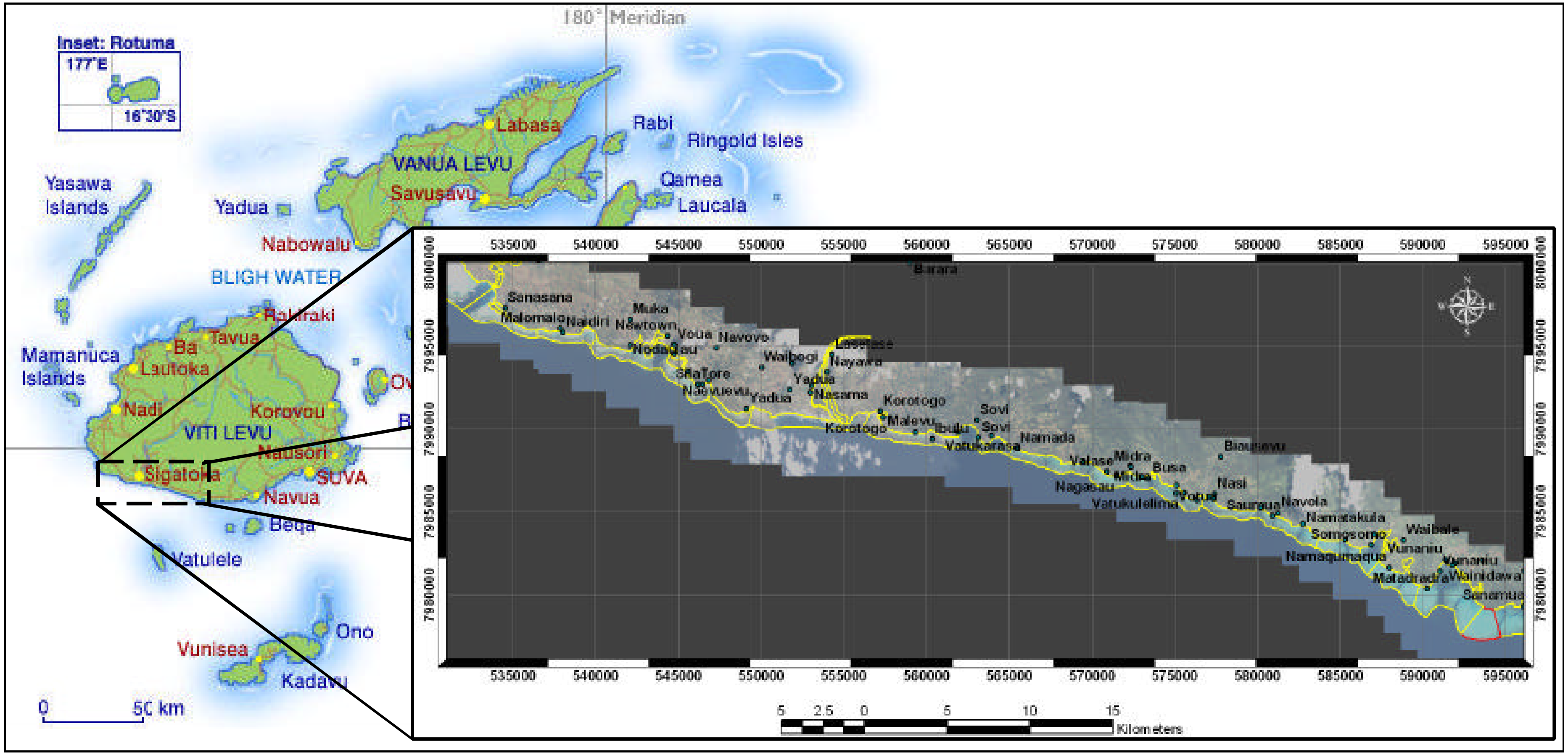

Figure 1. Map showing position of Coral Coast survey area within the Fiji Isles (Map courtesy of Fiji Visitors Bureau). Yellow lines denote individual fishing area boundaries. Red line denotes easterly extent of surveys

1.2 The Coral Coast project

The Coral Coast project had two distinct yet ultimately connected phases. Initially, CCC was invited to work on the Coral Coast by the Ministry of Tourism and the Integrated Coastal Management (ICM) group to determine the status of the coral reefs, threats to their integrity and inform management initiatives. With additional financial and logistical support of the Coral Coast Hoteliers Association, a member of the ICM group, a survey plan was devised to examine the condition of reef systems from the Sigatoka river mouth to Namatakula village. Following the completion of this objective, work continued in conjunction with the Ministry of Fisheries; the survey area was extended east into Serua District, and west up to Natadola bay. This work fed into the Ministry of Fisheries requirement to survey all native fishing areas (iqoliqoli) prior to the hand back of their management to native populations. Areas were selected based on the requirements of the Ministry of Fisheries and feasibility of access and are demonstrated in table 1 and figure 2. The whole of the Coral Coast was therefore ultimately surveyed.

This report documents the results and findings of the Coral Coast project and offers recommendations towards the continued management of marine resources in the region.

Table 1. Description of iqoliqoli user groups for use with figure 2

Refernece number	Iqoliqoli (Fishing ground) User group
1	The Yavusa Nadruku of Korovisilou village in the District of Serua
2	The Yavusa Noi Naculava of Namaqumaqua Village in the District of Serua
3	The Yavusa Burenitu of Naboutini and Nabukelevu villages in the District of Serua
4	The Yavusa Davutukia, Bolabola, Keasuganaqali, Kubunicere, Noi Tubai and Naculava in the District of Korolevuiwai
5	Vanua ko Conua kei Naivikabuta & Yavusa Noi-Weredruga comprising Vatukarasa, Korotogo, Nawamagi, Naroro, Narata, Malevu and Nadrala in the District of Conua
6	The Vanua ko Madudu comprising Nayawa & Laselase villages in the District of Nasigatoka
7	The Vanua ko Nasigatoka comprising Nasigatoka, Yavulo, Volivoli Vunavutu & Nasama villages in the District of Nasigatoka
8	The Vanua ko Yavuasuna and Voua comprising Cuvu, Yadua, Naevuevu, Rukurukulevu, Sosoinaviti, Voua, Semo, Emuri, Nadroumai and Nabau villages in the District of Cuvu and Tuva
9	The Vanua Tabanivono-I-ra (Malomalo) comprising of Yavusa Leweisave, Leweinavivasa, Tabanivono, Leweinuku, Noi Lau and Leweivucini in the District of Malomalo
10	The Vanua of Nasoqo comprising of Yavusa Ketenamasi, Leweitaqalulu, Tacini, Nalotawa and Leweiasiga in the District of Malolmalo
11	The Vanua of Komave comprising of Yavusa Vusu residing at Biausevu, Namatakula, Komave and Vusamaravu Villages

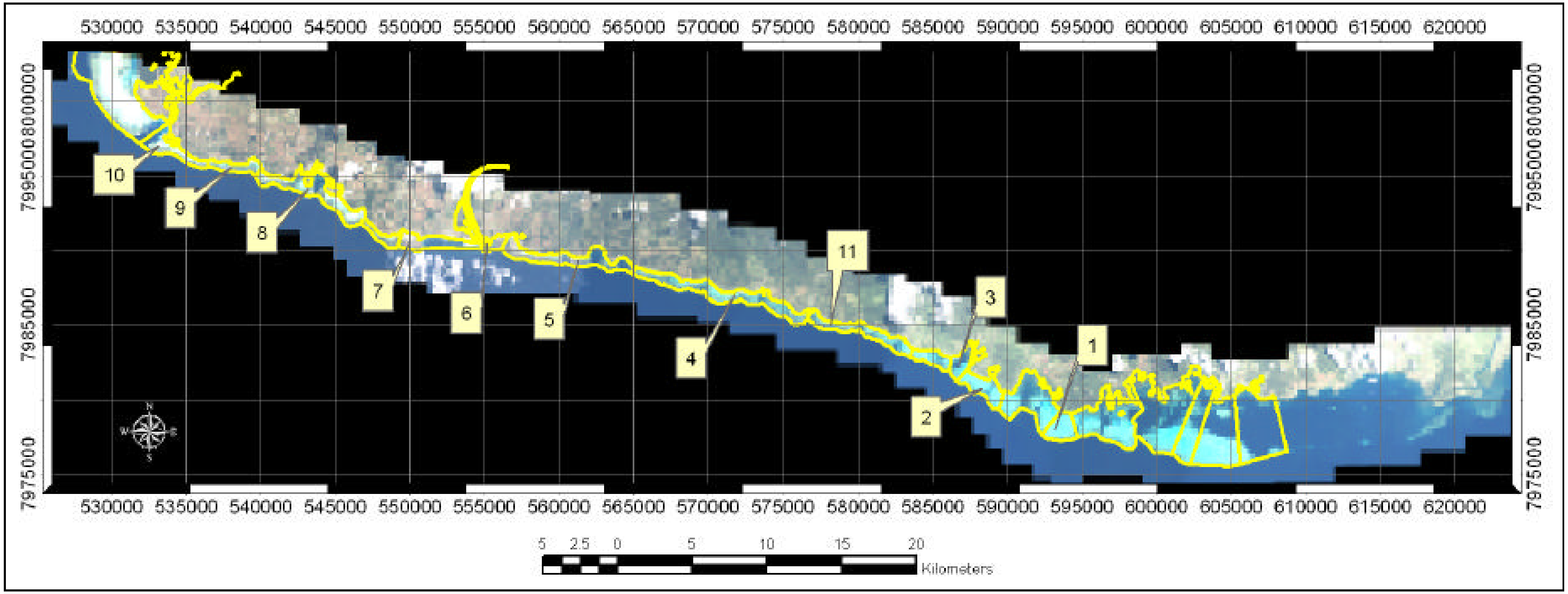

Figure 2. Iqoliqoli (native fishing area) surveyed during the project, labeled 1 to 11. Refer to Table 1 for iqoliqoli user groups. Iqoliqolis 1-10 are available as separate self-contained reports (Coral Cay Conservation, 2005[1-10]).

2. Background

2.1 The Coastal Zone of Fiji

Fiji comprises approximately 844 islands, of which two, Viti Levu and Vanua Levu, comprise 87% of total area (Vuki *et al*., 2000). The shallow coastal zone of Fiji is comprised of three major, interrelated habitat types: marine algae and seagrass; large areas of mangroves; and extensive coral reefs. The marine resources include approximately 1000 coral reefs with representatives of all major reef types (Vuki *et al*., 2000). Although marine biodiversity is lower than in the 'coral triangle' of Indonesia, the Philippines, Papua New Guinea and northeastern, Australia, Fiji does support approximately 200 species of coral (Veron, 2000). Furthermore it has been estimated that Fiji has approximately 1200 marine fish species (Vuki *et al*., 2000). Since taxonomic research in the country has been limited, further research will extend the known biodiversity of all marine taxa considerably.

Fiji's current population is approximately 775,000 and increasing rapidly (South and Skelton, 2000). Since much of this population is concentrated around the coast, the expanding development of coastal areas and exploitation of the reefs are resulting in a suite of threats to the coral reefs including siltation, eutrophication and pollution (Vuki *et al*., 2000). For example, some of the natural landscape has been converted for agriculture, particularly sugar cane, which impacts the coastal environment via soil erosion leading to elevated sediment loads smothering coral colonies. Further erosion is also caused by the removal of mangroves to re-claim land for urban development. Such expansion of urban areas has also led to pollution of the coastal zone because of inadequate sewage treatment and waste disposal. Industrial point sources have also been shown to contribute to decreasing water quality.

A recent study of nutrient levels along the Coral Coast of Viti Levu (Mosley and Aalbersberg, 2002) found that levels for nitrate and phosphate exceeded thresholds considered harmful to coral reef ecosystems. Furthermore nutrient levels were highest at sites located near hotels, other populated coastal locations and in rivers. In addition to coastal development, fishing in Fiji, which occurs at both traditional subsistence and commercial scales, has significantly reduced the populations of many species. Although data are scarce, even traditional techniques, such as hand-lines, fish traps and gill nets, in combination with commercial catches have led to over-fishing of many reef areas. For example, an earlier study by Jennings and Polunin (1996) found low abundances of certain highly targeted fish species, such as Groupers and Emperors. Over-fishing of prized invertebrate species such as *Tridacna* clams and Sea Cucumbers has also been reported close to urban areas and is thought to have increased since the introduction of SCUBA apparatus and escalating demands of foreign markets (Vuki *et al*., 2000). Fiji is the world's second largest exporter of live reef products for the aquarium trade (Wilkinson, 2002) with a well-established industry that has been operating for over 16 years exporting coral reef fishes and curio coral (Lovell, 2001).

The anthropogenic threats to reef health have been compounded by natural and semi natural threats such as storm damage, outbreaks of the coral eating Crown-Of-Thorns starfish (*Acanthaster planci*) and coral bleaching events. Bleaching events occur during occasional periods when climate conditions raise seawater temperatures and solar irradiance and cause a paling of coral tissue from the loss of symbiotic zooxanthellae (summarised in Brown, 1997 and Westmacott *et al*., 2000). A major coral bleaching event occurred in Fiji in March and April 2000 and had large-scale effects throughout the country, including the Mamanucas region. For example, South and Skelton (2000) reported bleaching of up to 90% of coral colonies with up to 40% mortality (Sulu *et al*.; in Wilkinson, 2002), although there was significant spatial variation in its severity throughout Fijian waters. There is evidence that many of the corals recovered but mortality was certainly significant although it is difficult to quantify because of the limited long-term monitoring data available. A second less severe bleaching event occurred in the Mamanucas in April 2002 but did not significantly alter the percentage cover of live hard coral (Walker *et al*., 2002).

Fiji is also affected by a severe cyclone every 3-4 years (Vuki *et al*., 2000), causing significant coral damage in shallow water. Population explosions of Crown-of-Thorns starfish (COTs) have also been recorded since 1979 (South and Skelton, 2000).

There is a growing network of locally owned and managed Marine Protected Areas or Tabu areas under the umbrella of the Fiji Locally Managed Marine Areas Project (FLAMMA) initiated by USP. This advocates the use of conservation education to highlight the advantages of voluntarily established marine reserves, such as increased fish catches and tourist revenue, to local communities.

2.2 The Coral Coast

The Coral Coast region is found in the Nadroga Navosa Province on the southern coast of Viti Levu and stretches from Natadola bay in the west to Namatakula village in the East. For the purposes of this study a number of reef areas of the neighbouring Serua Province east of Namatakula were also included (figures 1 and 2). Though not within the area formally described as 'The Coral Coast' these areas represent the continuation of fringing and back reef platform that typifies this coastline. As such they may be considered part of the Coral Coast as a working definition of the area of study.

Attractive reef and beach features combined with moderate rainfall stimulated rapid development along the Coral Coast after the sealing of the Queens Highway in the early 1970s (Thaman, 2002). This has resulted in erosion, habitat loss, elevated siltation, pollution, and the degradation of near shore habitats, such as mangroves, seagrass beds and coral reefs. Visitors at tourist resorts make use of the coastline for activities such as SCUBA diving, snorkelling, glass bottom boat rides, fishing, kayaking, and sailing. Tourism forms an integral part of the local economy as a number of local people work in hotels or related industries.

Small settlements and households are scattered along the coastline, however the majority of the population live in villages of between 100 and 300 people or in the market town Sigatoka, which is central to the region and houses approximately 8000 people. In addition to tourism, the fishing grounds of the Coral Coast region provide for a large proportion of the local diet.

The southwest coastline of Viti Levu is steeply shelving offshore; the 200m depth contour lies approximately 1km offshore (British Admiralty Chart 2691). Fringing reef extends along the Coral Coast for approximately 63 kilometres and up to 1000 metres offshore. Behind the break zone, back reef habitat extends over the comparatively flat platform towards shore. There is a distinct gap in the reef system where terrigenous sands have built up west of the mouth of the Sigatoka River to form the high dunes of the Sigatoka National Park

The continuity of the reef is periodically broken by channels cut through the reef due to fresh water influx from rivers and streams and sediment deposition. These channels provide suitable habitat for corals, other sessile forms, and their associated communities below the spring low tide. Persistent siltation and periodic pulses of freshwater near the river mouths condition species assemblages differentially, thus the complete fringing reef can be broadly divided into geomorphologic zones along a bio-physical gradient from inshore back reef extending to the lower fore reef area. Each zone is subject to different physical regimes and comprising a distinct ecological unit, see table 1. Clear zonation of corals, zooanthids, algae and ascidians has been noted at Cuvu, Korolevu, Namatakula, Malevu and Komave (Moreton & Raj, 1980; Ryland, 1981), along with a high diversity of scleractinians on the reef flat lagoon.

Table 2. Habitat Zonation on the Coral Coast of Viti Levu. Source: Ryland (1981) and Veron (2000)

Zone	Description
1	Seaward slope, wavebreak zone
2	Emergent reef crest
3	Crevice and tunnel reef flat
4	Gulleyed, isolated microatolls
5	Middle reef flat, regular lines of branching corals associated with rubble drifts, separated by sandy drainage channels

Channels are characterised by strong outward currents. The channels draw water off the reef platform creating strong currents parallel to shore. Semi-diurnal micro tides of around 1.7m at springs and 1.6m at neaps were recorded at the Rutua secondary tide station and are thought to be representative of tides experienced along the Viti Levu southern shores (Sanchez, 1999). Under normal conditions, the channel current is stronger at high tide when the fringing reef is submerged and provides little protection. Rip currents are a common feature of inshore channel dynamics where waves break directly onto the shoreline without the earlier opportunity of significant energy loss.

A detailed study of wave heights was produced by Green, (1980), while investigating the potential of a passive wave energy scheme for electricity generation, see table 2. Measurements used the zenith angle of the wave crest as it broke on the reef, where "maximum wave" was the average of the 5 biggest waves observed in a 10 minute period and an "average wave" was the average of 5 medium sized waves observed in the same period. A substantial proportion of wave energy is dissipated along the fringing reef, around 500m offshore. Figures fall within the range of waves commonly breaking on reefs across the South Pacific.

Table 3. Wave height and lagoon data from 7 sites along the Coral Coast. Source: Green, (1980).

SITE	LAGOON DATA			WAVE HEIGHTS/m
	LENGTH/km	WIDTH/m	AREA/k square metres	
Naindiri (Vanambua)	3.5	380	1.71	1.75-2.25
Malevu (W)	3.5	500	1.75	1.50-2.0
Malevu (E)	1.7	500	0.85	1.50-2.0
Namada	2.4	500	1.20	1.75-2.0
Komave (Korolevu)	2.7	450	1.21	1.25-1.75
Navutuleva	3.0	700	2.10	1.50-2.0

Waves with substantially increased energy levels will propagate directly onto the shoreline during more extreme events. Peak wave heights reached 7.2 and 9m respectively during cyclones Raja (December 1986) and Joni (December 1992), causing considerable damage to shoreline development. Offshore wave heights of >10m have been measured during other cyclonic events (Thaman *et al*, 2001).

2.3. Aims and Objectives

The aims and objectives of this study are outlined in table 4 below.

Table 4. Aims and objectives of the Coral Coast project

Aims	• Assess the resources and health of the coral reefs of the coral coast
Objectives	• Detailed baseline reef health assessments at various locations in the study area.
Anticipated Outputs	• Establishment of a Geographical Information Systems (GIS) database for the project area • Recommendations towards marine management strategies in the Coral Coast region.

3. Research Team

Baseline biological surveys were carried out in the Coral Coast region between July 2004 and May 2005. The research team of individuals from Coral Cay Conservation, with additional support provided by the Institute of Applied Sciences (University of the South Pacific) and associated Peace Corps volunteers represented as follows:

Coral Cay Conservation: Gwilym Rowlands, Louise McNamee, Lucy Ward, Mark Roberts, Matthew Crabbe, Chiara Bertelli, Lene Tuveng, James Couper.

Institute of Applied Sciences: Jolame Sikolia, Marika Tubuna, Napolioni Napote, Alefereti Qauqau, Saki Fong, Jim Reynolds (Peace Corps), Alyson Venti (Peace Corps), Laura Mattison (Peace Corps).

4. Survey Methodology

Survey effort was concentrated on the back reef area, using snorkellers. The back reef relates to the area where the majority of fishing effort and activity is concentrated. Information was collected using a point intercept transect to assess benthic coverage; belt transects to assess the fish and mobile invertebrate populations and a kayak marshal to collect positional data and provide safety cover. A modified Reef Check rapid reef assessment technique was utilised. Information on target species, substrate variables, and lifeforms as well as supplementary data on anthropogenic and oceanographic activities was recorded. Example data sheets used in the data collection phase are shown in Appendix 2. Data was transferred to these recording forms before being entered into a Geographic Information System (GIS) compatible database. The following specific methods were used for data collection on each of the biological and environment data variables:

4.1 Distribution of Transects and survey effort

One hundred and four transects were run out from shore towards the reef crest (figure 2) (Refer to section 5.2 and figure 5 for details of section designation used in analysis.). Initial scoping studies indicated the presence of three distinct habitats from shore to crest.

1) Near shore zone: relatively sheltered, typified by sandy substrate, seagrass, and algae.
2) A mid zone: sheltered habitat comprised of channels offering greater topographic complexity and a higher abundance of coral.
3) Break zone: habitat influenced by the effects of breaking waves and characterised by rubble and algae.

Three 100 metre sections were spaced along these transects to ensure coverage of these habitats, termed zone A. B, and C from shore to reef crest respectively.

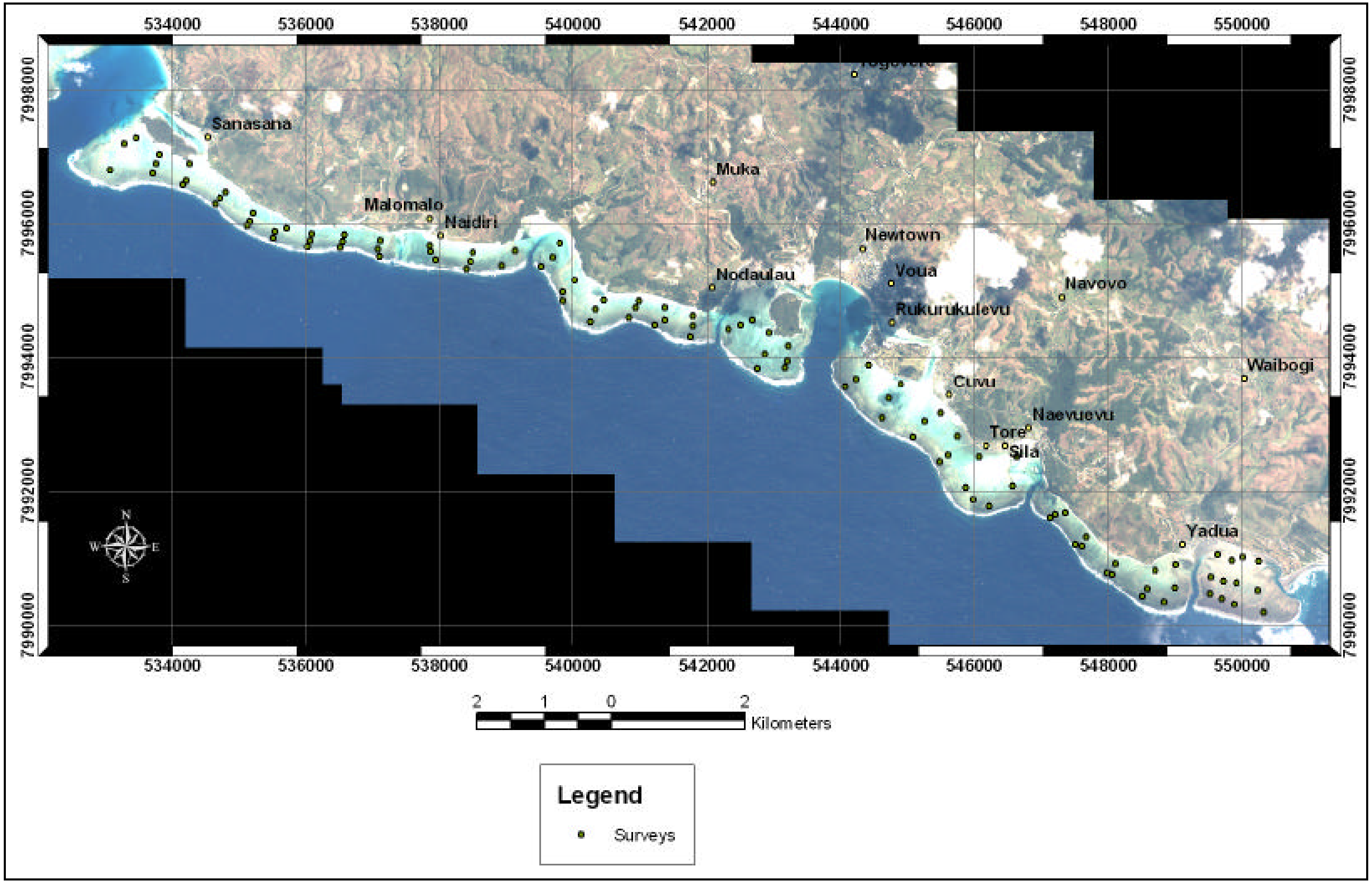

Figure 3 (a). Map showing position of transects within Section 1. Each red dot describes the start coordinates of a section of a transect.

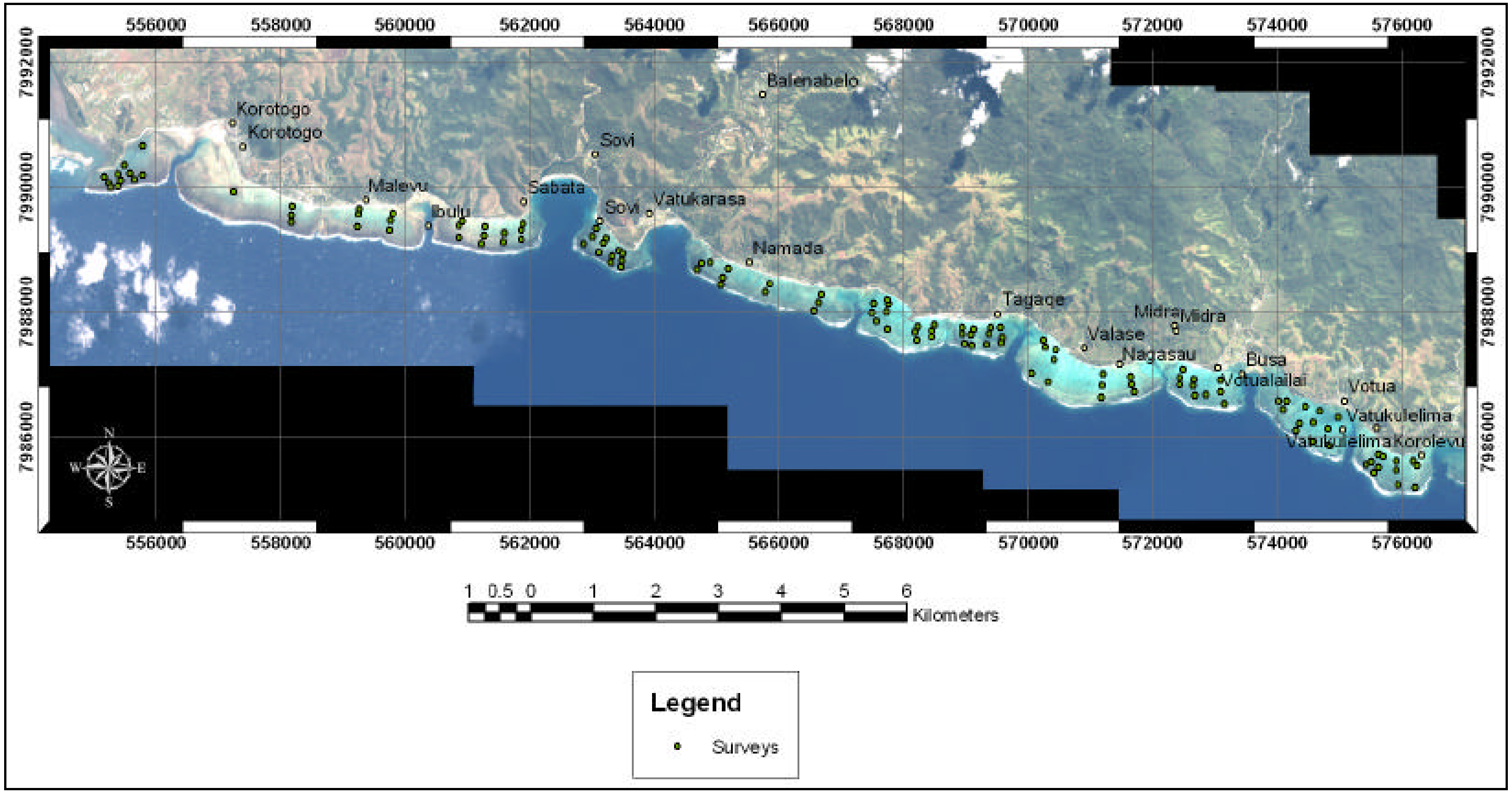

Figure 3 (b). Map showing position of transects within Section 2. Each red dot describes the start coordinates of a section of a transect.

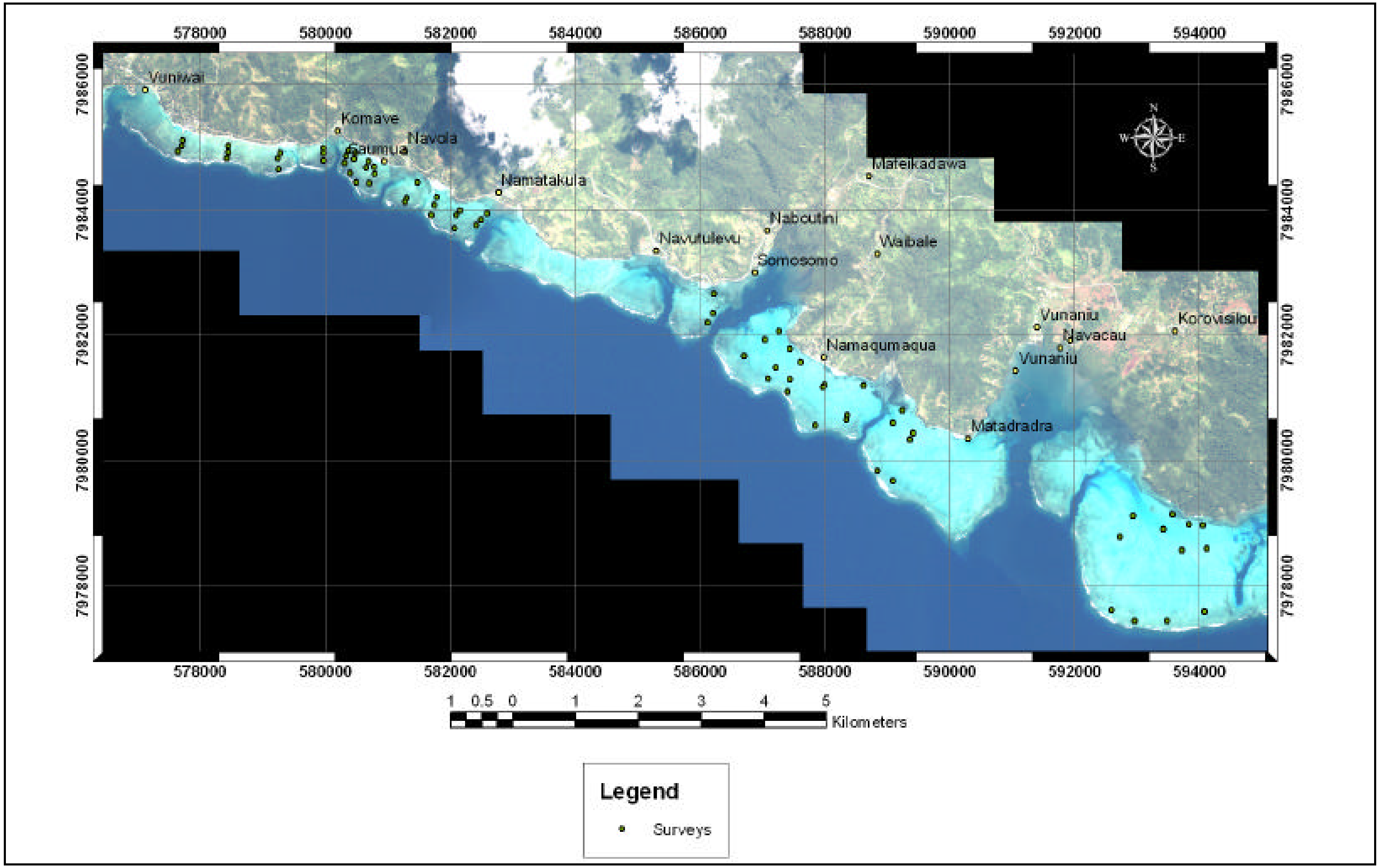

Figure 3 (c). Map showing position of transects within Section 3. Each red dot describes the start coordinates of a section of a transect.

4.2 Benthic habitat: Point intercept transect

Point intercept transects derive quantitative data on both biological and abiotic (substrate) cover. The precise percentage area cover allows direct comparison to be made between different geographical areas of the reef.

Using a 100 metre tape, four 25 metre transects were point sampled every 0.5 metres (substrate or biota directly under the point) to determine the substrate and benthic coverage of the reef. This provides a total of 200 data points per 100-metre section. The categories recorded under each point were: soft corals (life form), sponges (life form), algae and seagrass (target genus), hard coral (life form and target species), dead coral, dead coral with algae, bed rock, sand, rubble, and mud.

4.3 Fish: Belt transect

The belt transect methodology allows comparison of relative abundances across the region. The method is non-extractive and as such has no detrimental impact to fish populations in the area.

Using the same 100 metre tape, four 5 metre wide by 20 metre long sections were surveyed (centred on the transect line). A 5-meter gap was left un-surveyed between sections to make each section a distinct statistical unit. Absolute numbers of fish, target species, and families were recorded.

4.4 Invertebrates: Belt transect

A similar method was utilised for sampling invertebrate taxa. Four 2 metre wide by 20 metre sections were surveyed (centred on the transect line). Again, a 5-metre gap was left un-surveyed between sections. The smaller survey area was a compromise to the increased time required to complete accurate invertebrate census per unit area.

4.5 Background data: Kayak Marshal

Background physical information was collected. This included position (GPS reading), temperature, salinity, underwater visibility, time of day, current (strength and direction), and wind (strength and direction). In addition, the kayak marshal noted any surface and in-water impacts as well as information of underwater damage or impacts relayed from the snorkel surveyors.

4.6 Geographic Information System (GIS)

This report made use of an Ikonos high-resolution image of the Coral Coast (Image courtesy of Coastal Zone Management team, Institute of Applied Sciences, University of South Pacific, Fiji. Material © 2001, Space Imaging LLC, all rights reserved. All subsequent map images in this document are referenced to Universal Transverse Mercator Spheroid (Zone 60 South) and WGS84 datum).

By using the Inverse Distance Weighted function within *ArcView* GIS software, it was then possible to extrapolate the indicator values into areas of the image adjacent to the survey sites, thus producing a continuum of indices to highlight trends. The survey sites locations were chosen with sufficiently high spatial resolution to allow for accurate representation of the true levels in areas to which this extrapolation technique was applied.

These techniques were applied to produce GIS based data-contour 'maps' of the survey region, to facilitate visual interpretation of the large quantity of data gathered.

5. Results

Though a large number of variables were assessed, the analysis contained within this report concentrates on benthic class, as well as important food and economic species. Data on a number of recorded environmental variables, a series of summary statistics and GIS derived images are presented.

5.1 Environmental Variables

There was a steady increase in surface water temperature with temperature rising from an average of 25°C to around 30°C over the over the course of the study (figure 4a).

The horizontal visibility varied with a maximum visibility of 25 metres and a minimum visibility of 5 metres. Generally, horizontal visibility was between 10 and 15 metres (figure 4b).

Wind direction varied over the course of the study however prevailing winds were from the southeast (figure 4c). This represents a general onshore wind. Wind was typically force 2 or 3.

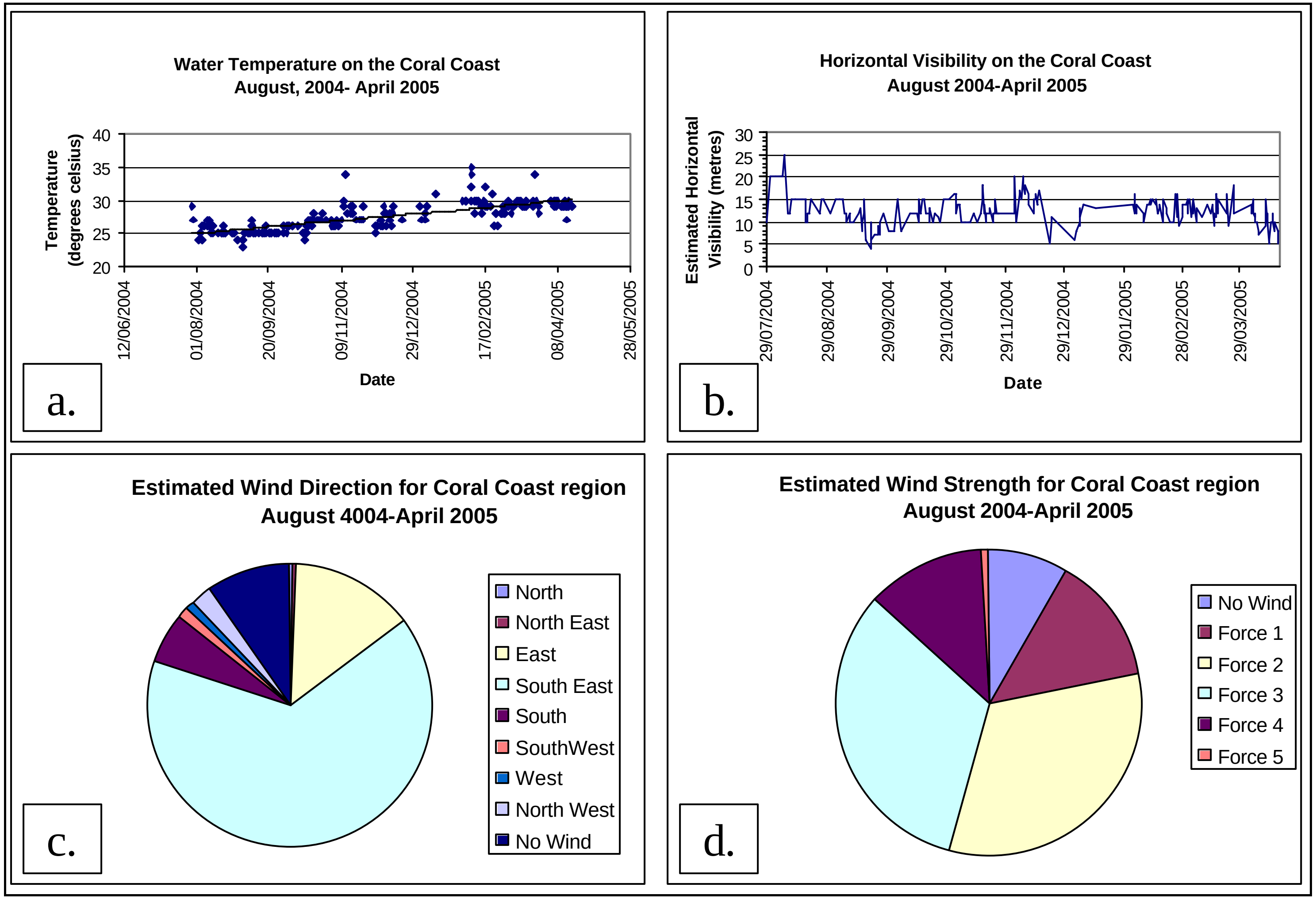

Figure 4. Environmental Statistics for the Coral coast region showing (a) Water temperature, (b)Horizontal visibility, (c) Wind direction (d) Wind strength (Beaufort scale).

5.2 Summary Statistics

There are noticeable differences in the benthic community across the Coral Coast region (table 5). Algae dominate the benthic community of the back reef area of the Coral Coast, accounting on average for 33.57% of cover. Algal cover is highest in iqoliqoli 6 where it comprises 57.92% of the benthic cover and is lowest in iqoliqoli 1, where it makes up 20.11% of cover. *Sargassum* accounts for half of all algae across the region, though this proportion varies widely along the coast. Coralline red algae accounts for a very small percentage of algae as a whole. Rubble contributes heavily to benthic structure, covering 24.22% of the Coral Coast surface area. Exposed bedrock is seen across approximately 12.62% of the Coral Coast area. At 2.72%, live hard coral cover is generally low across the Coral Coast. Average back reef coral cover ranges from 0.33 to 5.93% across the region.

The density of fish varies widely across the Coral Coast region (table 6). Of those fish groups analysed here, Wrasse (*Labridae*) are most abundant with an average density of 165.4 fish per 500 square metres reef area. Parrotfish (*Scaridae*) are comparatively abundant with an average density of 34.4 fish per 500 square metres reef area. Surgeonfish (Acanthuridae) have an average density of 17 fish per 500 square metres reef area while there are approximately 7.4 Rabbitfish (Siganidae) per 1000 square metres reef area. Goatfish (*Mullidae*) are seen at an average density of 2.2 fish per 1000 square metres reef area. The carnivorous, Grouper (*Serranidae*), Emperor (*Lethrinidae*) and Snapper (*Lutjanidae*) have average densities of 3, 0.7 and 1.5 fish per 1000 square metres respectively. Density of all groups analysed varies widely from region to region.

Table 5. Percentage benthic cover for Coral Coast.

Iqoliqoli	Sand *Nuku*	Bedrock *Mahara*	Rubble *Lase kamusu*	Live Hard Coral *Lahe cola*	Algae *Alaqi*	Sargassum *Lecau*	Coralline red algae
1	35.17	3.72	16.50	0.94	20.11	4.50	3.00
2	30.44	9.19	26.36	2.61	25.03	10.89	3.36
3	17.00	6.83	20.08	0.67	37.75	24.50	2.50
4	16.00	10.00	32.56	5.10	34.39	16.90	2.14
5	9.68	12.30	33.16	3.21	37.33	22.79	2.59
6	5.63	13.21	14.38	0.33	57.92	40.13	1.00
7	17.75	8.92	24.13	0.71	27.21	19.17	1.21
8	11.51	17.57	24.79	5.93	28.82	12.25	2.72
9	12.61	17.00	19.00	3.50	36.44	8.00	2.06
10	10.29	29.33	24.67	5.14	25.43	4.76	1.71
11	16.30	10.76	30.80	1.81	38.81	25.24	1.93
Overall Coral Coast average	16.58	12.62	24.22	2.72	33.57	17.19	2.20

Table 6. Estimated density of popular families of food fish per 1000 square metres for the Coral Coast.

Iqoliqoli	Parrotfish *Ulavi*	Surgeonfish *Sivisivi*	Goatfish *Daunau*	Wrasse *Dradra*	Groupers *Kawakawa*	Emperors *Kabatia*	Snapper *Kabatia*	Rabbitfish *Nuqa*
1	18.7	7.1	3.6	151.3	1.8	0	5.8	5.8
2	38	22.7	4.9	188.8	0.9	1.3	0.6	1.9
3	41.7	8	2	207.7	0.7	0	0	27
4	59.3	23.6	1.8	159.5	6.4	1.5	0.6	7.9
5	33.2	15.7	1.2	132.8	2.4	0.4	0.3	2.1
6	4	2.3	0.7	149	0.3	0.5	2.2	0
7	2.8	20.3	2.7	59.3	3.5	0	2.2	1.2
8	74.2	33.4	2.3	260.9	4.2	0.2	0.5	6.9
9	25.9	29.4	0.6	264.3	4.6	0.4	0.1	14.3
10	64.2	40.3	1.8	217.1	3	0.1	0.5	8.4
11	37.3	19.7	1	179.5	6.6	2.5	1.5	13.6
Coral Coast average	34.4	17	2.2	165.4	3	0.7	1.5	7.4

Density of invertebrates is generally low across the Coral Coast (table 7). Average density of Octopus and Giant Clam (*Tricadna* sp.) is particularly low at 0.5 per 1000 square metres. Edible Sea Cucumber density is also low at 1 Sea Cucumber per 1000 square metres. Numbers of Sea Urchins are comparatively higher with an average of 69.3 urchins per 1000 square metres. Numbers of all invertebrate species analysed vary widely from region to region.

Table 7. Estimated density of commonly fished invertebrates per 1000 square metres for the Coral Coast.

Iqoliqoli	**Octopus** ***Hulua***	**Giant clams (Tridacna)** ***Coko***	**Edible seacucumbers** ***Dri***	**Urchins** ***Cawaki***
1	1.1	0	0.6	5.6
2	0	0.6	0.1	17.8
3	0	0.8	0.8	24.2
4	1.4	0.9	1.8	51.7
5	0.1	0.8	1.4	117.9
6	0.4	0.4	0.1	73.3
7	0	0	1.1	207.9
8	0.3	0.5	2.3	34.4
9	0.8	2.2	0.3	26.4
10	1	0.5	0.2	7.1
11	1.1	0.4	0.6	91.1
Overall Coral Coast average	0.5	0.5	1	69.3

5.2 GIS Contour Mapping

Presentation of data as a series of contour maps allows comparison in the distribution of different variables. In order to allow adequate visual representation of data collected, the coral coast has been split into three sections as outlined below and in figure 2.

Section 1: Natadola bay to the reef area west of Yacula. Encompassing the districts of Malomalo, Cuvu and part of Nasigatoka.
Section 2: Sigatoka river mouth to Korolevu village. Encompassing part of the district of NaSigatoka as well as the districts of Conua and Korolevuiwai.
Section 3: Korolevu village to Rokwaqa Point. Encompassing the district of Komave, as well as isolated reef areas in the Serua district.

Greater acuity of images and analysis may be found in the series of internal iqoliqoli *Fisheries Resource Assessment Reports* produced on behalf of the Ministry of Fisheries (Coral Cay Conservation, 2005[1-10]).

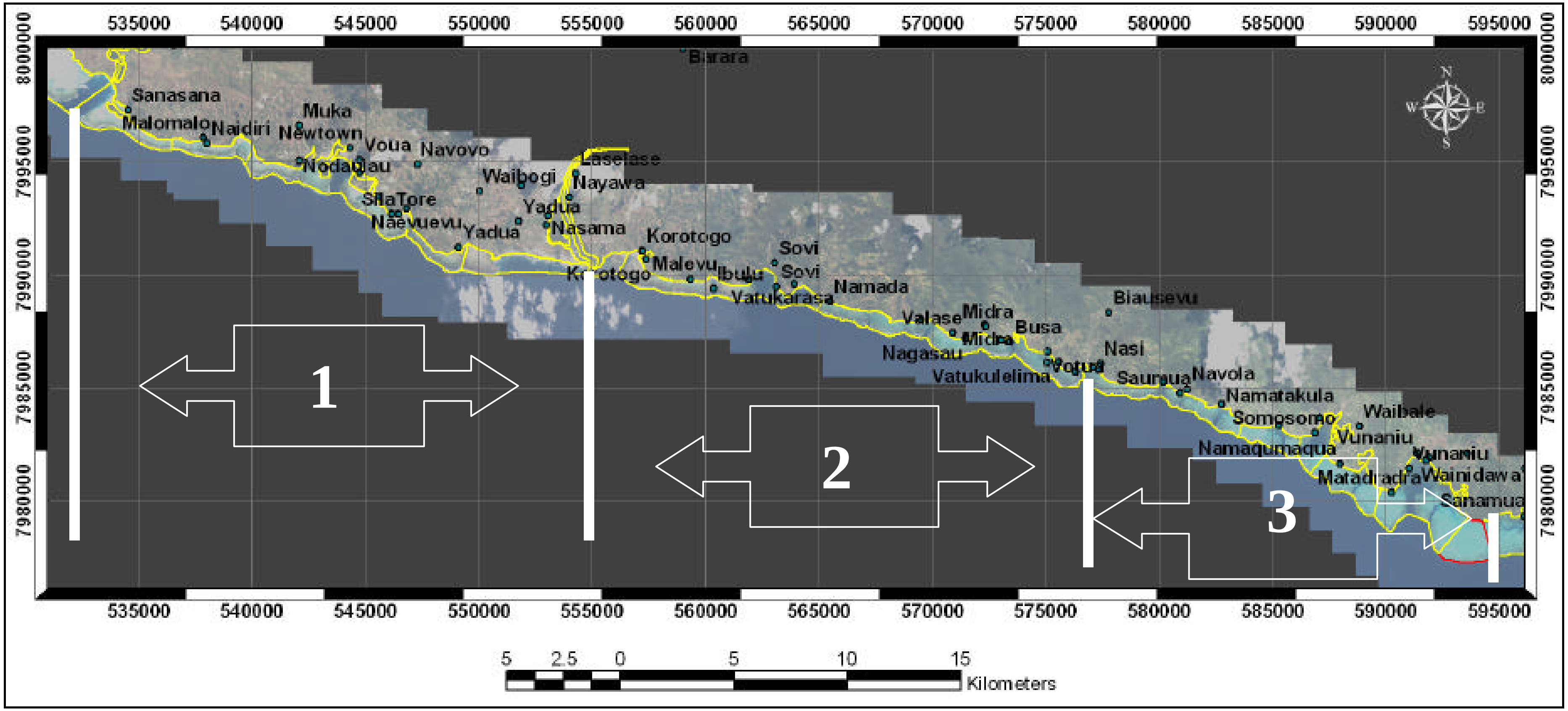

Figure 5: The three different sections used in presentation and discussion of results.

5.2.1 Reef Section One

Benthic cover

Areas of exposed bedrock are common across section 1 (figure 6). Average cover ranged from 0 to 55.8% cover. Highest cover is seen in the West either side of Sanasana settlement and across towards Malomalo, while the area east of Yadua has the lowest levels of bedrock. Bedrock cover is generally higher in the inner and middle reef zones.

Rubble distribution follows a similarly patchy pattern (figure 7). Cover ranges from 0 cover up to 52.9%. Highest cover is seen outside of Tore and Sila and lowest cover outside of Nadiri. Cover is generally higher on the margins of river channels and low in the centre of large reef areas such as outside Cuvu village and Malomalo and Naidiri settlement where rubble cover is low.

Coral cover is incredibly patchy across section 1 (figure 8). Cover ranged from 0 to 11.2 %, with the highest levels of live coral cover seen outside Sanasana, East of Malomalo/Naidiri and West of Nodaulau and Cuvu villages. Elsewhere coral cover is sparse or absent.

As discussed above, algae dominates total benthic cover of the Coral Coast however it is not distributed evenly (figure 9). Levels of between 6.8 and 73.6% algal cover are seen. Algae tends to be more abundant towards the outer reef zone, as well as on the margins of river channels and bays. Algal cover is particularly dense over the reef sections east of Nodaulau and Yadua villages and outside of Malomalo and Naidiri. *Sargassum* cover is particularly dense in many of these reef areas though unlike algae as a whole, percentage cover tends to decrease away from shore (figure 10).

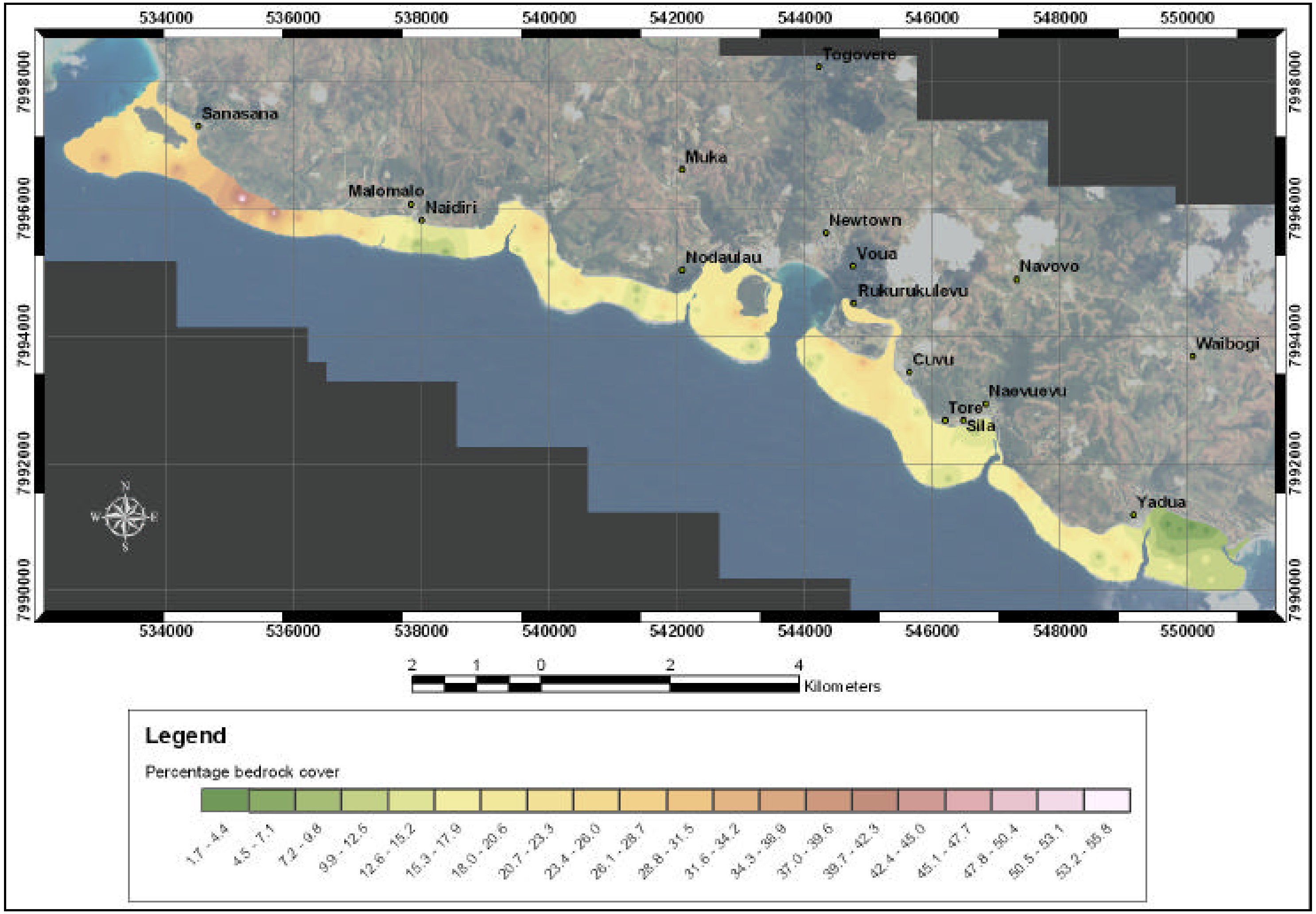

Figure 6. Percentage bedrock cover for section 1.

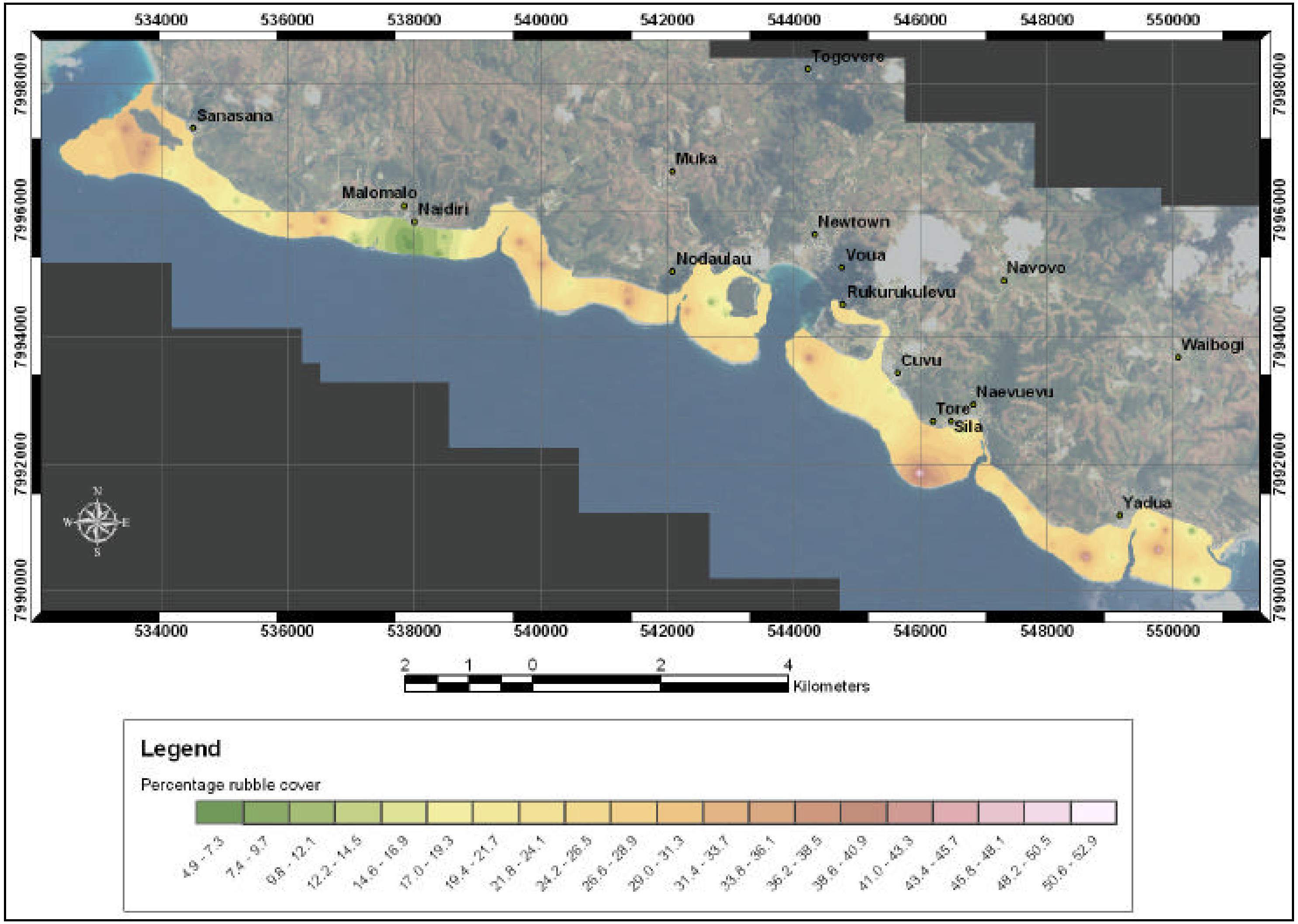

Figure 7. Percentage rubble cover for section 1.

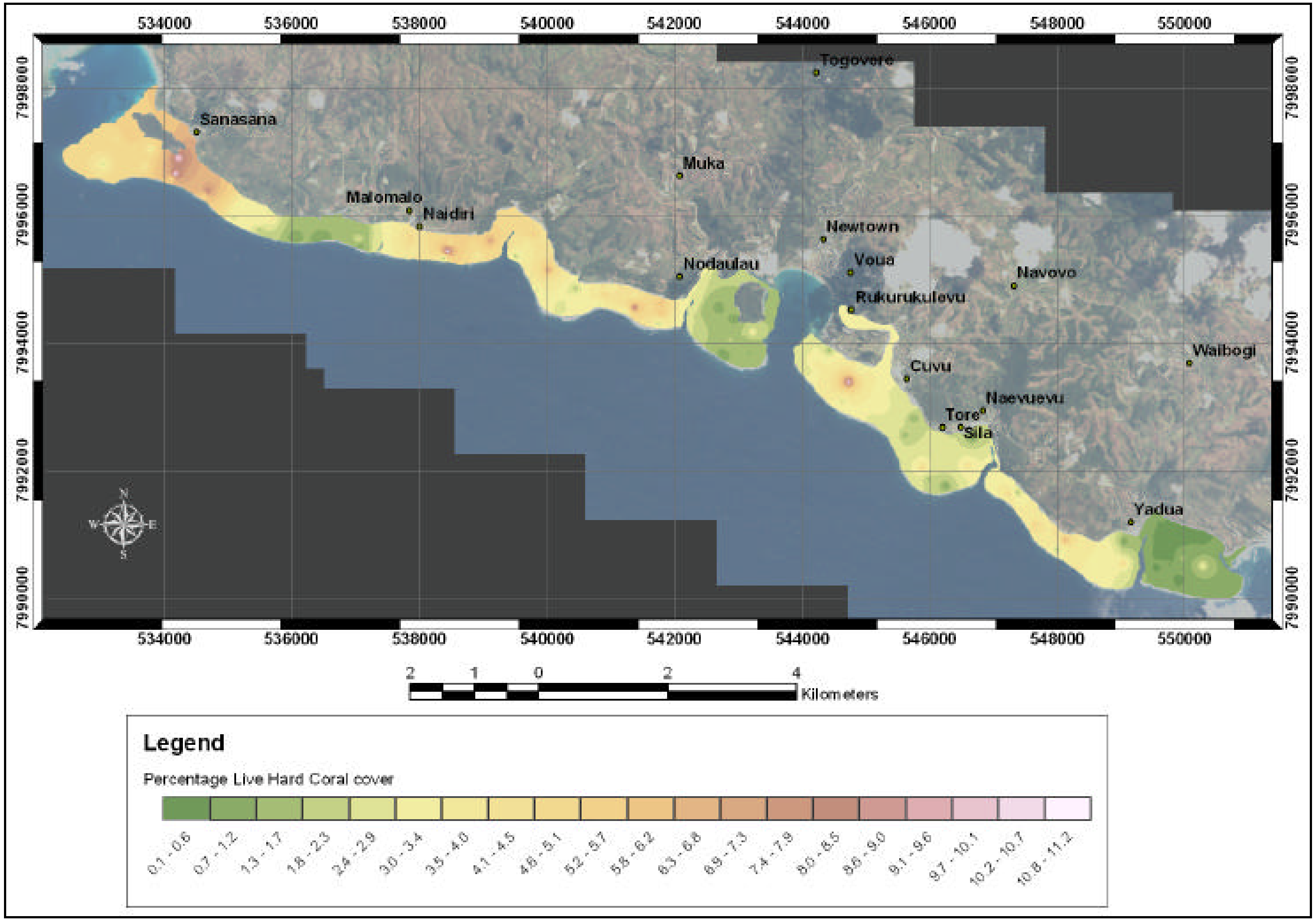

Figure 8. Percentage live hard coral cover for section 1.

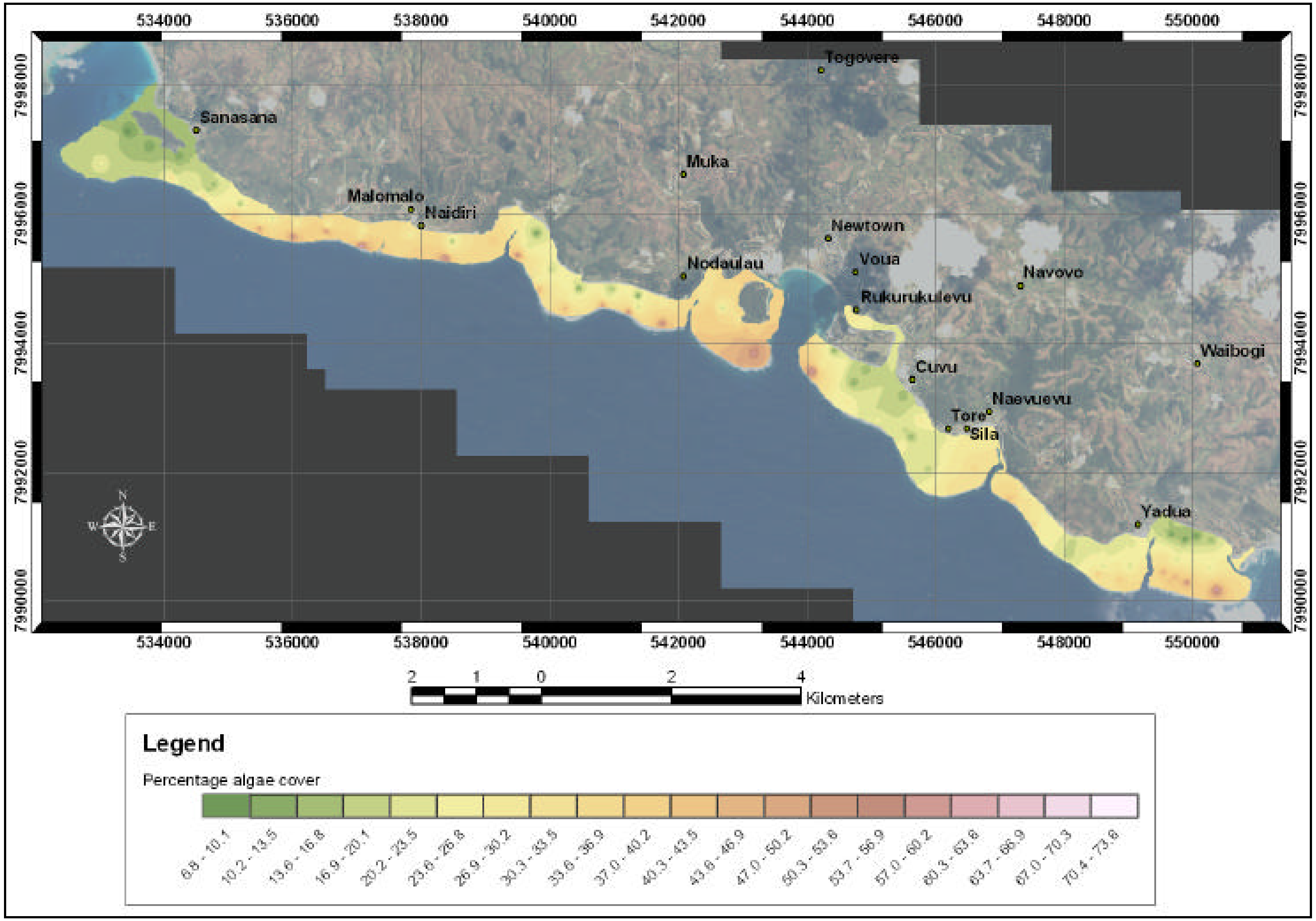

Figure 9. Percentage algae cover for section 1.

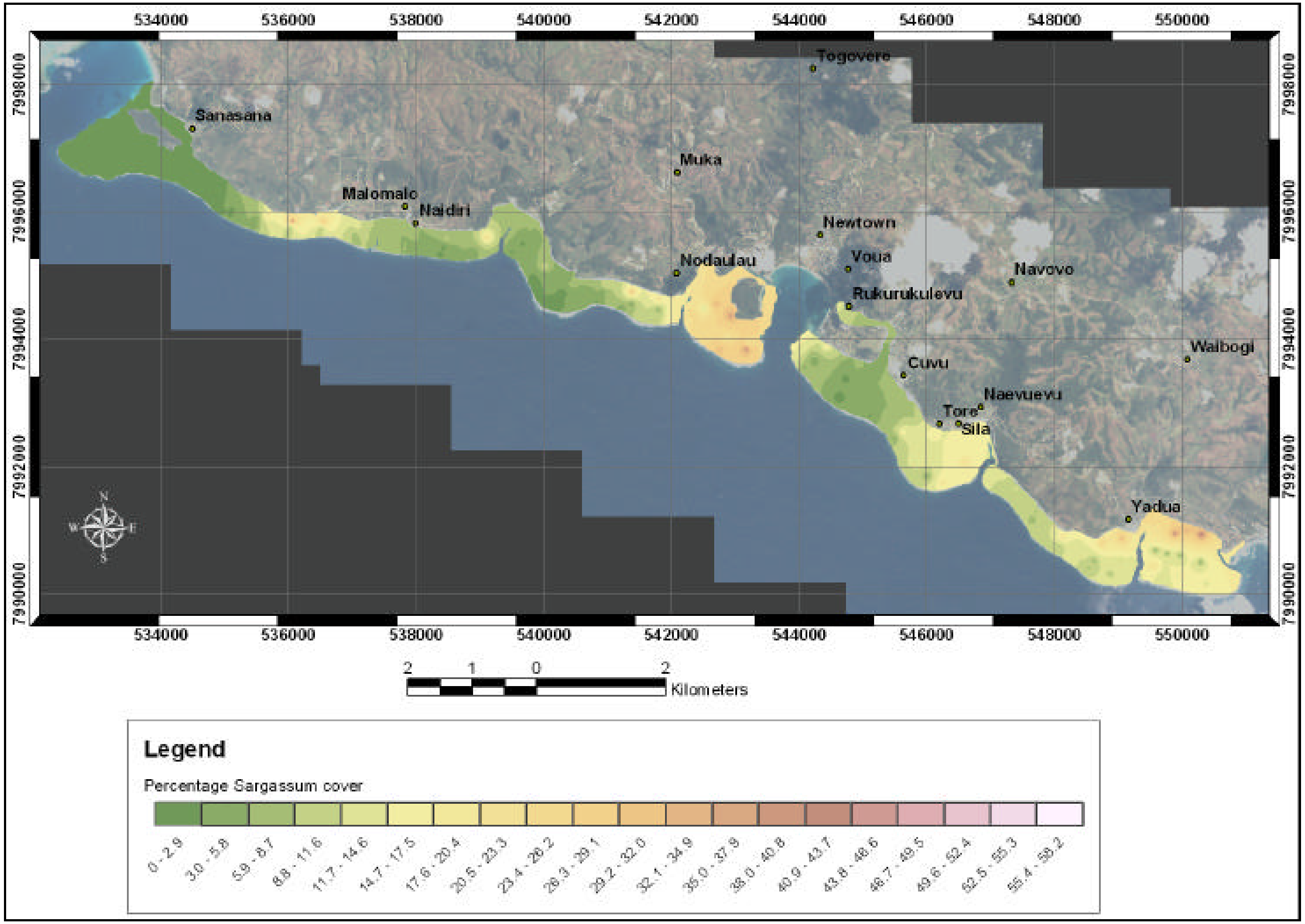

Figure 10. Percentage *Sargassum sp* cover for section 1.

Fish

Density of fish species varies along the coast. Wrasse show particularly high densities reaching as high as 258.9 fish per 500 square metres reef area in many regions, though drop to densities as low as 6.7 fish per 500 square metres elsewhere (figure 11). Density of Wrasse tends to increase away from shore. The highest density of Wrasse is seen outside and East of Naidiri and Tore villages.

While not a group commonly targeted by fishermen, Butterflyfish (*Chaetodontidae*) are good indicators of reef health. The distribution of Butterflyfish is incredibly patchy and fish are rare or absent across much of the iqoliqoli (figure 12).

Grouper distribution is very localised with hotspots of density, combined with large areas of low abundance (figure 13). Few grouper are seen West of Naidiri, in the reef area East of Nodaulau and East of Yadua.. Small patches with a density of up to 7.4 fish per 500 square metres are seen east of Naidiri and off the island west of Cuvu.

Parrotfish density lies between 0 and 30 fish per 500 square metres reef area across much of the iqoliqoli (figure 14). Large concentrations of Parrotfish are seen outside Cuvu village where density reaches as high as 189.1 fish per 500 square metres and east of Sanasana village

Rabbitfish are rare across most of the iqoliqoli (figure 15) The greatest density of fish occurs in the reef outside of Malomalo where density reaches 40.2 fish per 500 square metres and in the outer zone of the reef area east of Nodaulau.

Though Snapper are absent across much of the iqoliqoli, they are seen between Sanasana and Malomalo, in the Cuvu/Tore region and east on Yacula (figure 16). Density never exceeds 6.7 fish per 500 square metres reef area.

Surgeonfish are found at densities between 0 and 69 fish per 500 square metres reef area (figure 17). The population is densest in the middle and outer zones off Tore and Sila villages. The reef area east to Yandua, between Nodaulau and Naidiri and Malomalo to Sanasana show more moderate Surgeonfish densities of between 10 and 40 fish per 500 square metres reef area. Elsewhere Surgeonfish are rare.

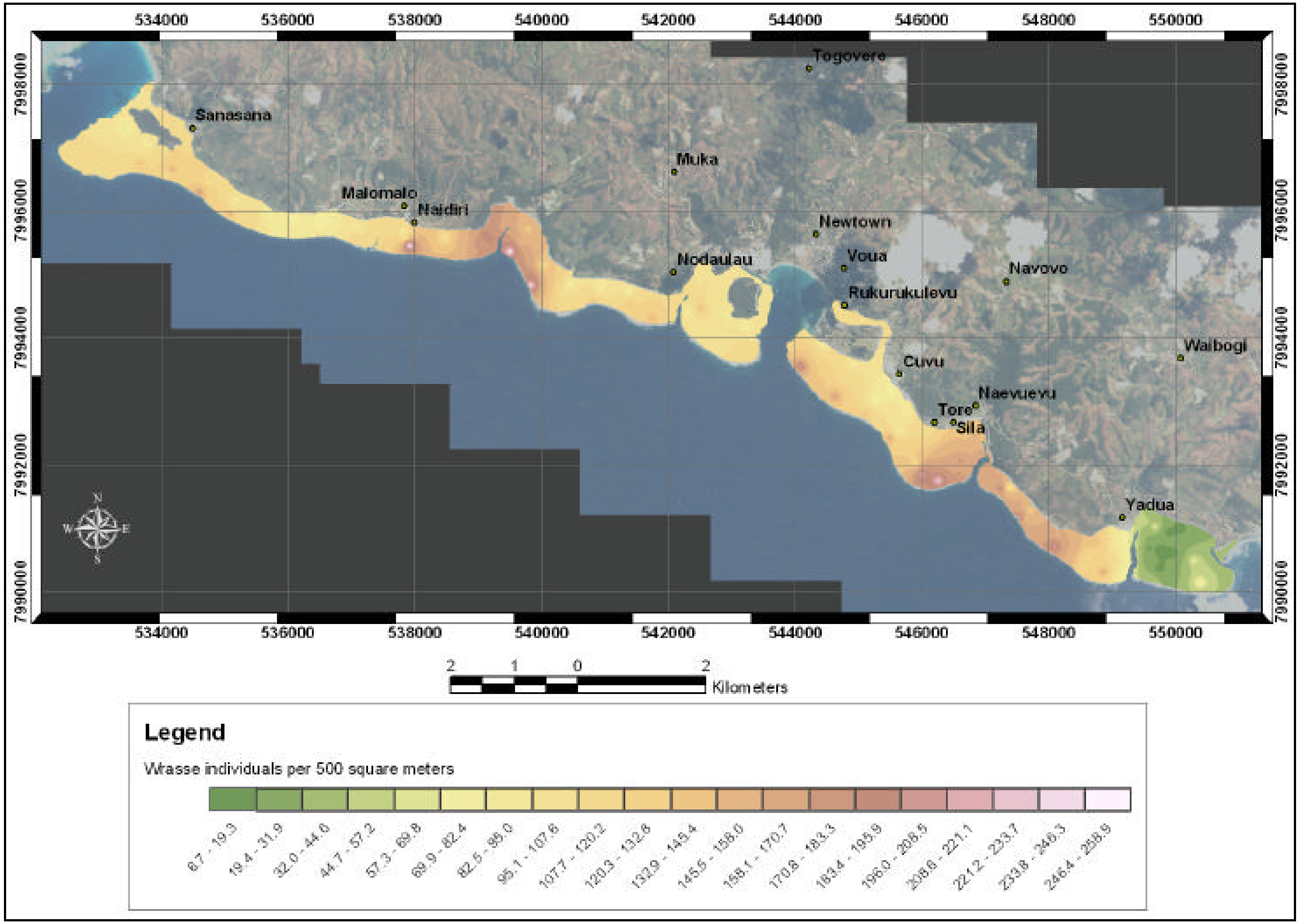

Figure 11. Density of Wrasse (*Labridae*) per 500 square metres reef area of section 1

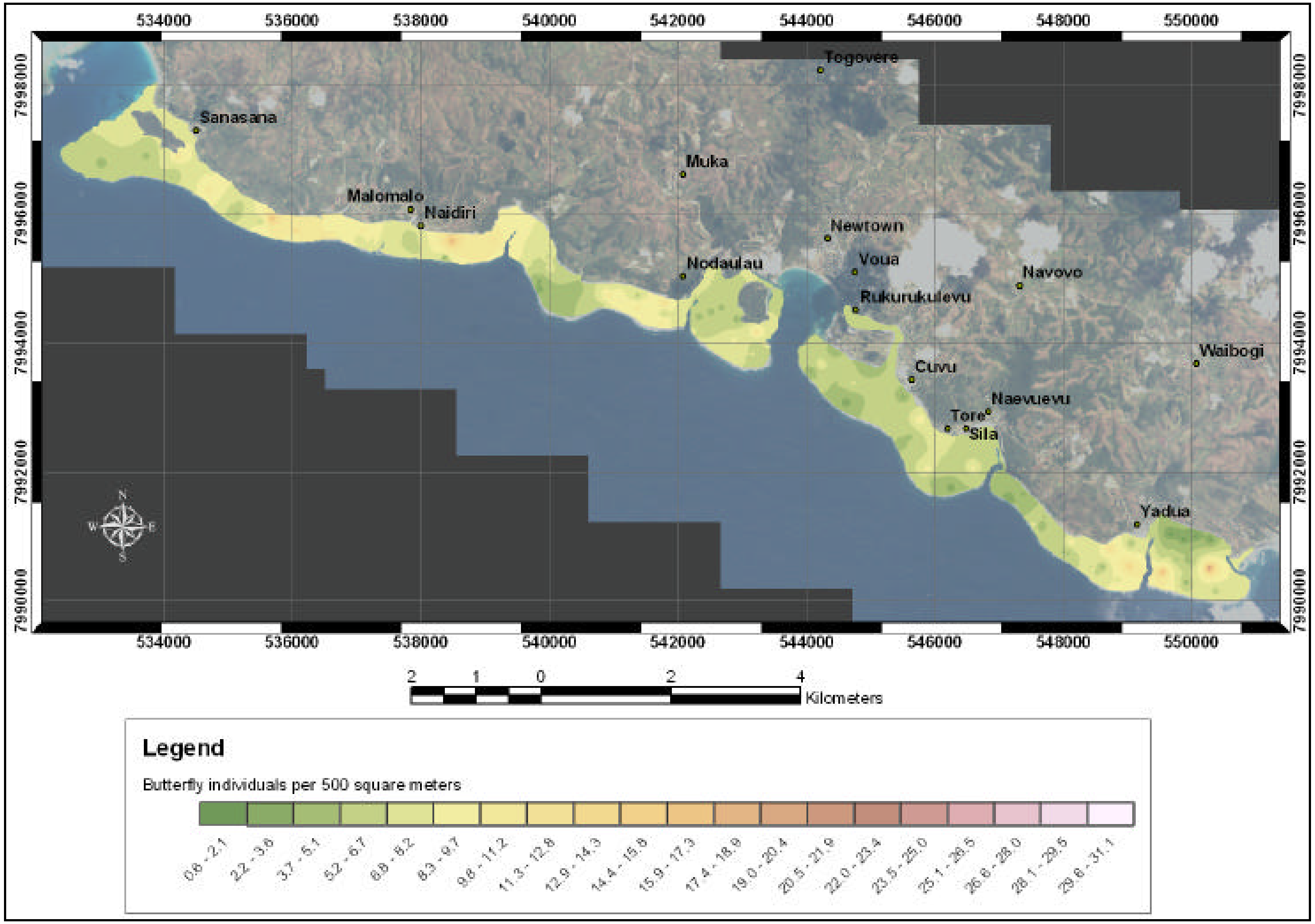

Figure 12. Density of Butterflyfish (*Chaetodontidae*) per 500 square metres reef area of section 1.

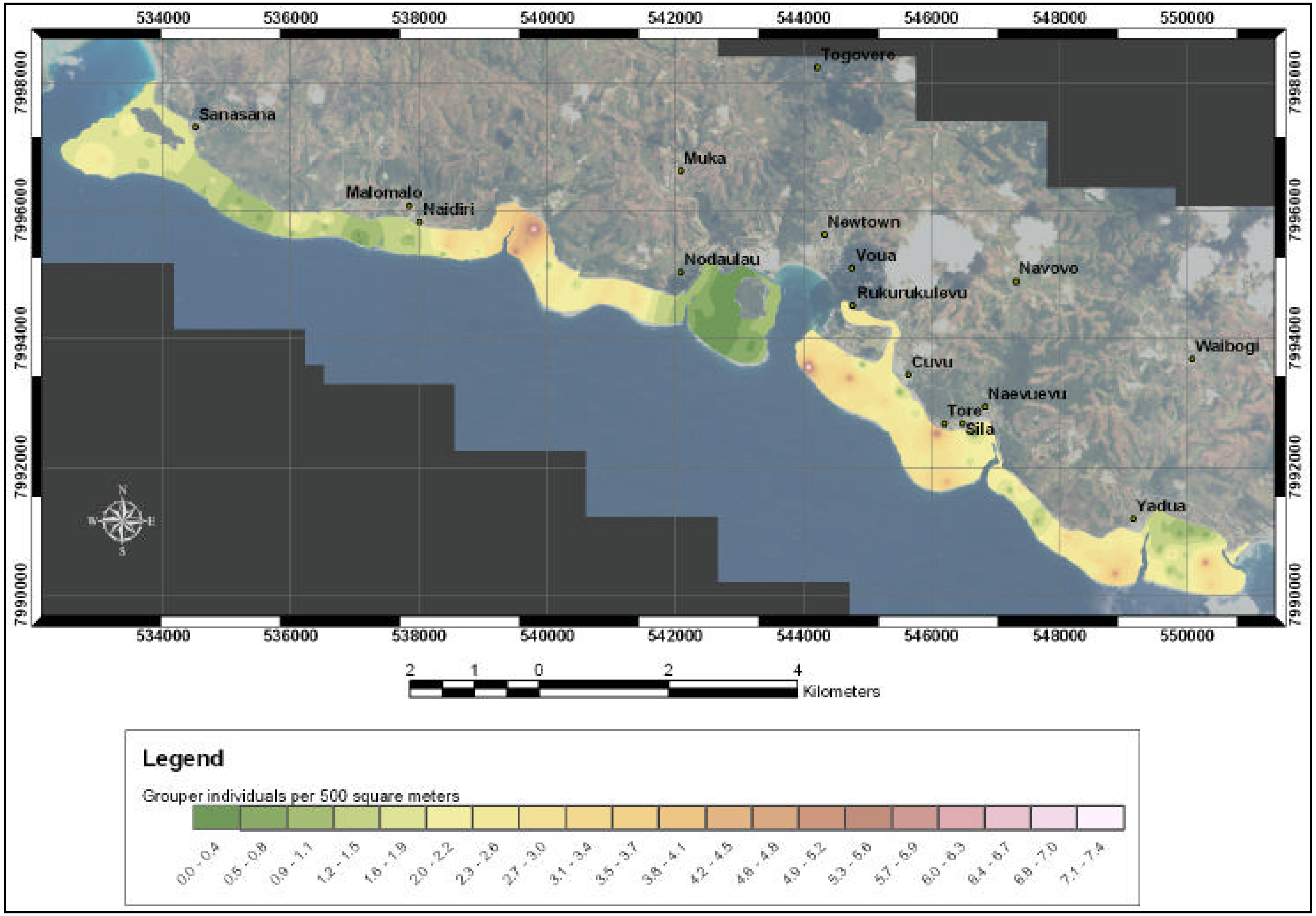

Figure 13. Density of Grouper (*Seranidae*) per 500 square metres reef area of section 1.

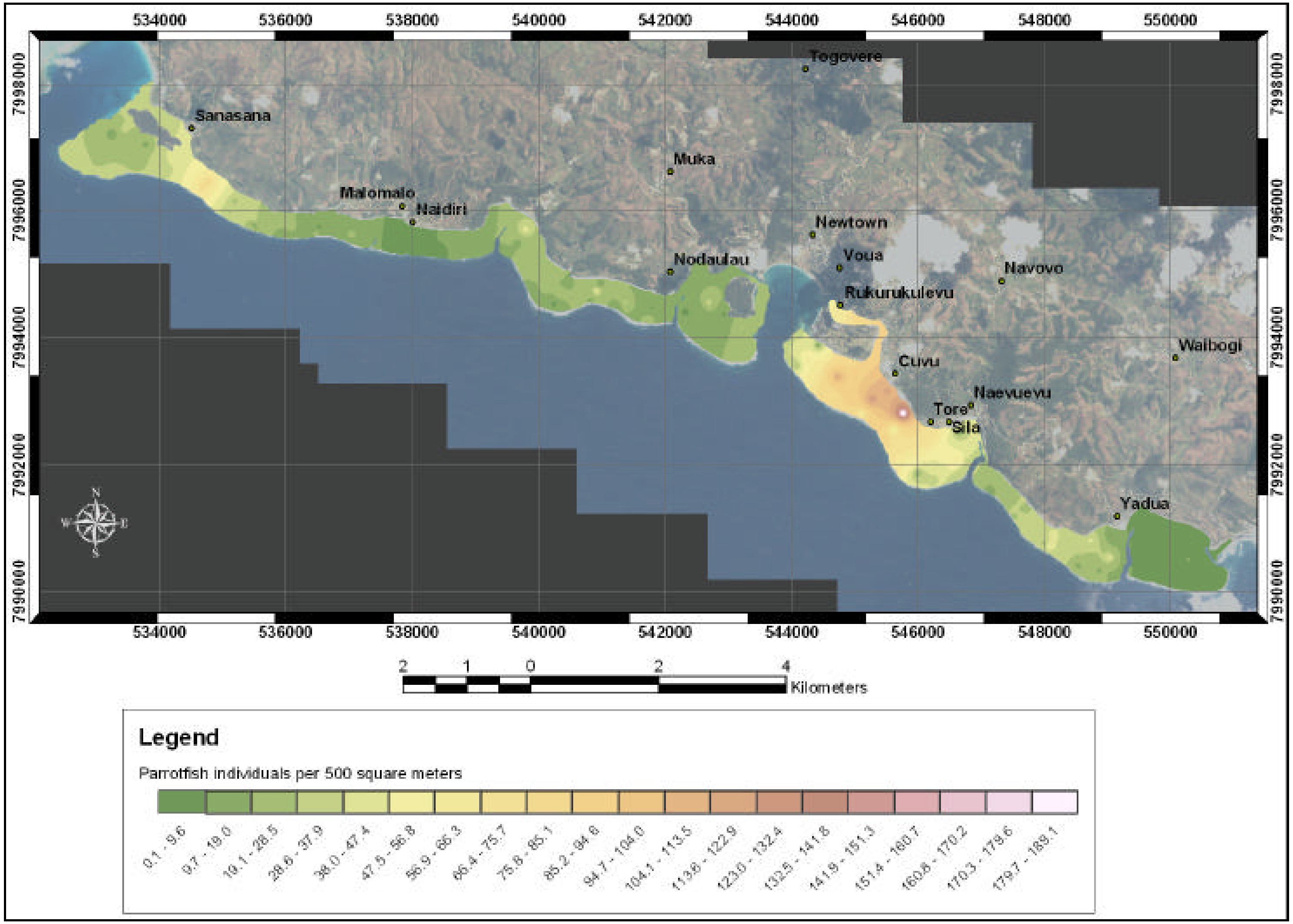

Figure 14. Density of Parrotfish (*Scaridae*) per 500 square metres reef area of section 1.

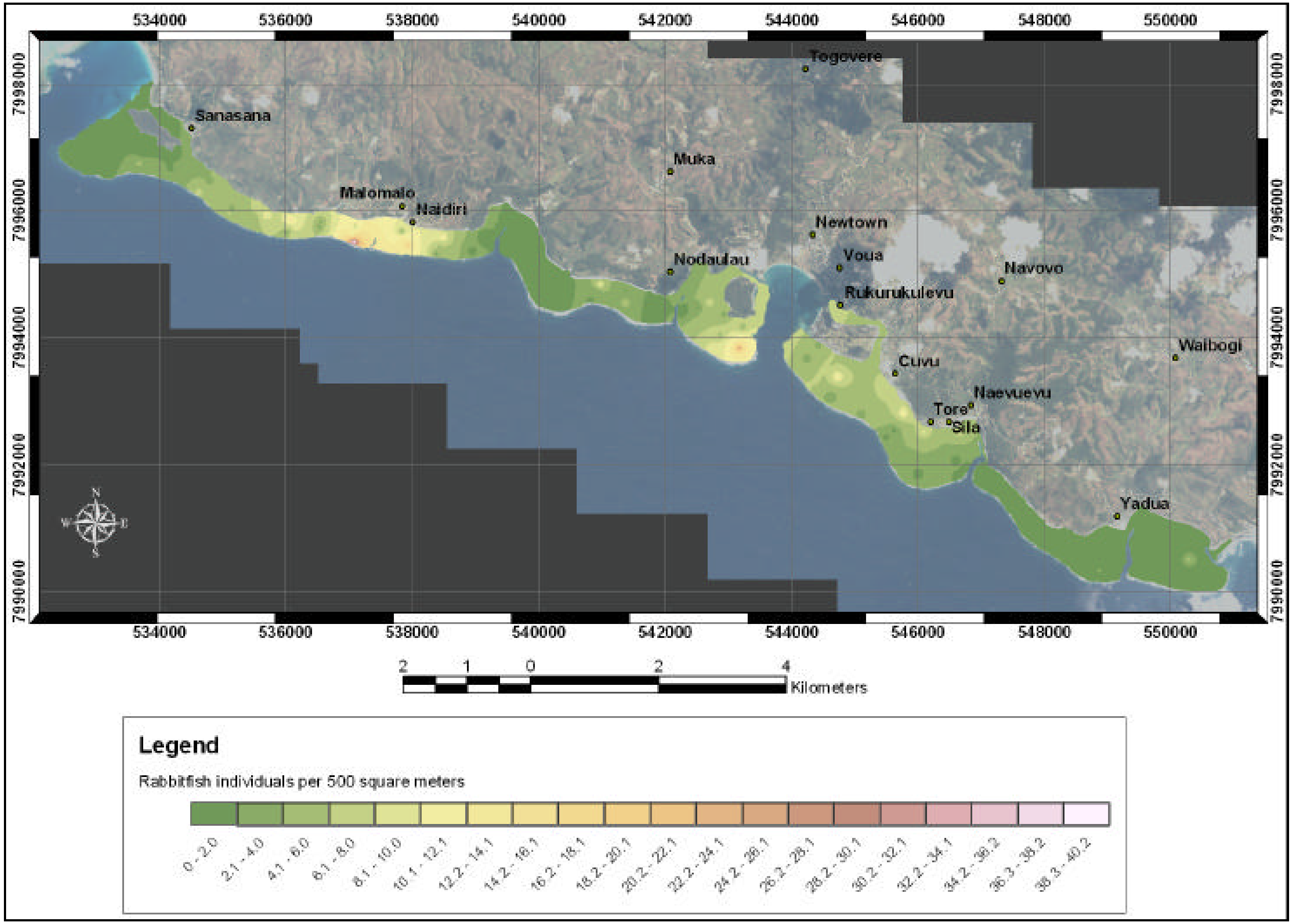

Figure 15. Density of Rabbitfish (*Siganidae*) per 500 square metres reef area of section 1.

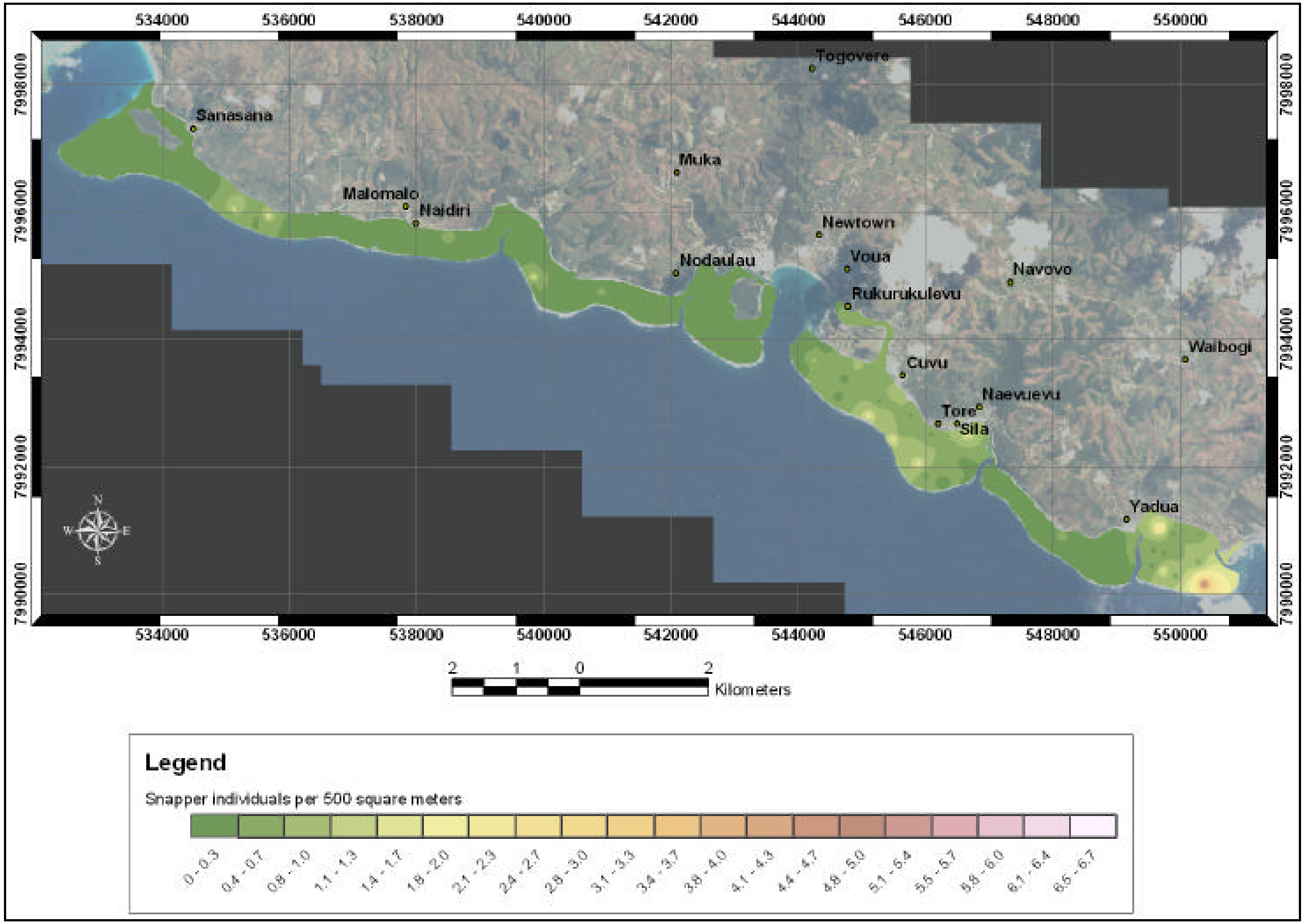

Figure 16. Density of Snapper (Lutjanidae) per 500 square metres reef area of section 1

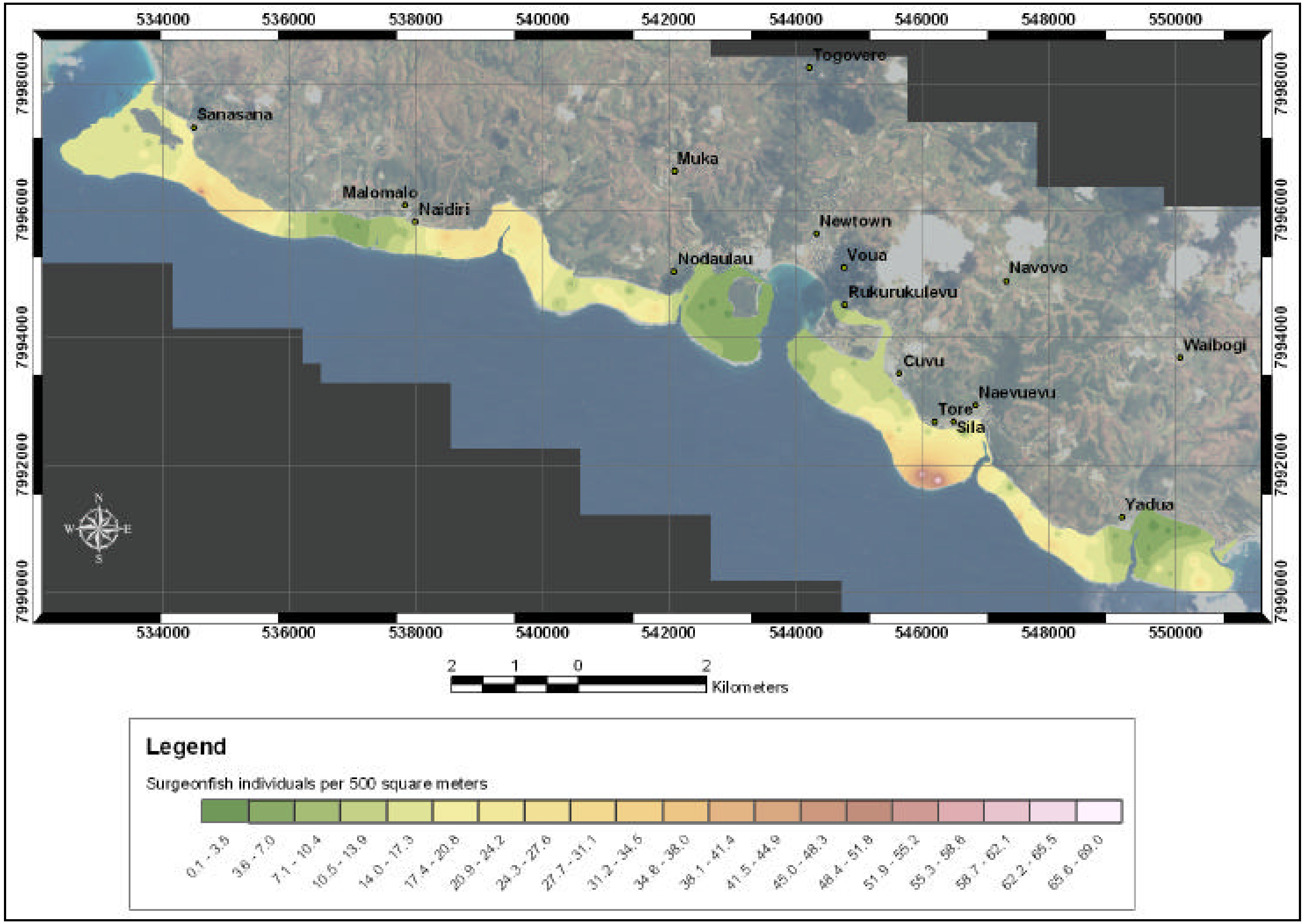

Figure 17. Density of Surgeonfish (*Acanthuridae*) per 500 square metres reef area of section 1.

Invertebrate data

Giant Clams are not seen across much of section 1 however a few clams are present in the reef areas either side of Malomalo, where a maximum density of 2.4 clams per 200 square metres reef area can be seen (figure 18).

Crown of Thorns (*Acanthaster plancii*) are also rare across much of the section (figure 19). Highest density is seen in the reef area outside of Sanasana, where density reaches 3.0 clams per 200 square metres reef area. Sightings are common in the reef region between Naidiri and Nodaulau as well between Cuvu and Tore.

There are very few Sea Cucumbers across the section, with most Sea Cucumbers concentrated in an area just west of Yadua (figure 20). Here the density reaches as high as 22.7 sea cucumbers per 200 square metres reef area. Sea Cucumber distribution is very patchy, though sightings tend to be higher in the inner reef zones.

Octopus population densities are generally low in the section (figure 21). There are more Octopus in the western half of the section than the eastern with concentrations around Sanasana and Naidiri.

Numbers of Short Spined Sea Urchin are low across the section (figure 22). The Urchin population is densest east of Yadua, and in the outer zone between the reef area east of Nodaulau and west to Malomalo.

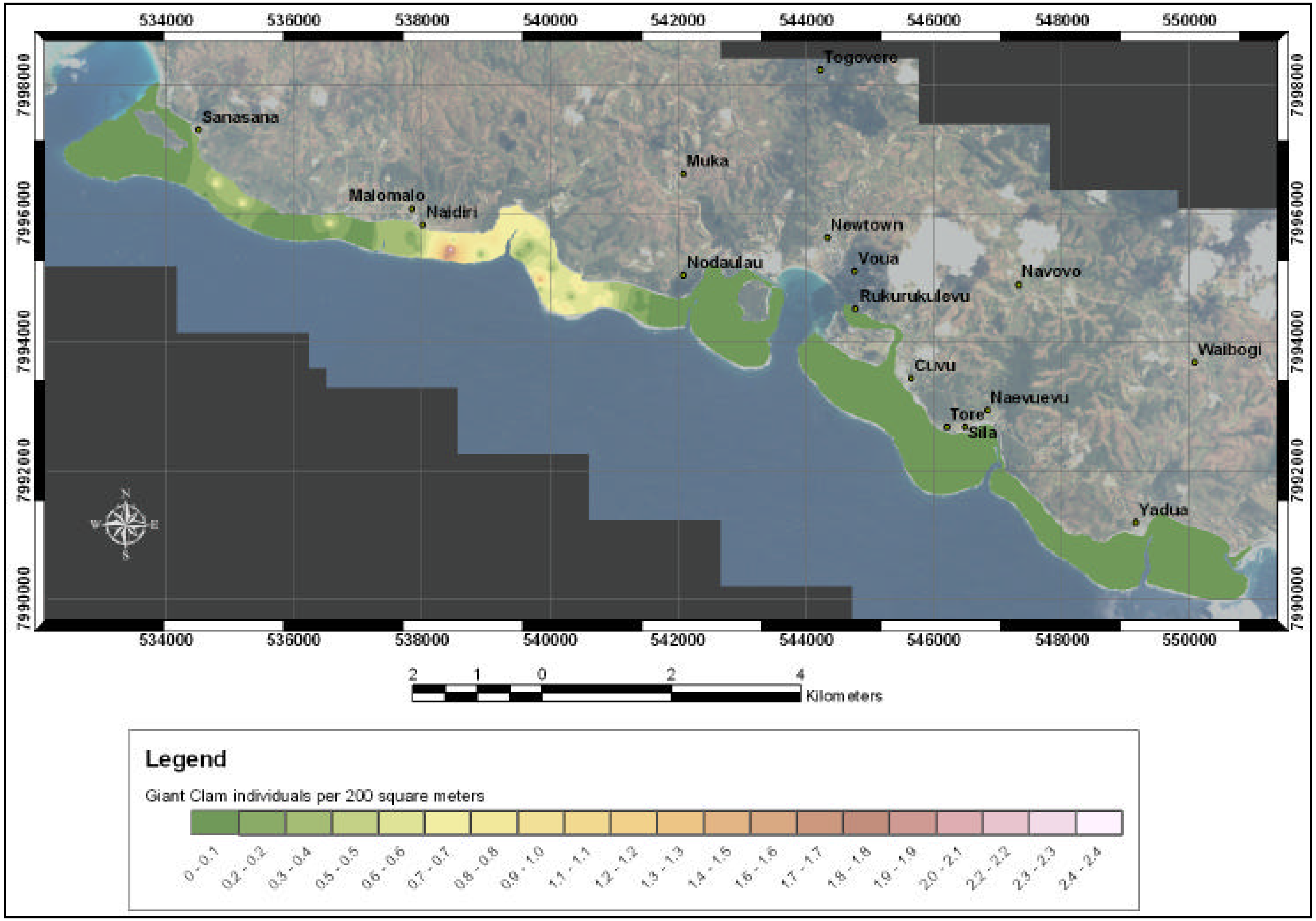

Figure 18. Density of Giant clams (*Tricadna sp*) per 200 square metres reef area of section 1.

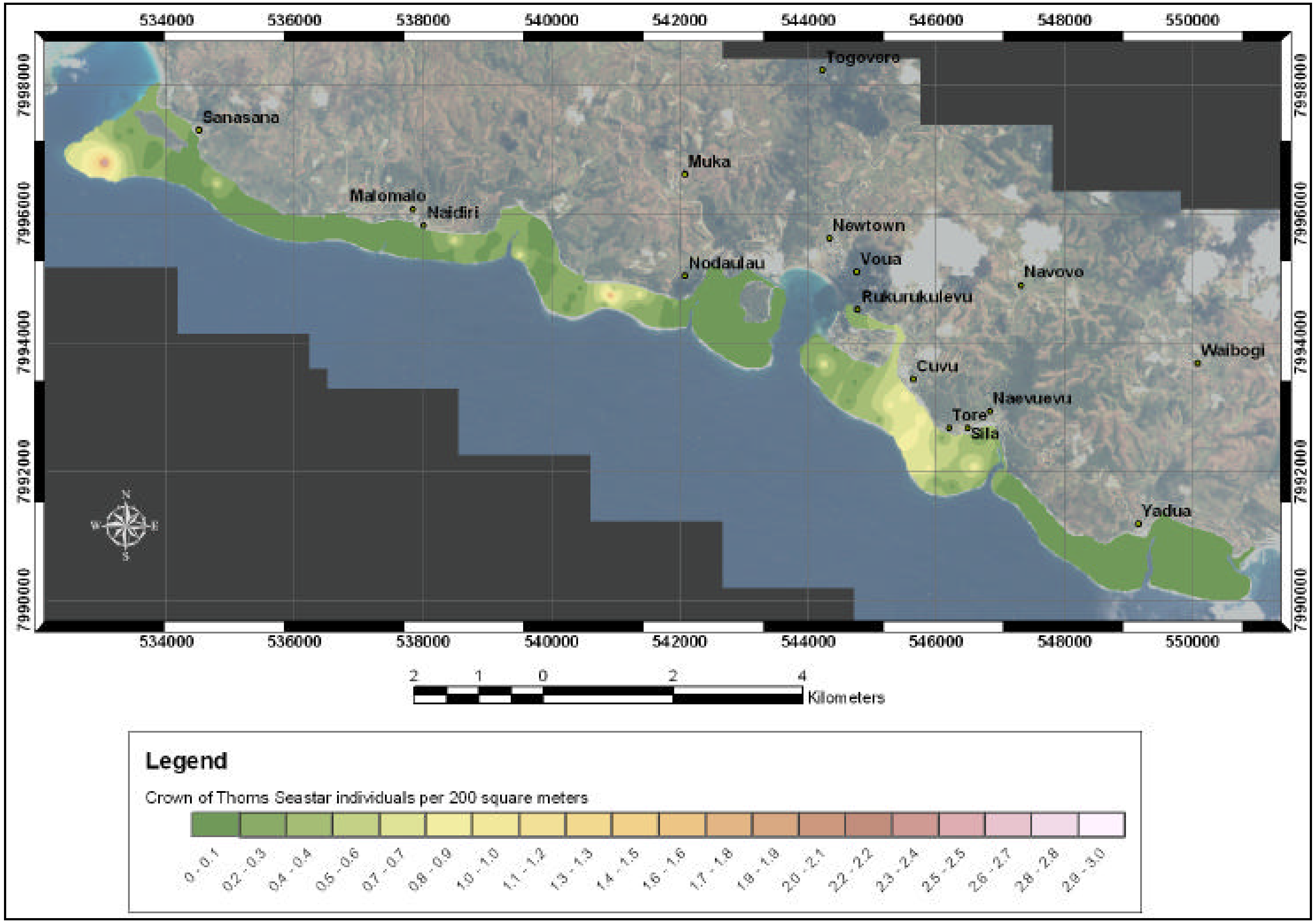

Figure 19. Density of Crown of Thorns (*Acanthaster Plancii*) per 200 square metres reef area of section 1.

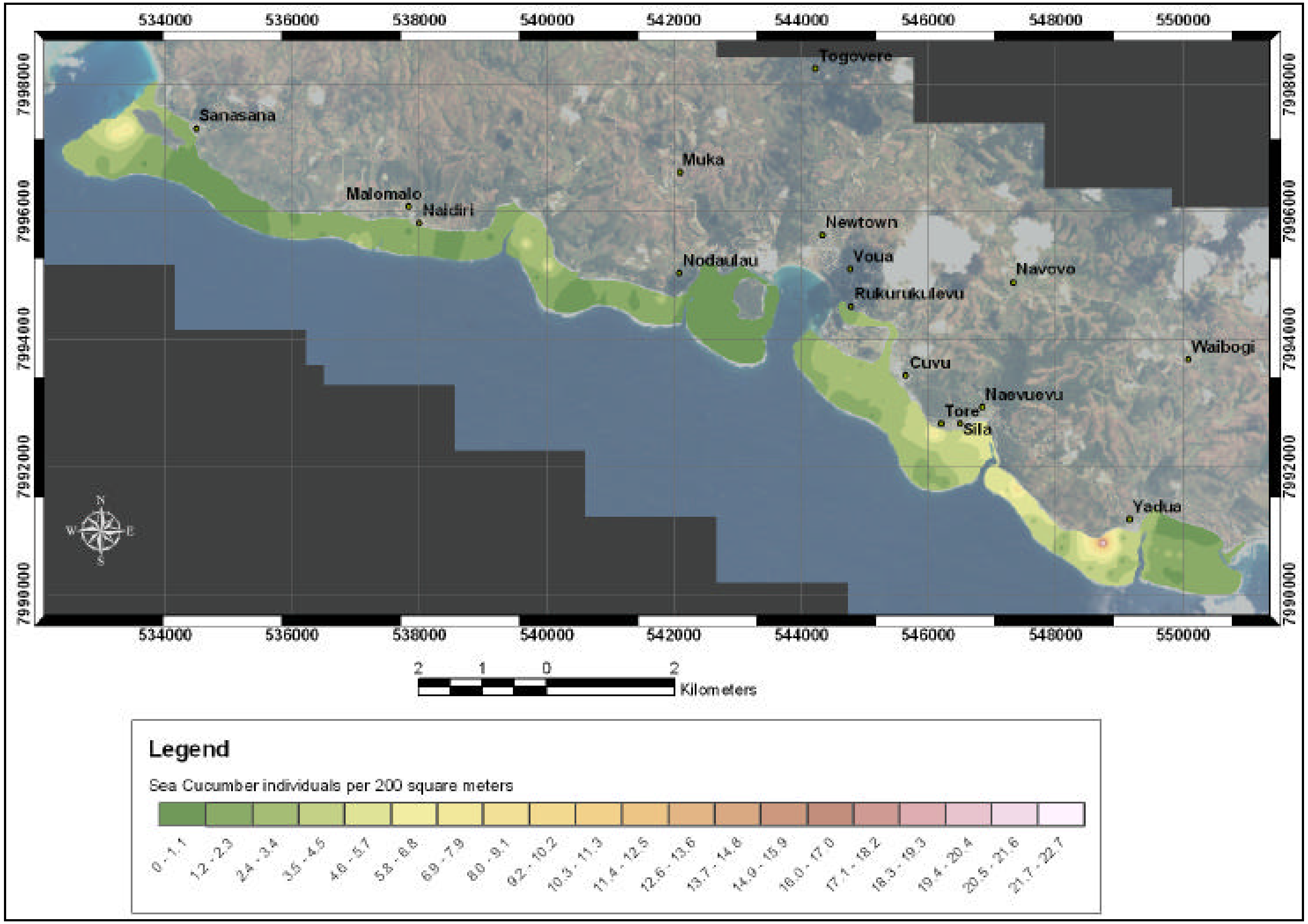

Figure 20. Density of Sea Cucumbers (*Holothuridae*) per 200 square metres reef area of section 1.

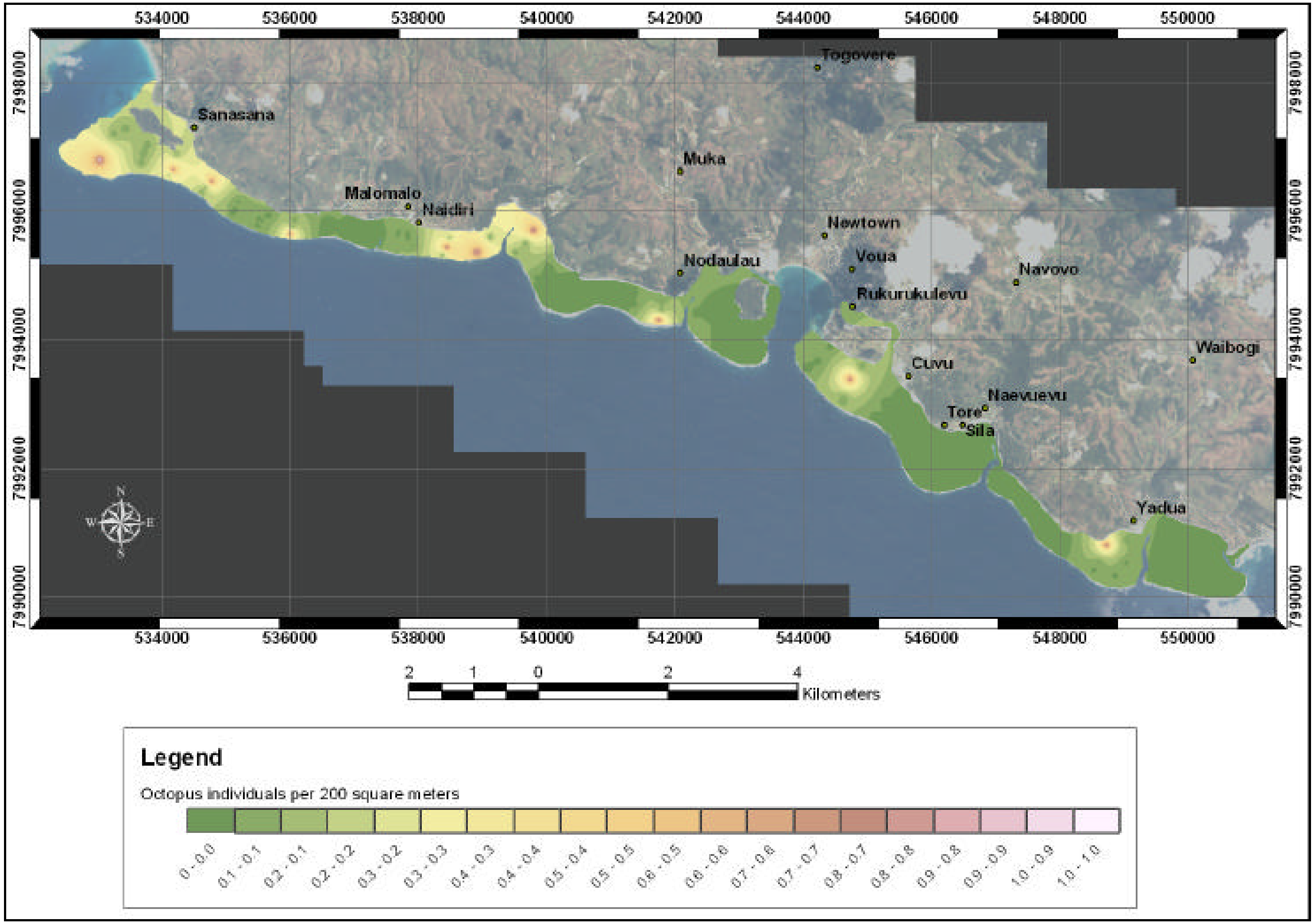

Figure 21. Density of *Octopus* per 200 square metres reef area of section 1.

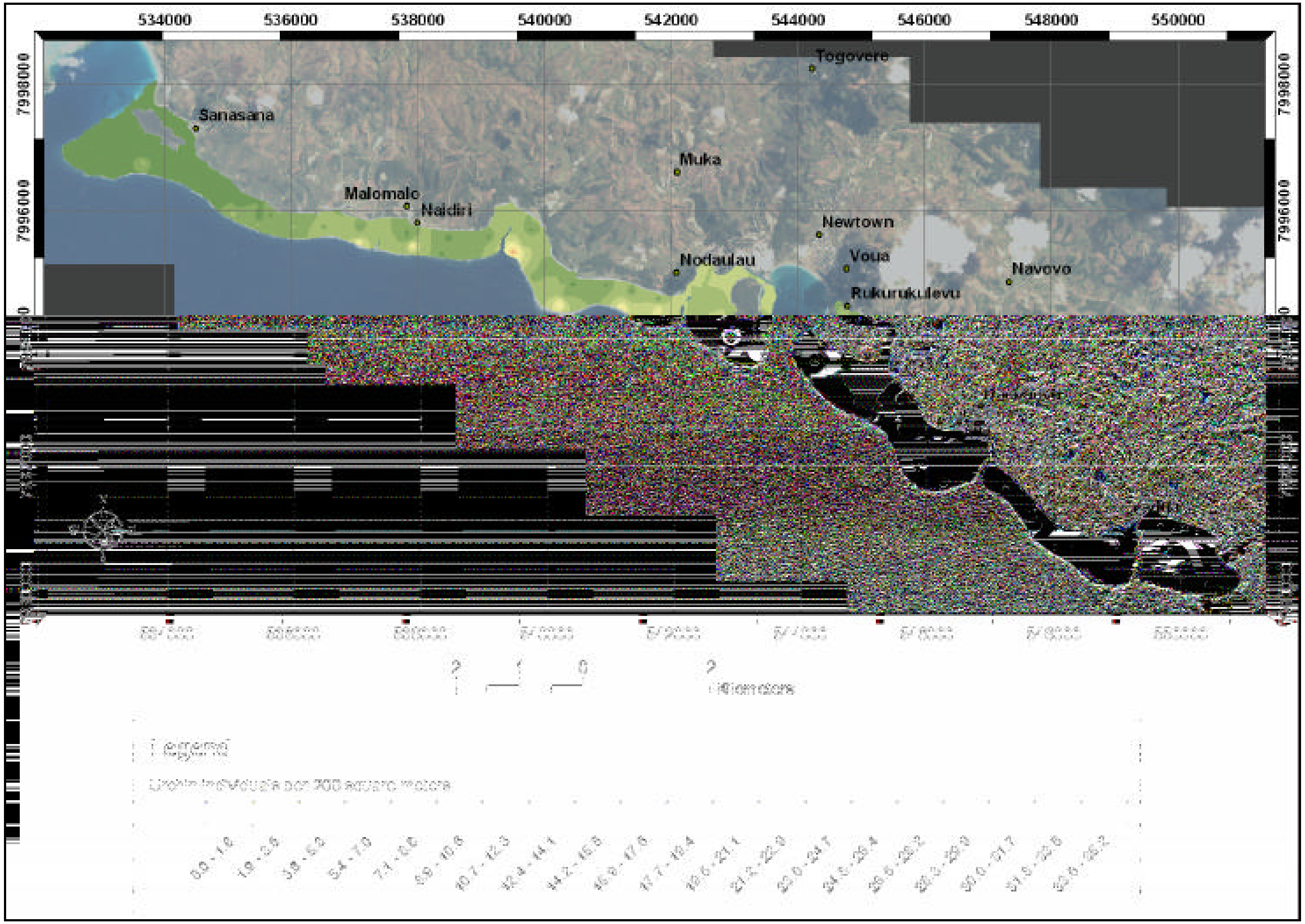

Figure 22. Density of short spined urchin (*Tripneustes* sp) per 200 square metres reef area of section 1

5.2.1 Reef Section Two

Benthic cover

Areas of exposed bedrock are common across section 2 (figure 23). Average cover ranged from 0 to 35.4% cover. Highest cover is seen east of Tagaqe village, though the majority of reef area outside and east of Tagaqe has very low bedrock levels. West of this area, bedrock levels are generally between 10 and 25%. Bedrock cover is generally higher in the outer and middle reef zones.

Rubble distribution follows a similarly patchy pattern (figure 24). Cover ranges from 2% up to 67.6% cover. Widespread and high Rubble cover is seen between Votua and Votualailai. High cover is also seen west of Tagaqe village and between Malevu and Sabata. While high rubble cover is common in the outer reef zone of many areas, in areas where rubble cover is generally low the greatest concentration of rubble tends to collect closer to the shore.

Coral cover is incredibly patchy across section 2 (figure 25). Cover ranged from 0 to 18.8 %, with the highest levels of live coral cover seen between Malevu and Korotogo, Tagaqe and Nagasau, outside Votualailai and east of Votua villages. Coral cover is generally low around river channels. This is particularly evident outside of Korotogo where little coral is seen.

As discussed above, algae dominate total benthic cover of the Coral Coast however it is not distributed evenly (figure 26). Levels of between 6.8 and 79.5% algal cover are seen. Algae tend to be more abundant towards the outer reef zone, as well as on the margins of river channels and bays. Algal cover is particularly dense over the reef area either side of Korotogo, as well as between Sovi Bay and Namada. Tagaqe, Votua lailai and Votua villages. *Sargassum* cover is particularly dense in many of these reef areas though unlike algae as a whole, percentage cover tends to decrease away from shore (figure 27).

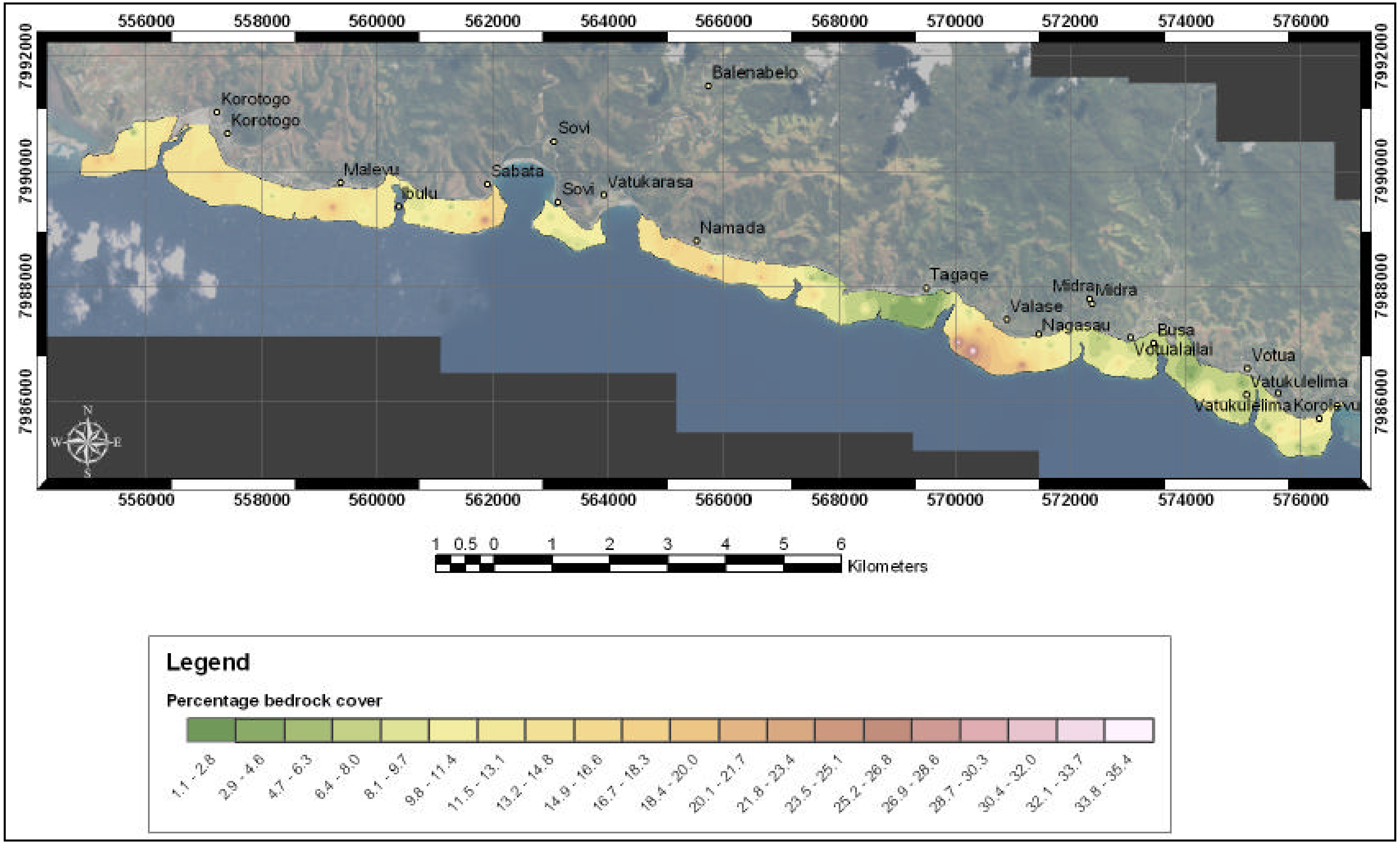

Figure 23. Percentage bedrock cover for Section 2

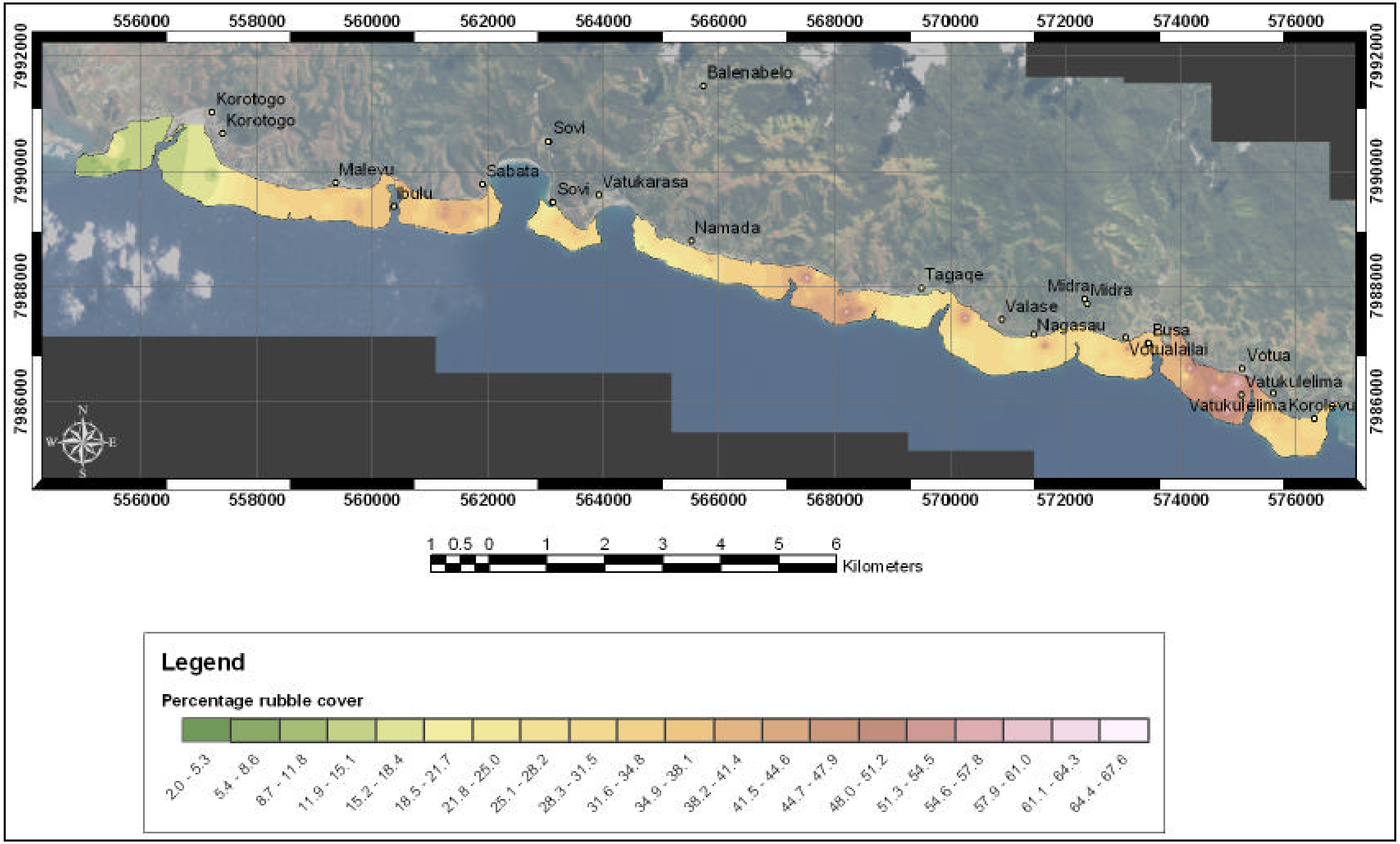

Figure 24. Percentage rubble cover for Section 2

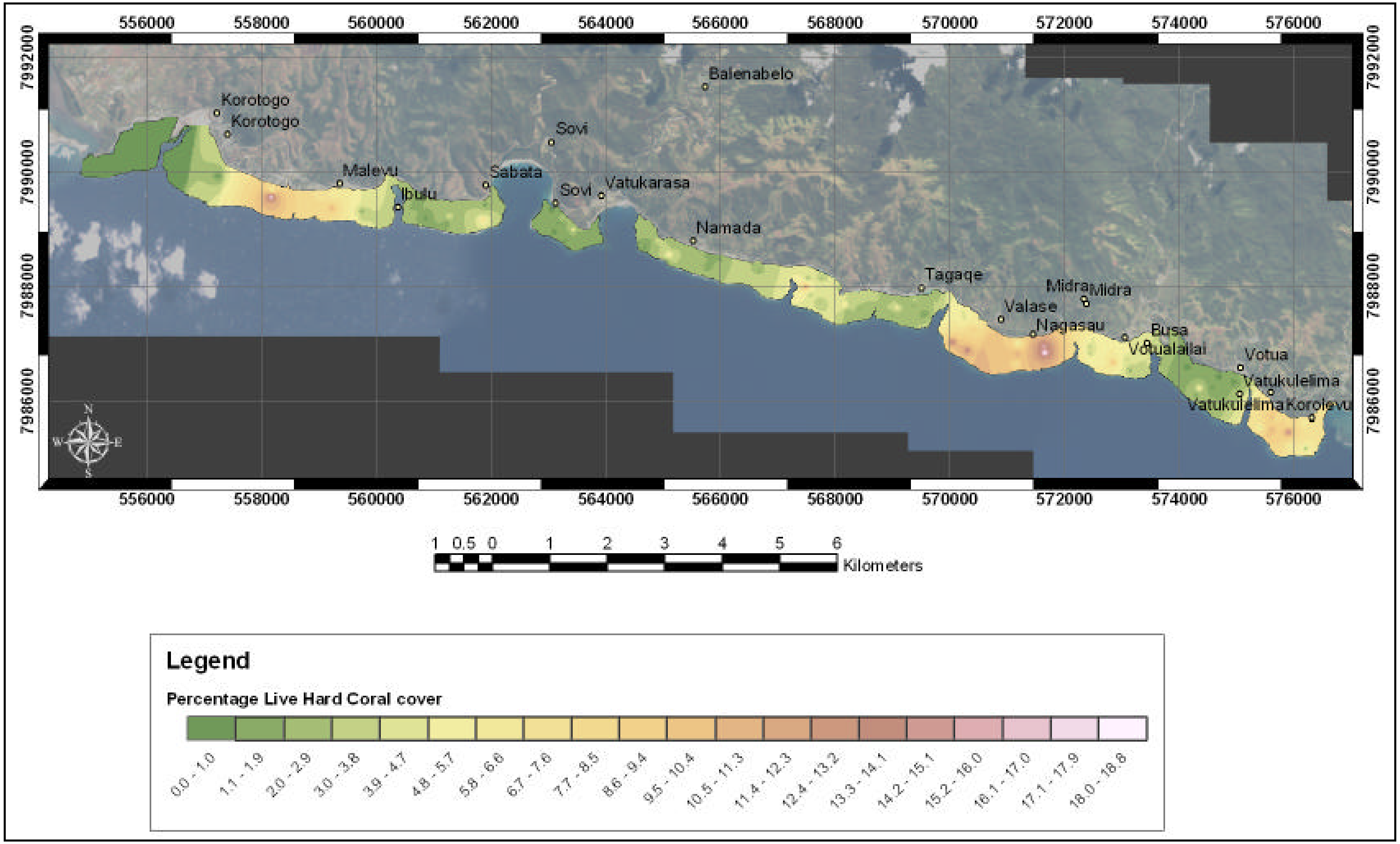

Figure 25. Percentage live hard coral cover for Section 2.

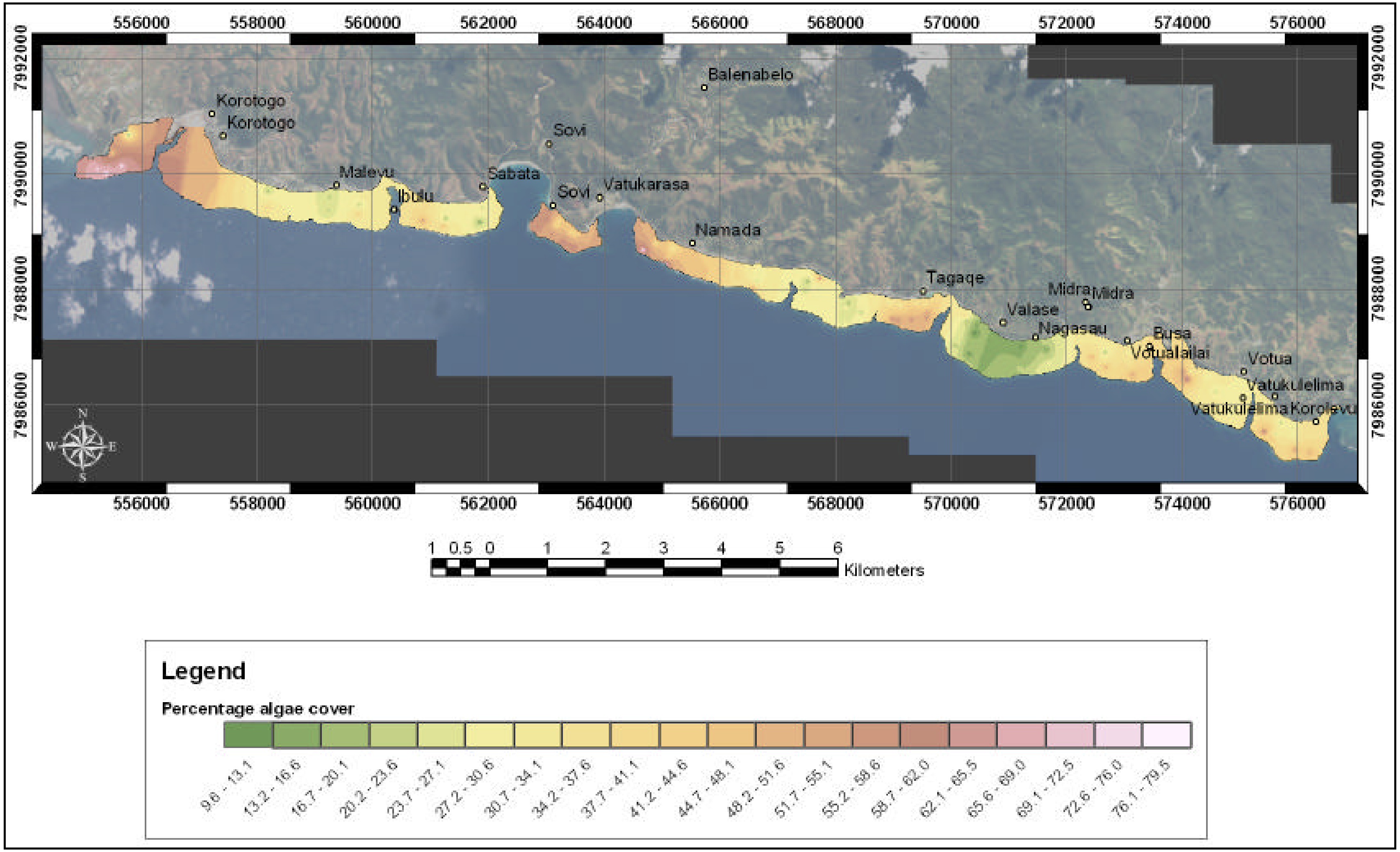

Figure 26. Percentage algae cover for Section 2.

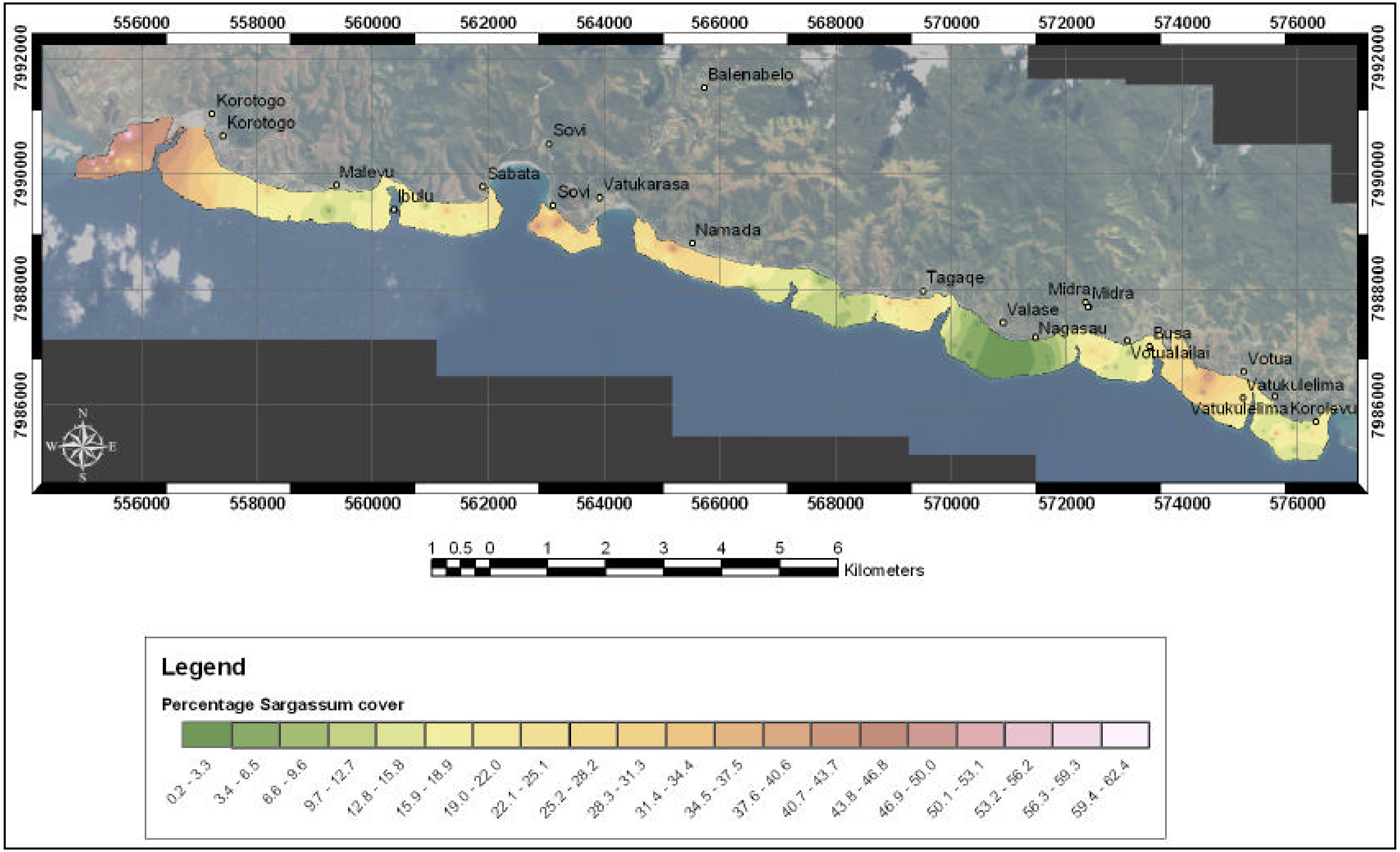

Figure 27. Percentage *Sargassum sp* cover for S*ection 2*.

Fish

Wrasse show particularly high densities reaching as high as 199.8 fish per 500 square metres reef area in many regions, though drop to densities as low as 12.3 fish per 500 square metres elsewhere (figure 28). Density of Wrasse tends to increase away from shore. The highest density of Wrasse is seen in the east of the section between Nagasau and Korolevu. In the western half of the section highest numbers are seen on Oria reef immediately west of Vatukarasa, as well as on the reef area west of Korolevu.

The distribution of Butterflyfish is incredibly patchy (figure 29). By far the greatest density was recorded in the reef area west of Korotogo however density generally lies in the region of 0 to 10 fish per 500 square metres reef area across the section.

Distribution of grouper is again very localised in section 2 (figure 30). The majority of Grouper are seen outside of Tagaqe, Votua lailai and east of Votua villages. Elsewhere Grouper are rare, though there are ocasional patches of density between Malevu and Vatukarasa.

Parrotfish density lies between 0 and 83.2 fish per 500 square metres reef area (figure 31). Highest densities are seen east of tagaqe village towards Nagasau, outside votualailai and west of Votua, east of namada and for several kilometreses of coastline either side around Malevu.

Rabbitfish density is low across the section (figure 32) Very few Rabbitfish are seen between Sovi Bay west to end of the reef section and the reef area outside Valase and Nagasau. The greatest density of fish occurs in the reef west of Votua where density is generally between 10 and 20 fish per 500 square metres.

Snapper density is low across the section with most of the reef area below 1 fish per 500 square metres (figure 33). A peak density of 8.5 fish per reef area is seen east of Korotogo, though such densities are rare. Additional increases above the norm are seen outside of sabata, Votua lailai and Votrua villages.

Surgeonfish are found at densities between 0 and 35..3 fish per 500 square metres reef area (figure 34). Low Surgeonfish densities, typically between 0 and 9 fish per 500 square metres, are seen in the reef area outside of Korotogo and between Malevu and Vatukarasa. Elsewhere, higher densities are seen however, these tend to be concentrated in the middle and outer reef zones.

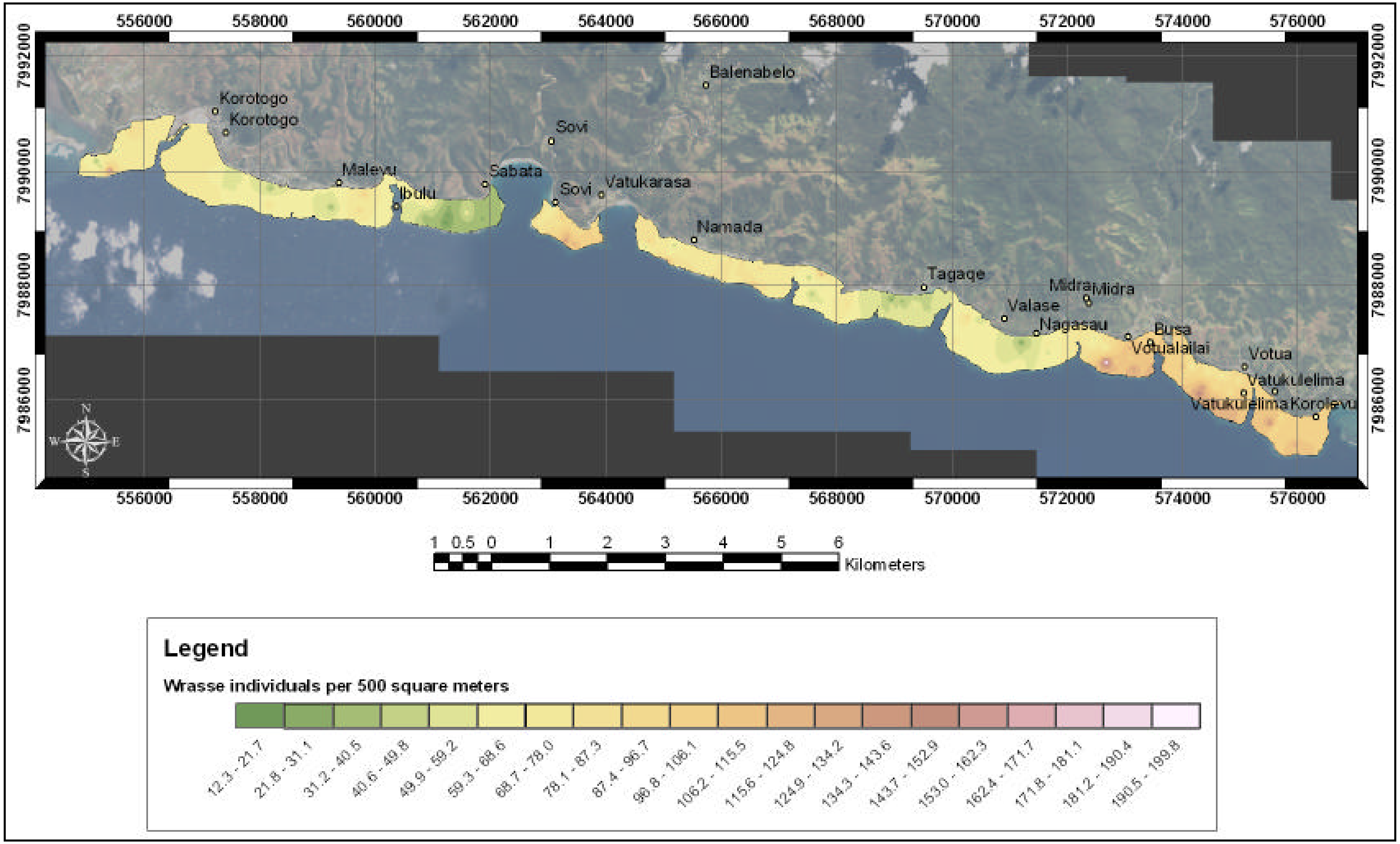

Figure 28. Density of Wrasse (*Labridae*) per 500 square metres reef area for Section 2.

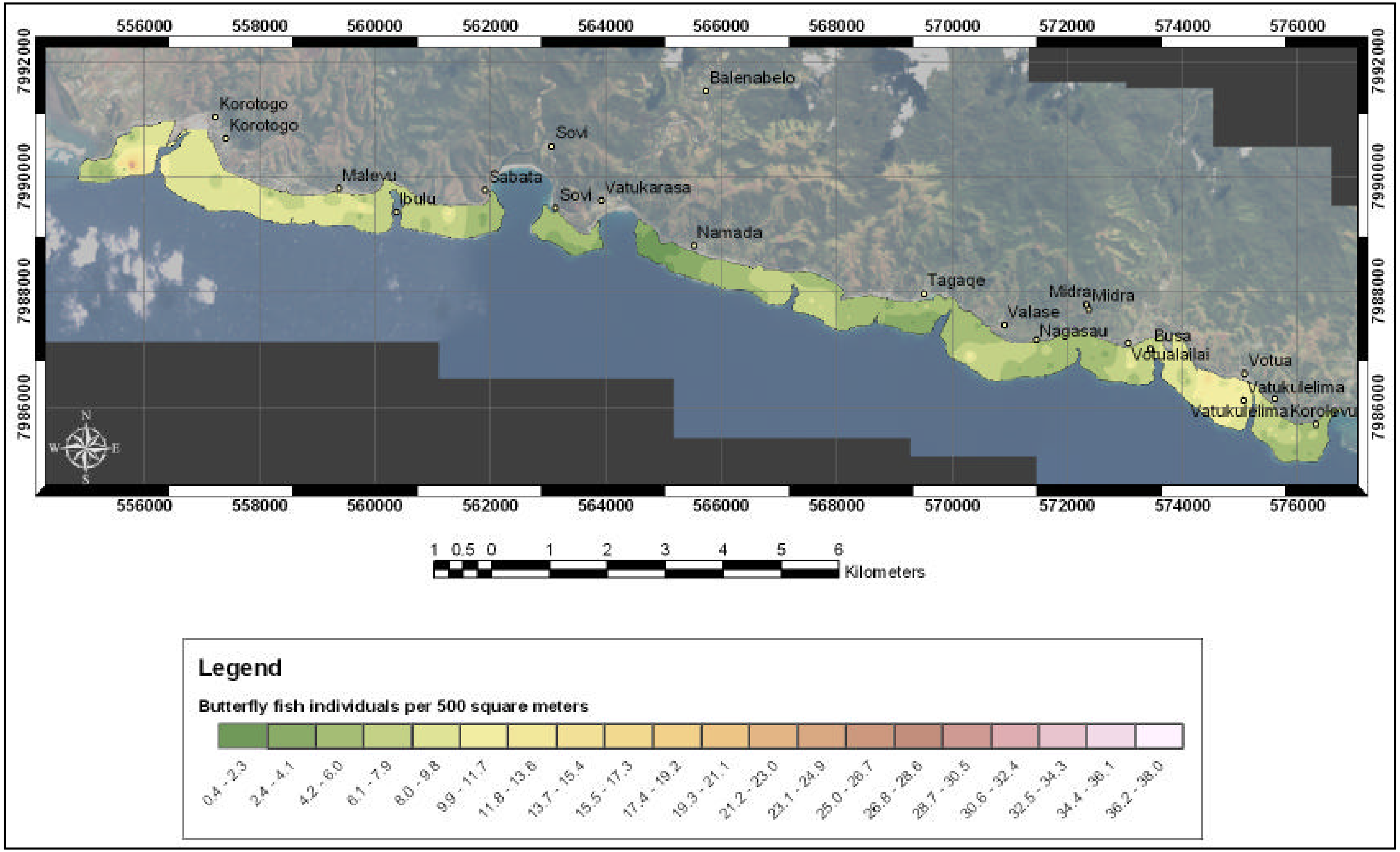

Figure 29. Density of Butterflyfish (*Chaetodontidae*) per 500 square metres reef area of Section 2.

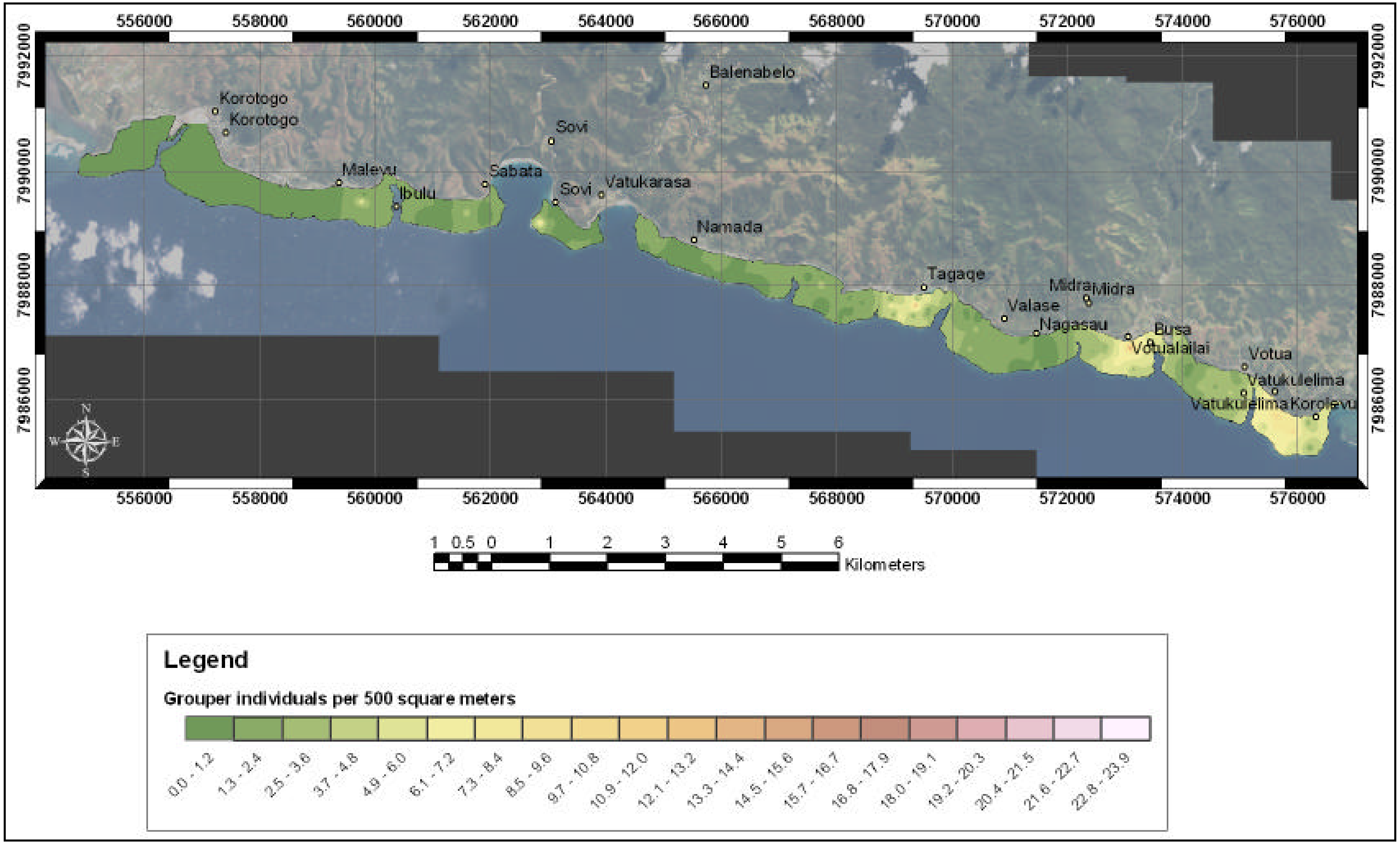

Figure 30. Density of Grouper (*Seranidae*) per 500 square metres reef area of Section 2.

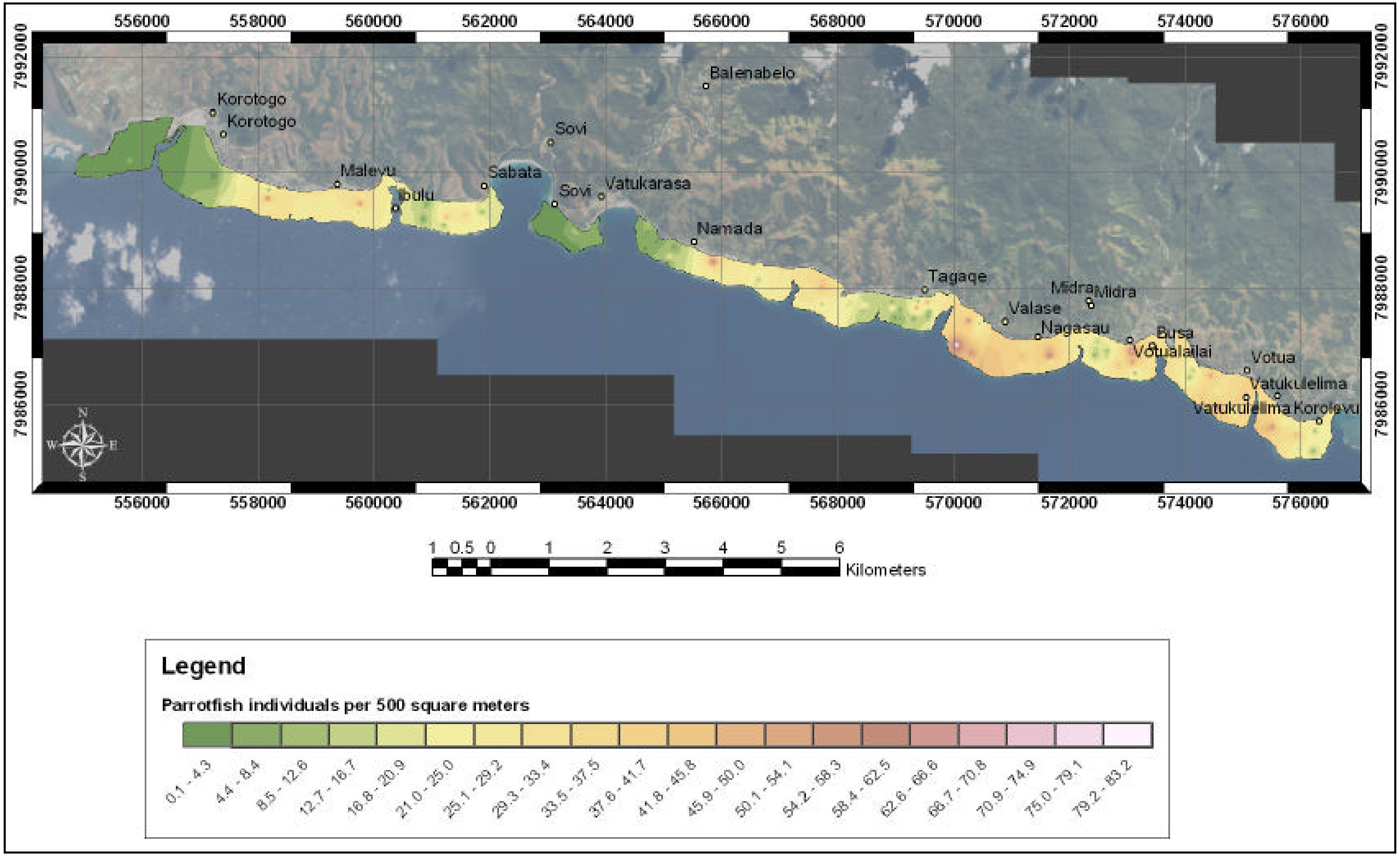

Figure 31. Density of Parrotfish (*Scaridae*) per 500 square metres reef area of Section 2.

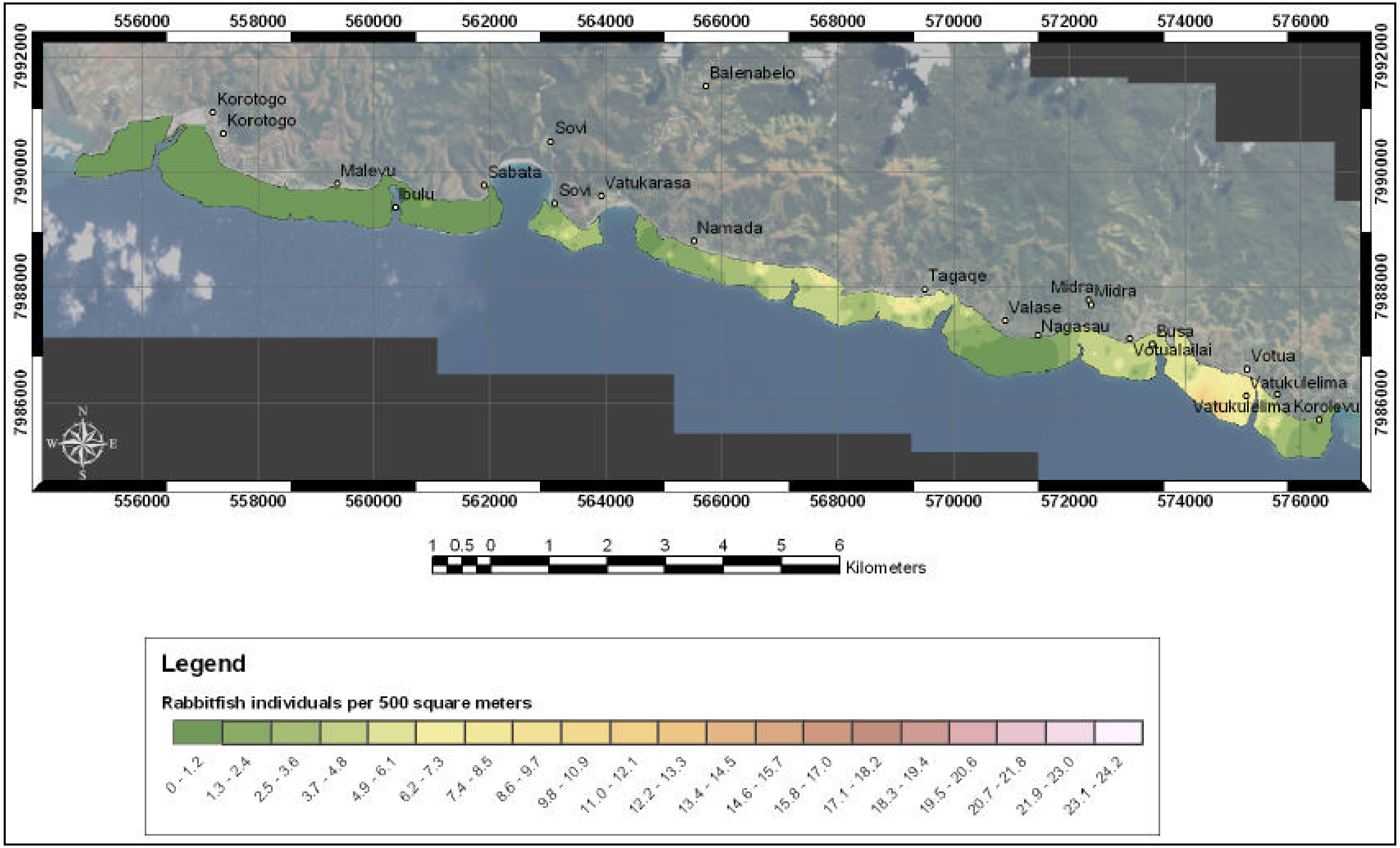

Figure 32. Density of Rabbitfish (*Siganidae*) per 500 square metres reef area (Section 2).

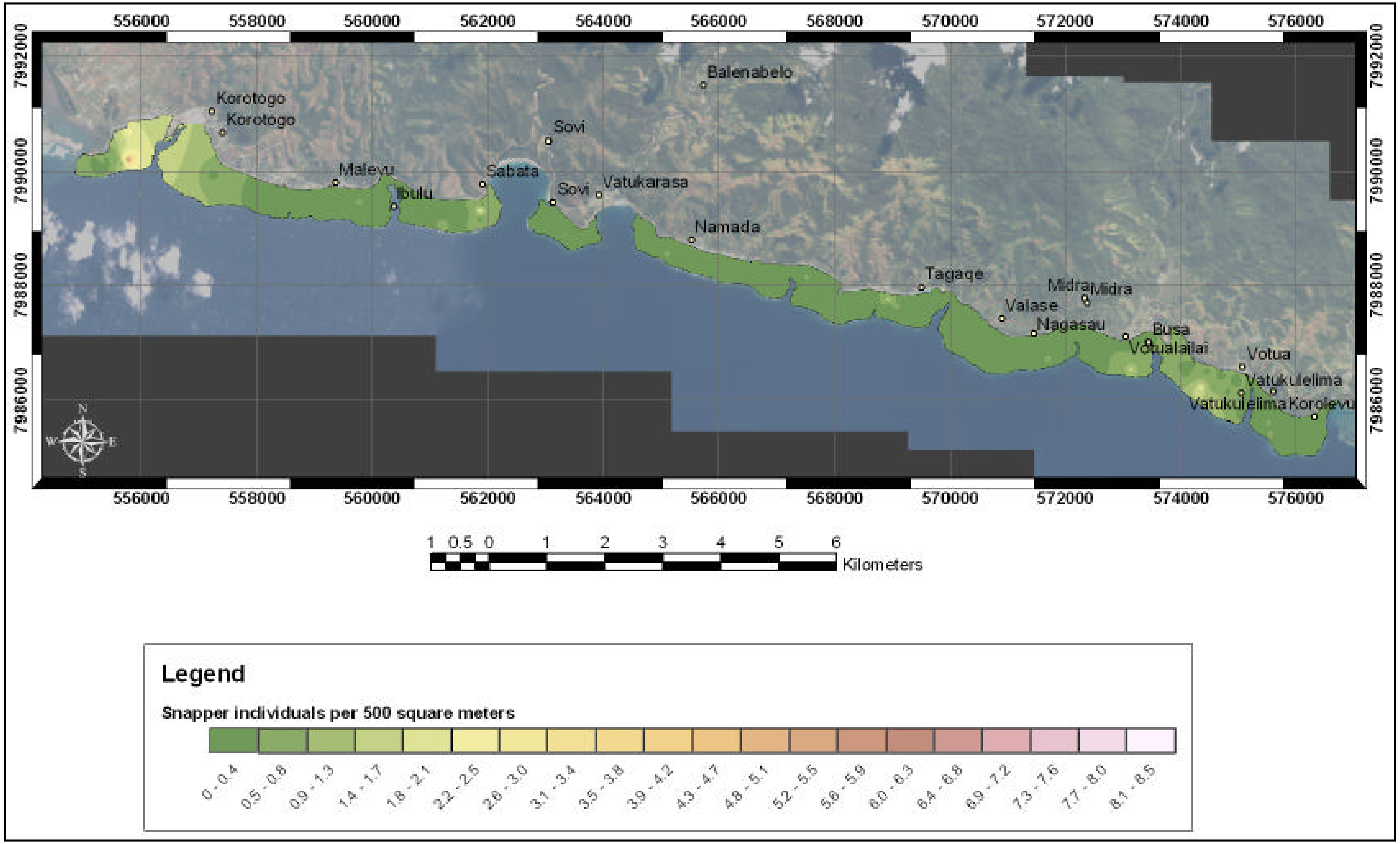

Figure 33. Density of Snapper (Lutjanidae) per 500 square metres reef area of Section 2.

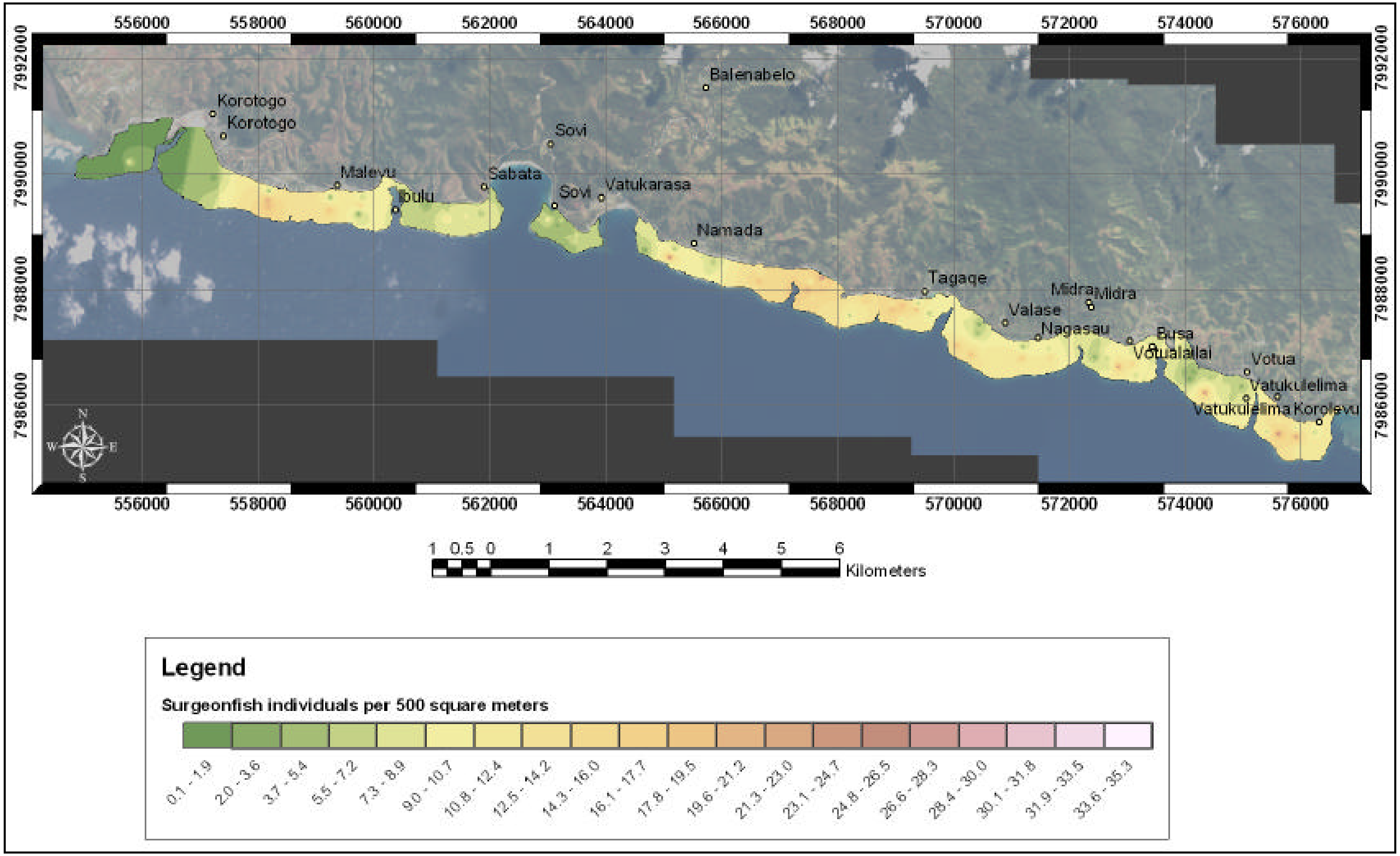

Figure 34. Density of Surgeonfish (*Acanthuridae*) per 500 square metres reef area of Section 2.

Invertebrate data

Giant clams are not seen across much of section 2, however a few clams are present in scattered locations throughout the section. A maximum density of 2.4 clams per 200 square metres reef area is seen just east of Namada (figure 35).

The highest density of Crown of Thorns (*Acanthaster plancii*) is seen in the reef area east of Tagaqe, where density reaches 5.2 starfish per 200 square metres reef area (figure 36). A density of around 3 starfish per 200 square metres reef area is also seen in the reef area east of Namada. Density is generally low across the rest of the section.

Density of Sea Cucumber is generally low, typically lying between 0 and 6 Sea Cucumbers per 200 square metres reef area (figure 37). Highest density is seen west of Namada where density approaches 30.4 individuals per 200 square metres reef area.

Octopus are generally rare in the section (figure 38). Concentrations of Octopus can be seen outside Tagaqe and west of Votua village. Maximum density in these regions is in the order of 2.7 individuals per 200 square metres.

Numbers of Short Spined Sea Urchin are low across the section (figure 39). The Urchin population is densest between Nagasau and Votua village. Maximum density in this region is in the order of 47.8 Urchins per 200 square metres. Additional hotspots of density are scattered along the coastline though these are interspersed with large areas of reef where population density is below 12 urchins per 200 square metres reef area.

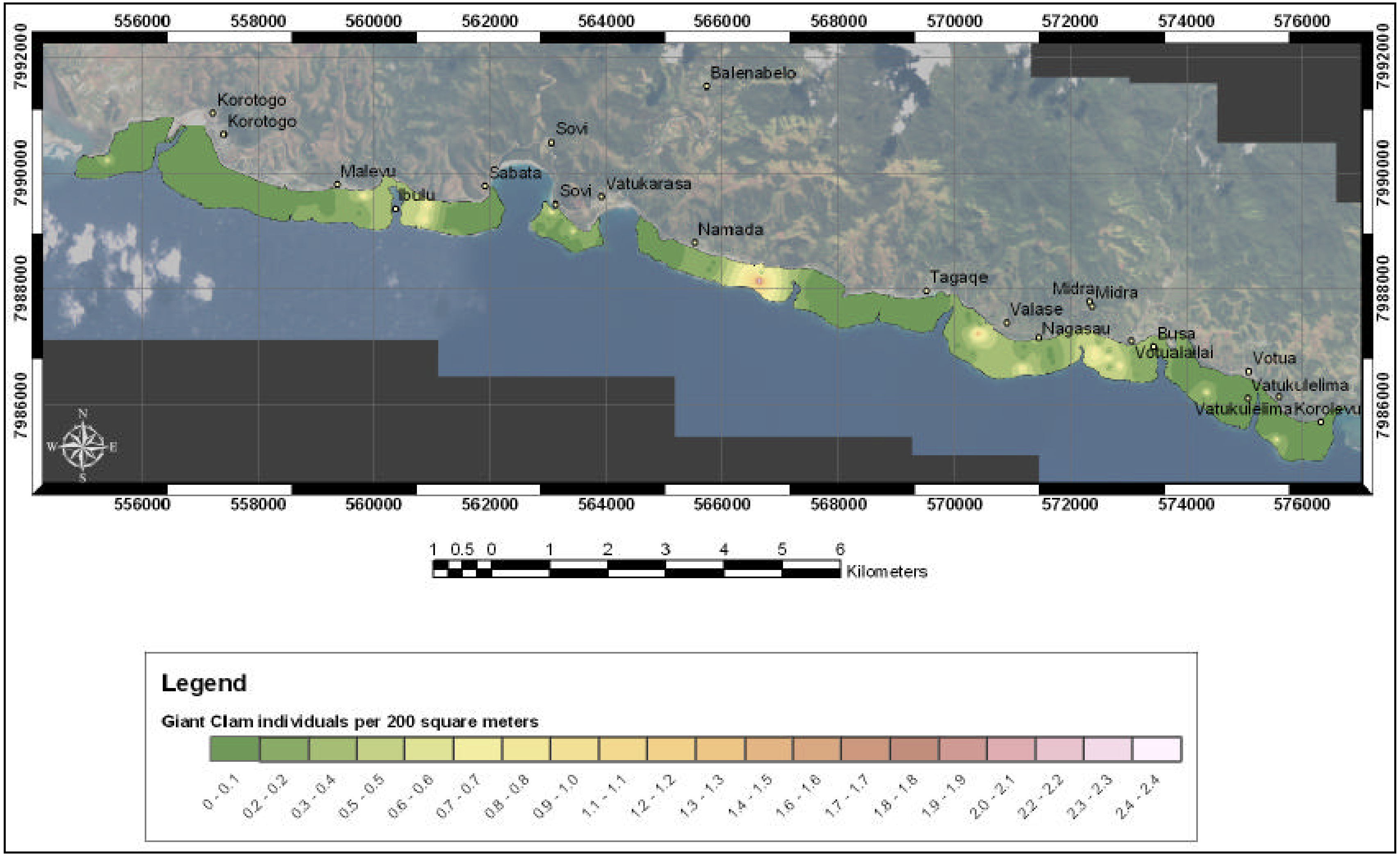

Figure 35. Density of Giant clams (*Tricadna sp*) per 200 square metres reef area of Section 2.

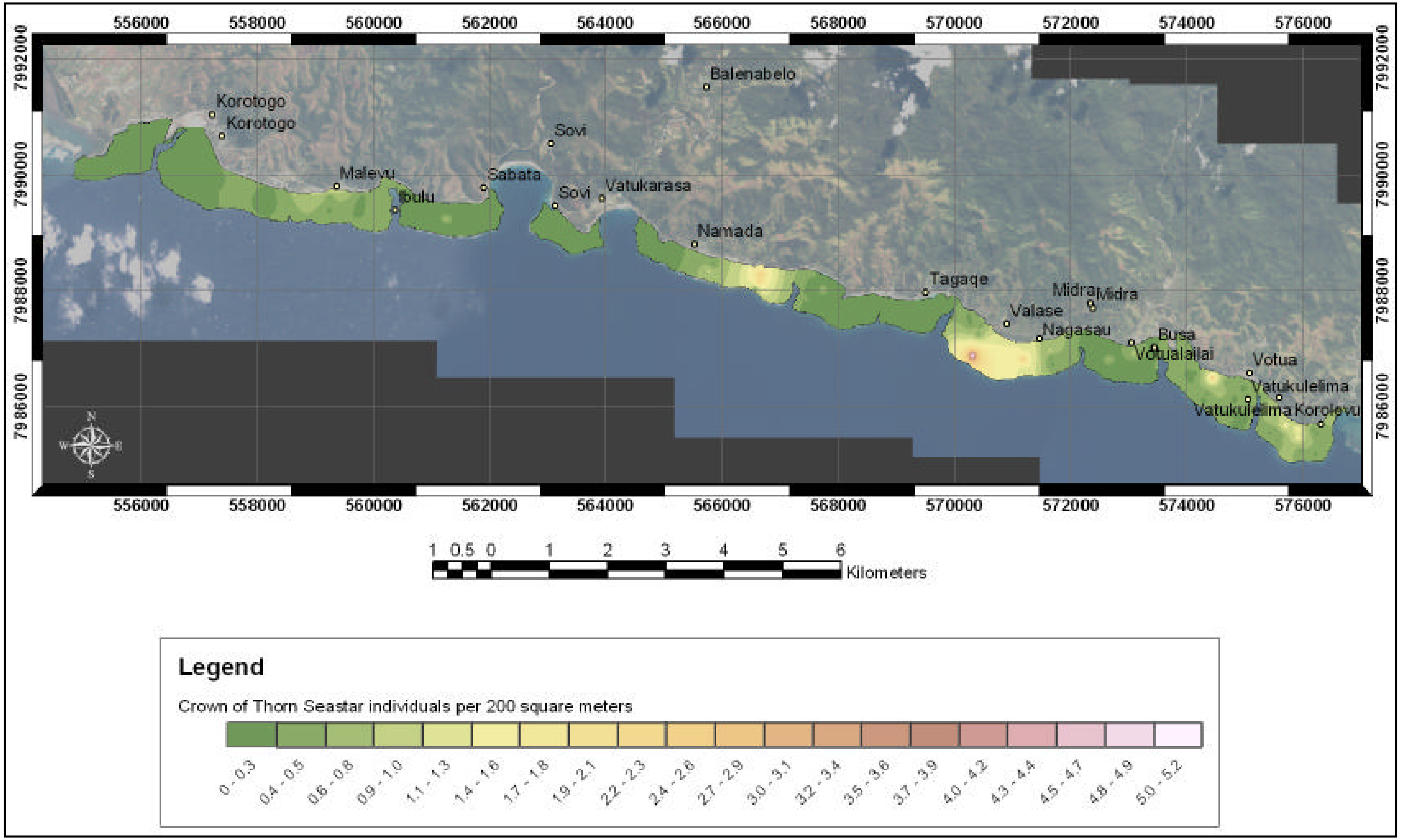

Figure 36. Density of Crown of Thorns (*Acanthaster Plancii*) per 200 square metres reef area of Section 2.

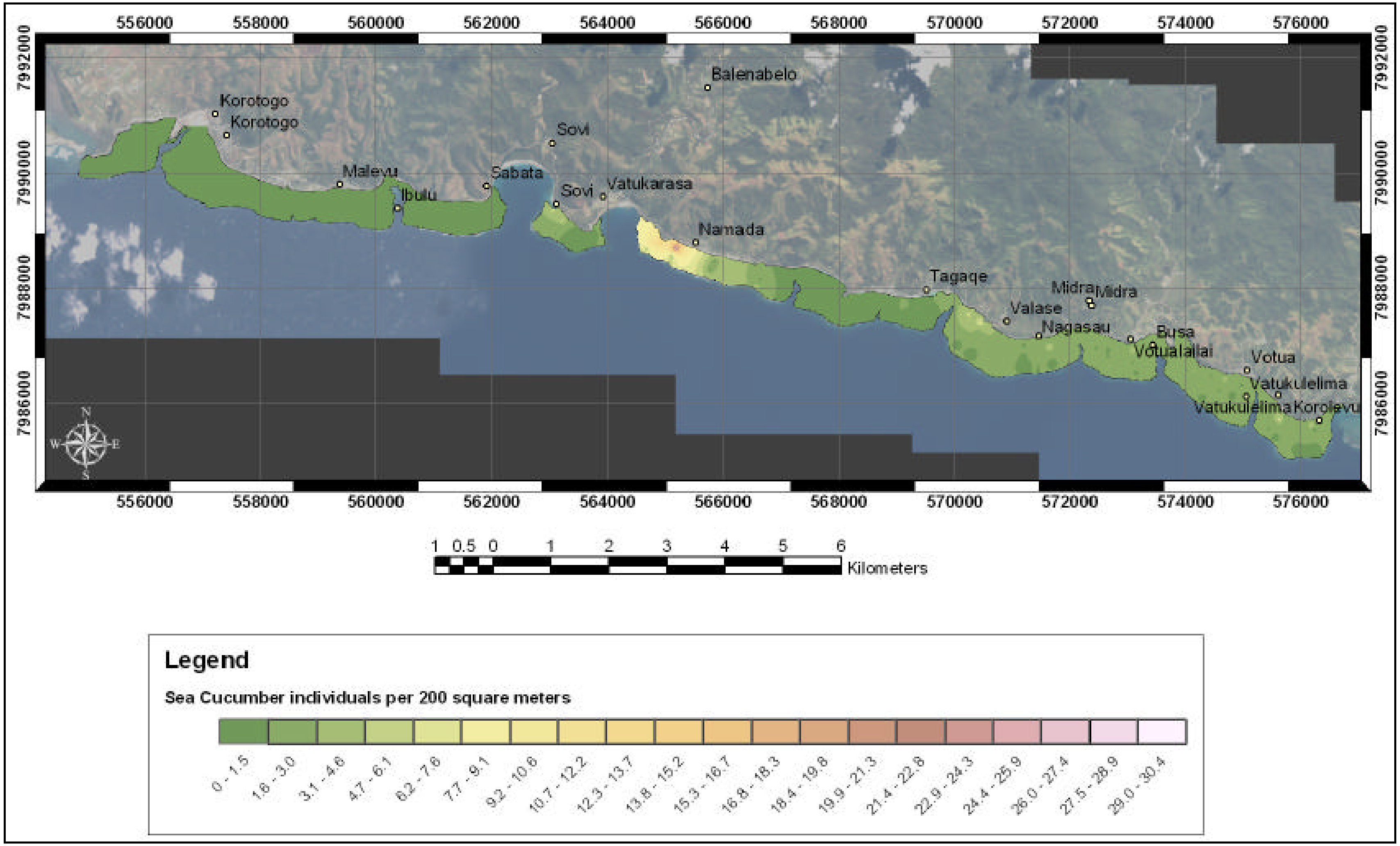

Figure 37. Density of Sea Cucumbers (*Holothuridae*) per 200 square metres reef area of Section 2.

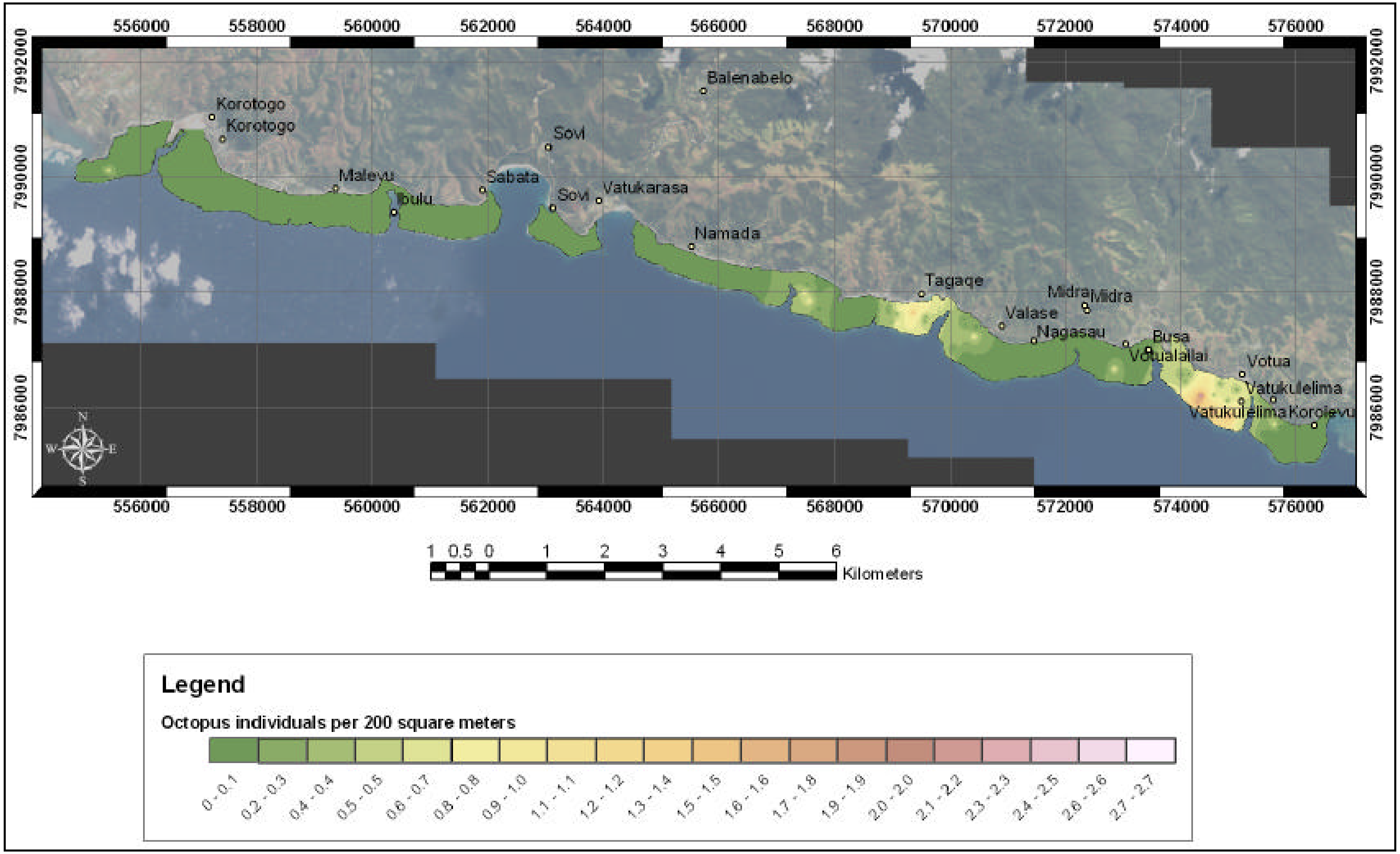

Figure 38. Density of *Octopus* per 200 square metres reef area of Section 2.

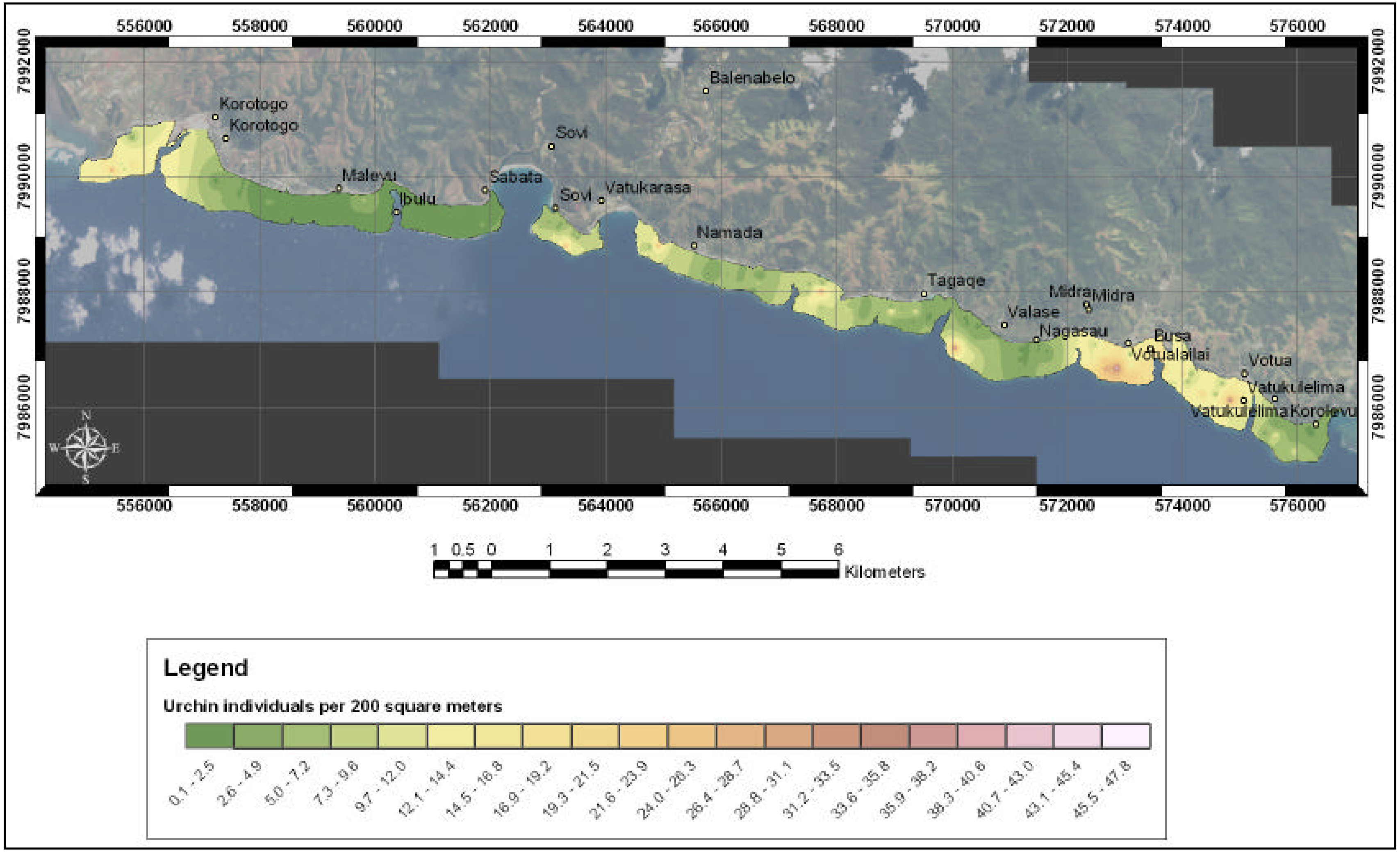

Figure 39. Density of short spined urchin (*Tripneustes* sp) per 200 square metres reef area of Section 2.

5.2.1 Reef Section Three

Benthic cover

Areas of exposed bedrock are less common than in other sections (figure 40). Average cover ranged from 0.5% to 28% cover. Highest cover is seen outside and west of Namatakula. Levels Cover was typically between 6% and 15% across the rest of the section. The outlying reef area to the east contains much less bedrock cover.

Rubble cover is generally high across the coast (figure 41). Rubble is again low in the outlying easterly reef area, though in common with other reef areas there is a general trend of increasing rubble cover towards the outer reef zone. Cover ranges from 2.1 cover up to 62.5%. Highest cover is seen in the reef areas either side of Namaqumaqua, and between Komave and Namatakula.

Coral cover is incredibly patchy (figure 42). Cover ranged from 0 to 16.1%, with the highest levels of live coral cover seen in the reef area east of Namaqumaqua. Areas of high coral cover such as this, are however uncommon and most of the section's reef area has less than 3% coral cover.

As in other sections, algae dominate benthic cover (figure 43). Levels of between 6.5 and 63.1% algal cover are seen. Algae tends to be more abundant towards the outer reef zone, as well as on the margins of river channels and bays. Algal cover is particularly dense between Korolevu and Namatakula villages with algae tending to drop off eastwards. *Sargassum* cover is particularly dense in many of these reef areas though unlike algae as a whole, percentage cover is often higher close to shore (figure 44).

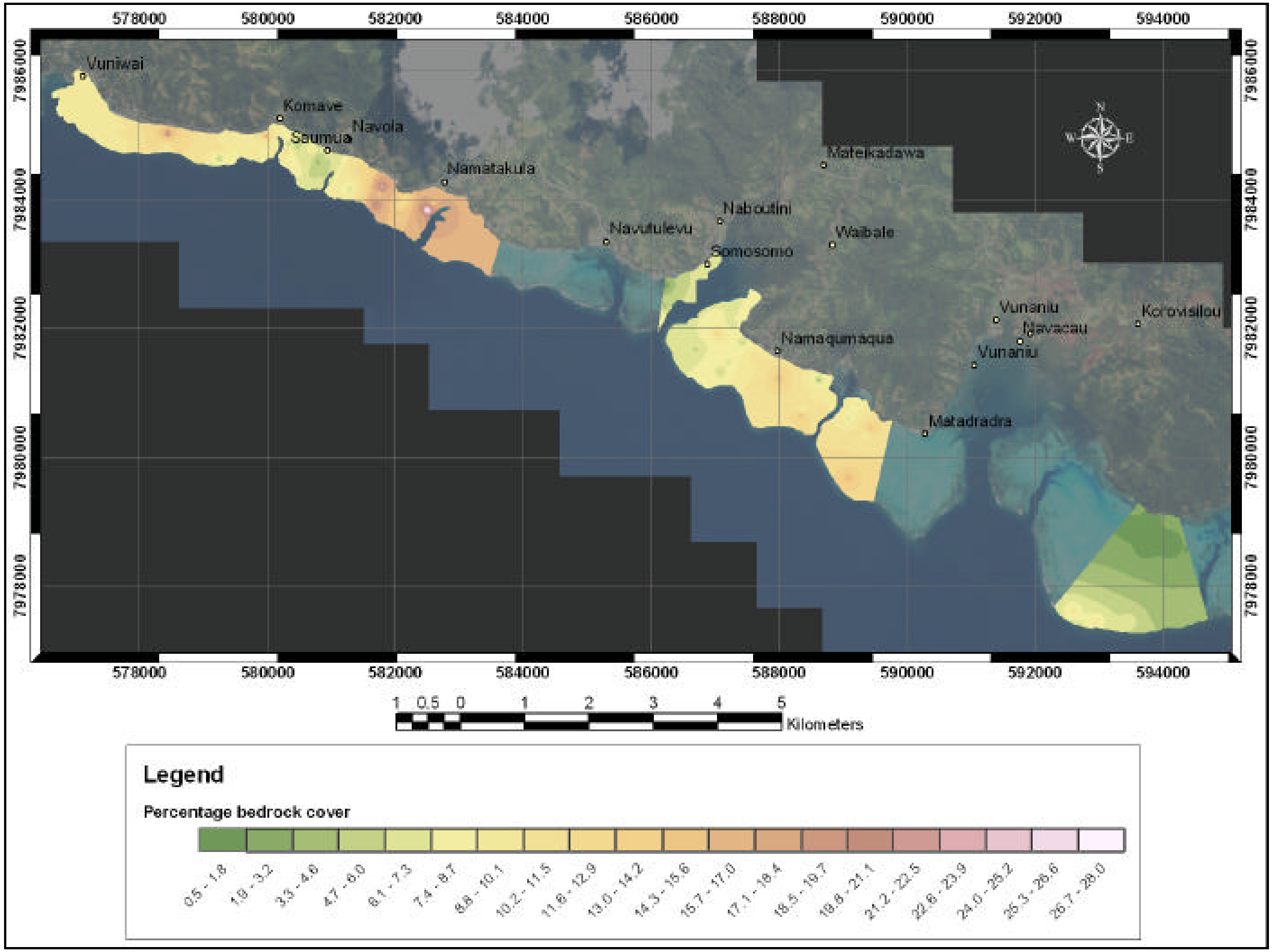

Figure 40. Percentage bedrock cover for Section 3.

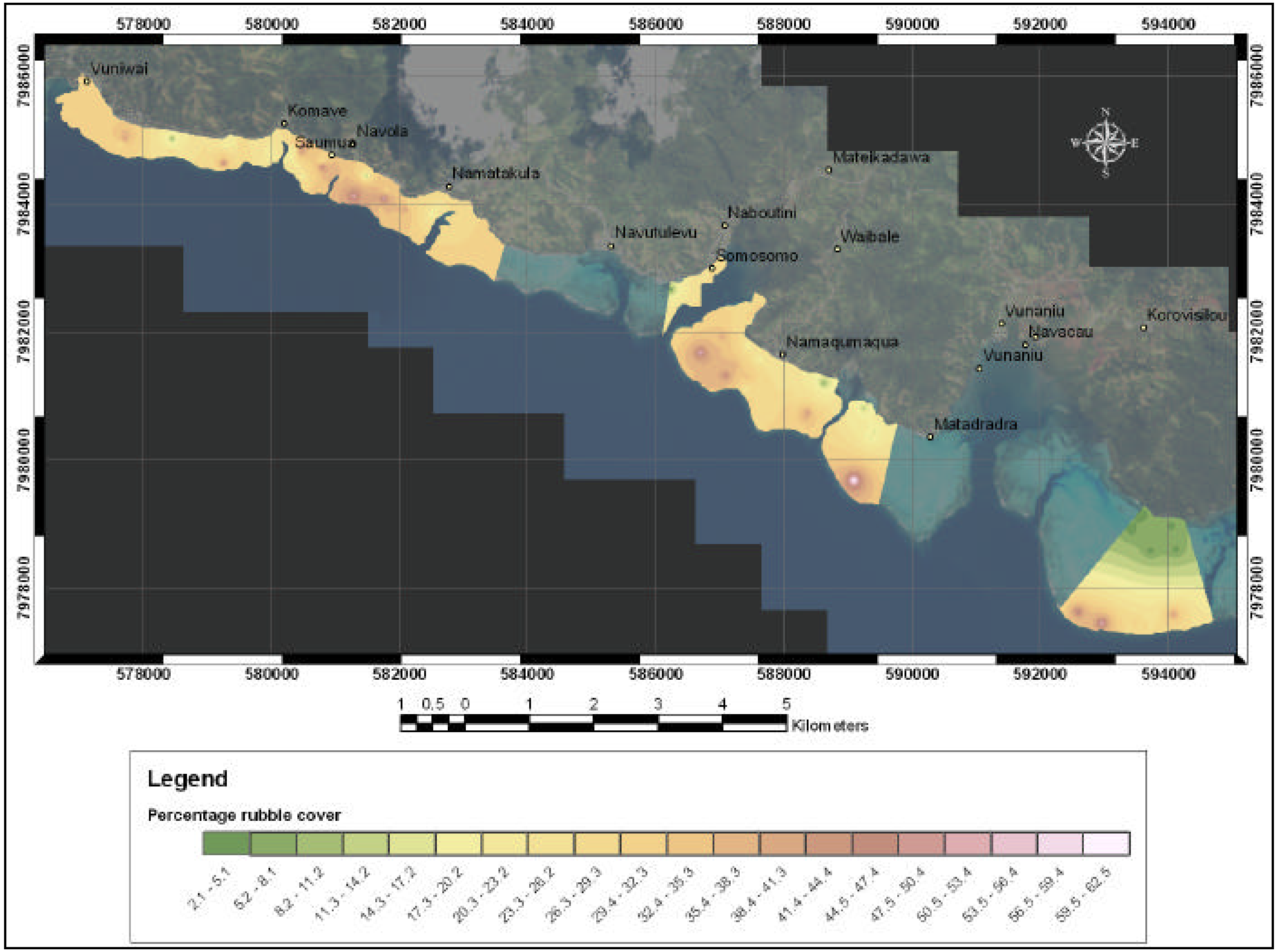

Figure 41. Percentage rubble cover for Section 3.

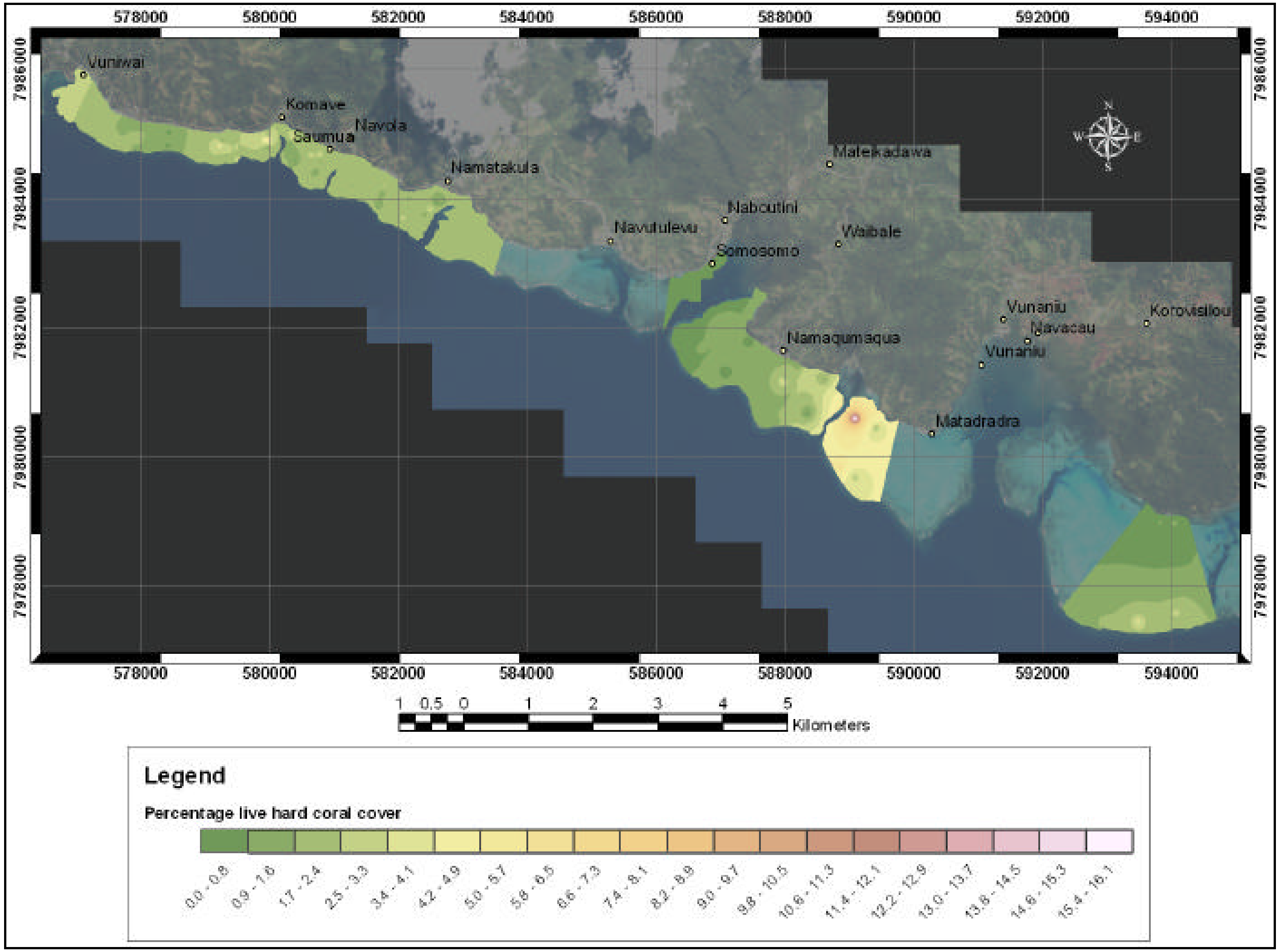

Figure 42. Percentage live hard coral cover for Section 3.

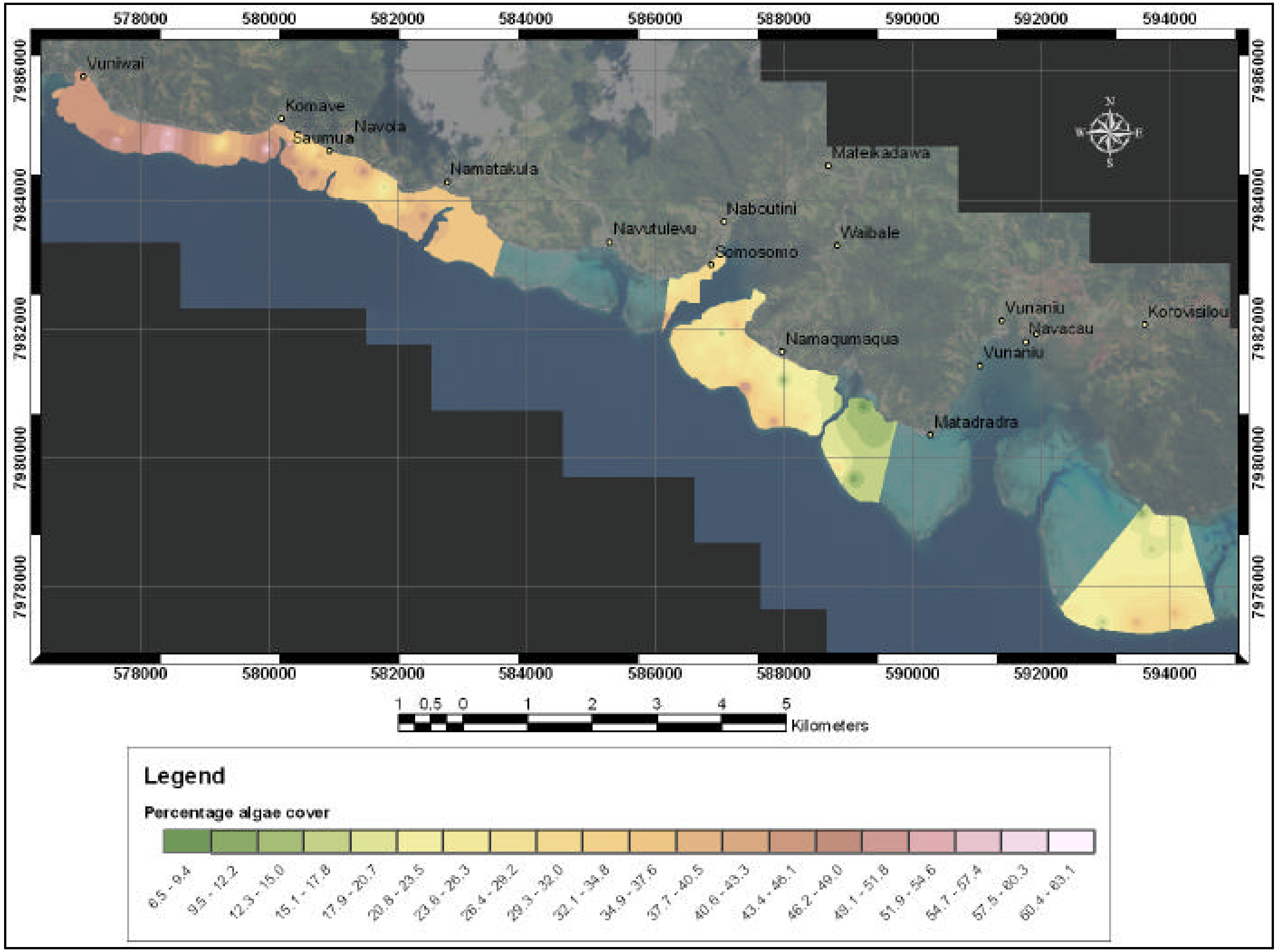

Figure 43. Percentage algae cover for Section 3.

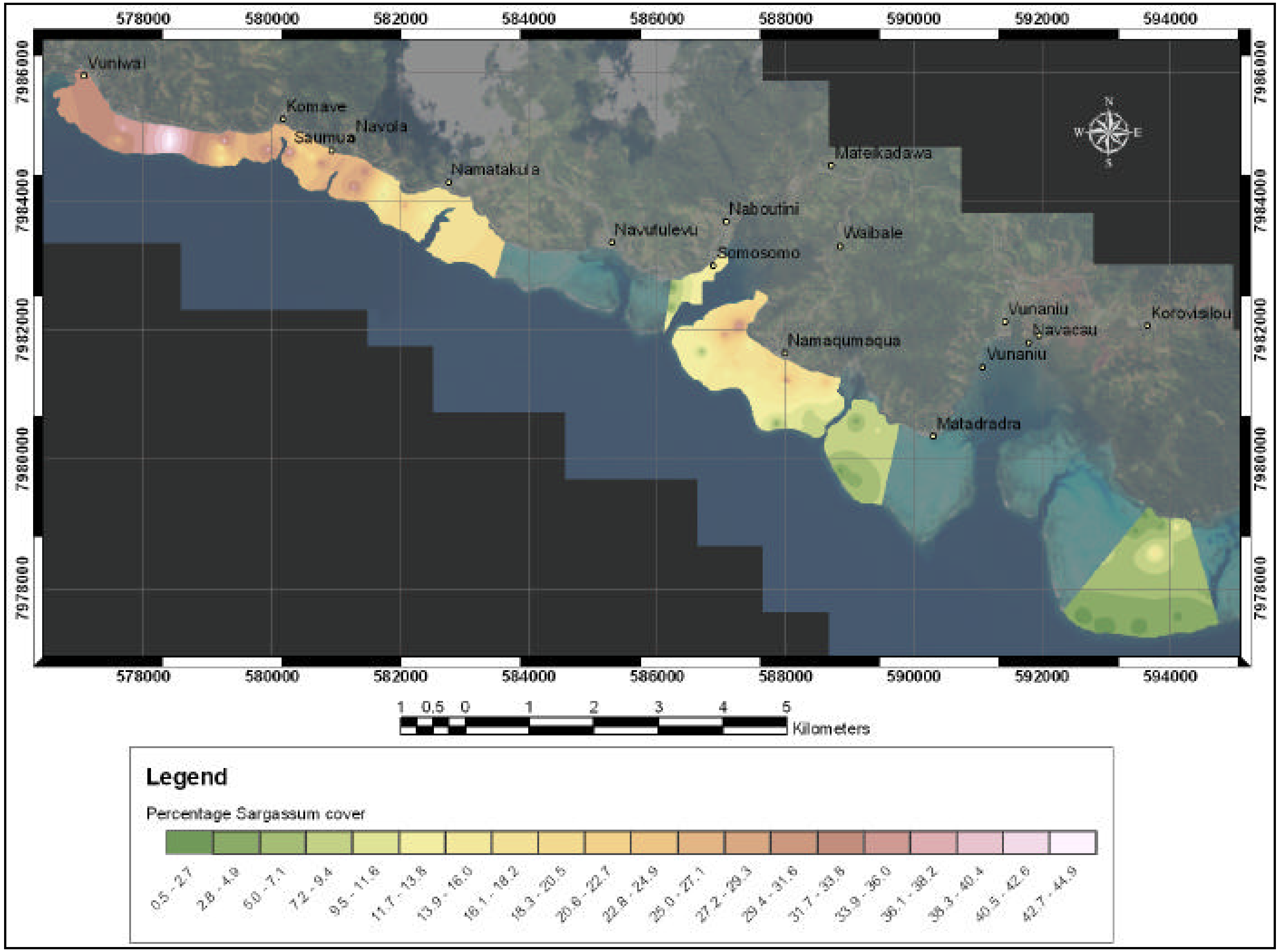

Figure 44. Percentage *Sargassum sp* cover for Section 3.

Fish

Wrasse show particularly high densities reaching as high as 222.9 fish per 500 square metres reef area in many regions, though drop to densities as low as 29.3 fish per 500 square metres elsewhere (figure 45). Like in other sections, density of Wrasse tends to increase away from shore however the area of highest density, in the reef area to the east of Namaqumaqua, is close to shore. Lowest levels of Wrasse are recorded around Korotogo and Namaqumaqua villages and the outlying reef area to the east.

The highest density of Butterflyfish is again seen in the reef area east of Namaqumaqua, where density reached 23.3 fish per 500 square metres (figure 46). Density was also high between Navola and Namatakula. Elsewhere density was generally much lower..

Grouper density is below 3 fish per 500 square metres for most of the reef area east of Navola (figure 47). A peak density of 19.1 fish per 500 square metres is seen outside the Warwick hotel in the reef area between Komave and Vuniwai villages.

Parrotfish density varies significantly along the coast (figure 48). Peak density is again seen in the reef area east of Namaqumaqua where a density of 123.3 fish per 500 square metres reef area is seen. Elsewhere in the section density is generally between 0 and 50 fish per 500 square metres.

The number of Rabbitfish in section 3 is generally low (figure 49). The greatest density of fish occurs in the reef outside of the Somosomo channel, where density reaches 62.3 fish per 500 square metres. Densities of between 0 and 12 fish are however more typical.

Though a density of 24.3 Snapper per 500 square metres is seen on the eastern boundary, a density below 2 is more typical of the section (figure 50).

Surgeonfish are found at densities between 0 and 90 fish per 500 square metres reef area (figure 51). Again, the population is densest in the reef area east of

Namaqumaqua. A population density of between 0 and 30 is more typical of the section

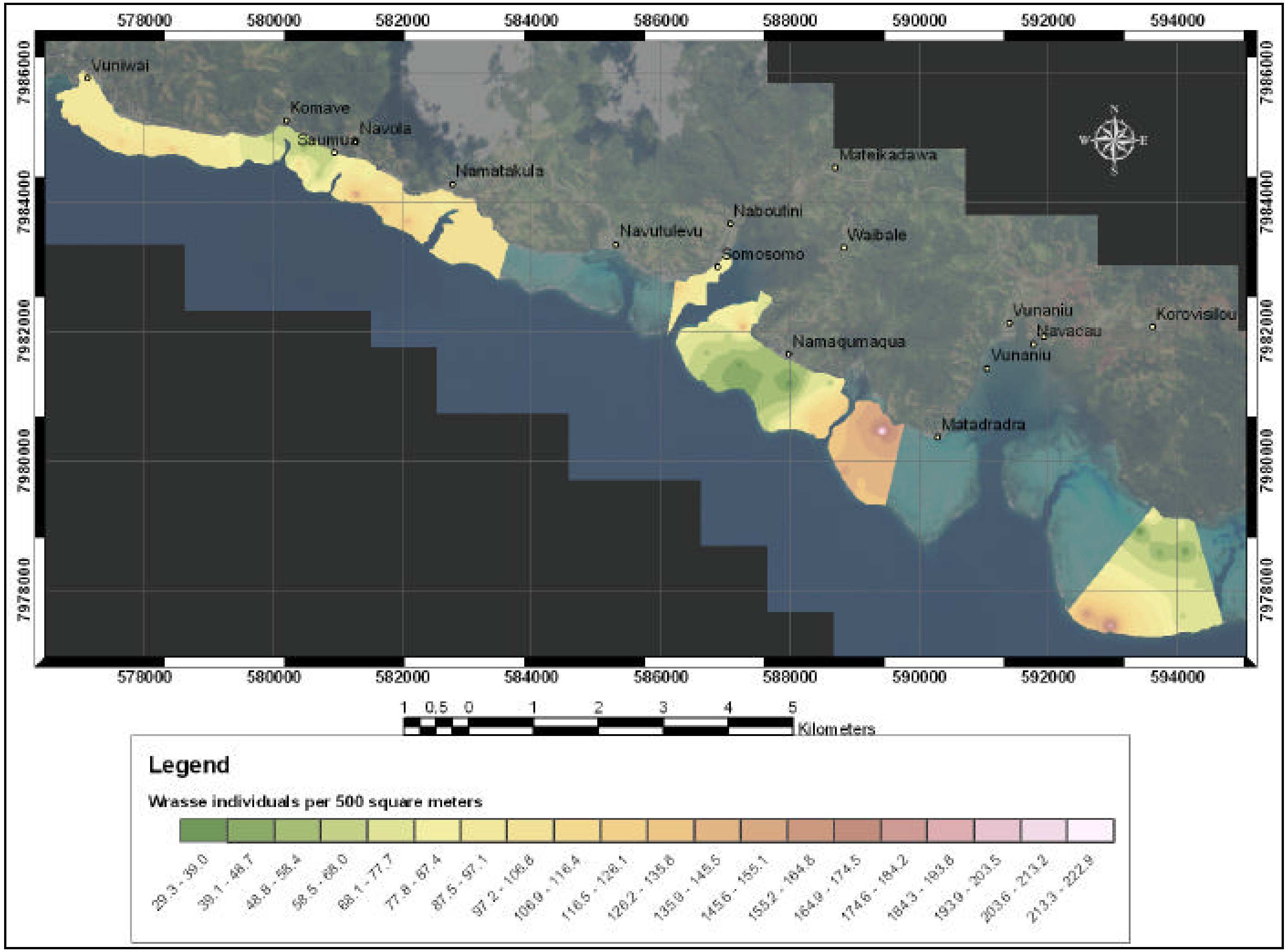

Figure 45. Density of Wrasse (*Labridae*) per 500 square metres reef area for Section 3.

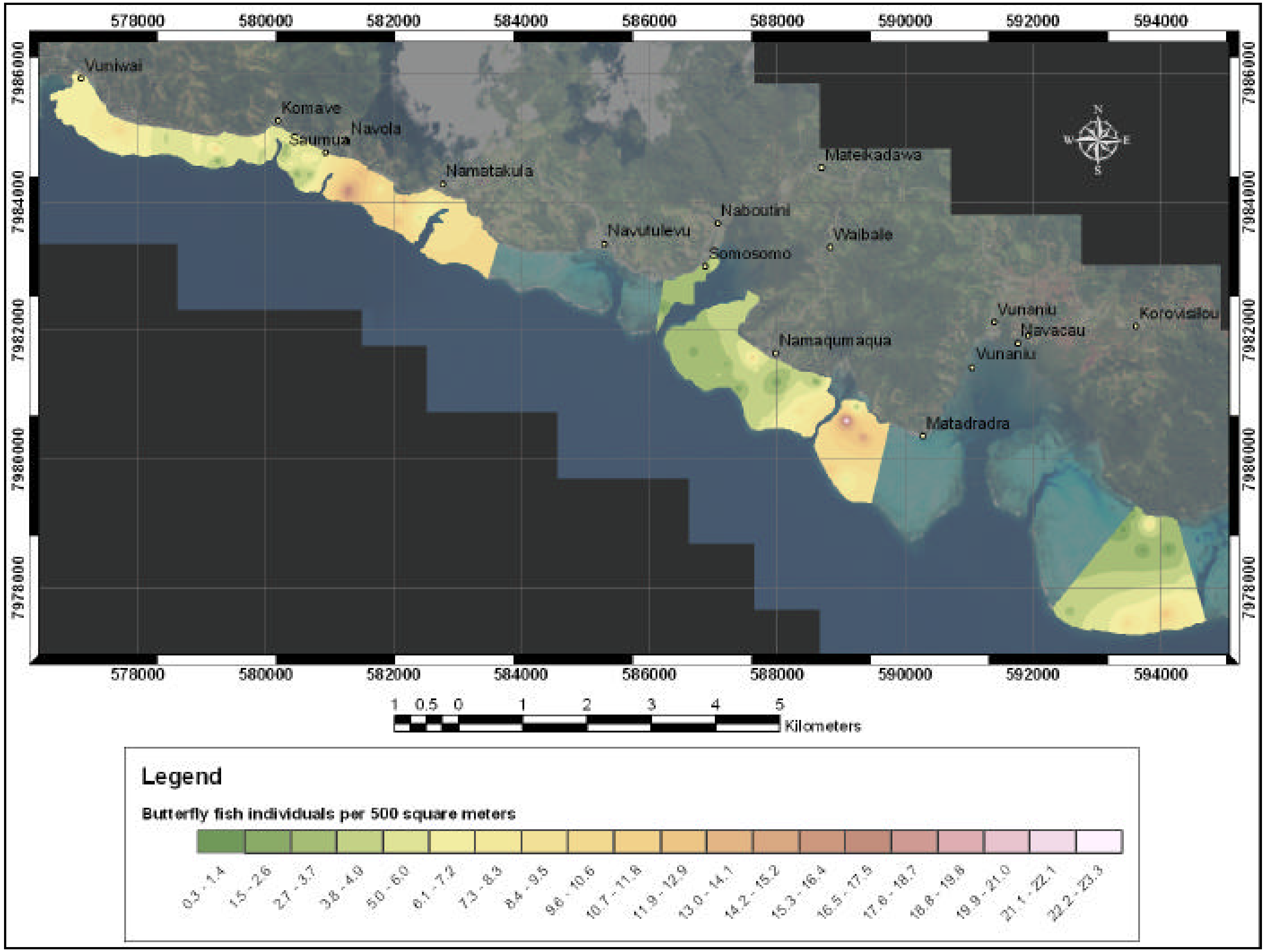

Figure 46. Density of Butterflyfish (*Chaetodontidae*) per 500 square metres reef area for Section 3.

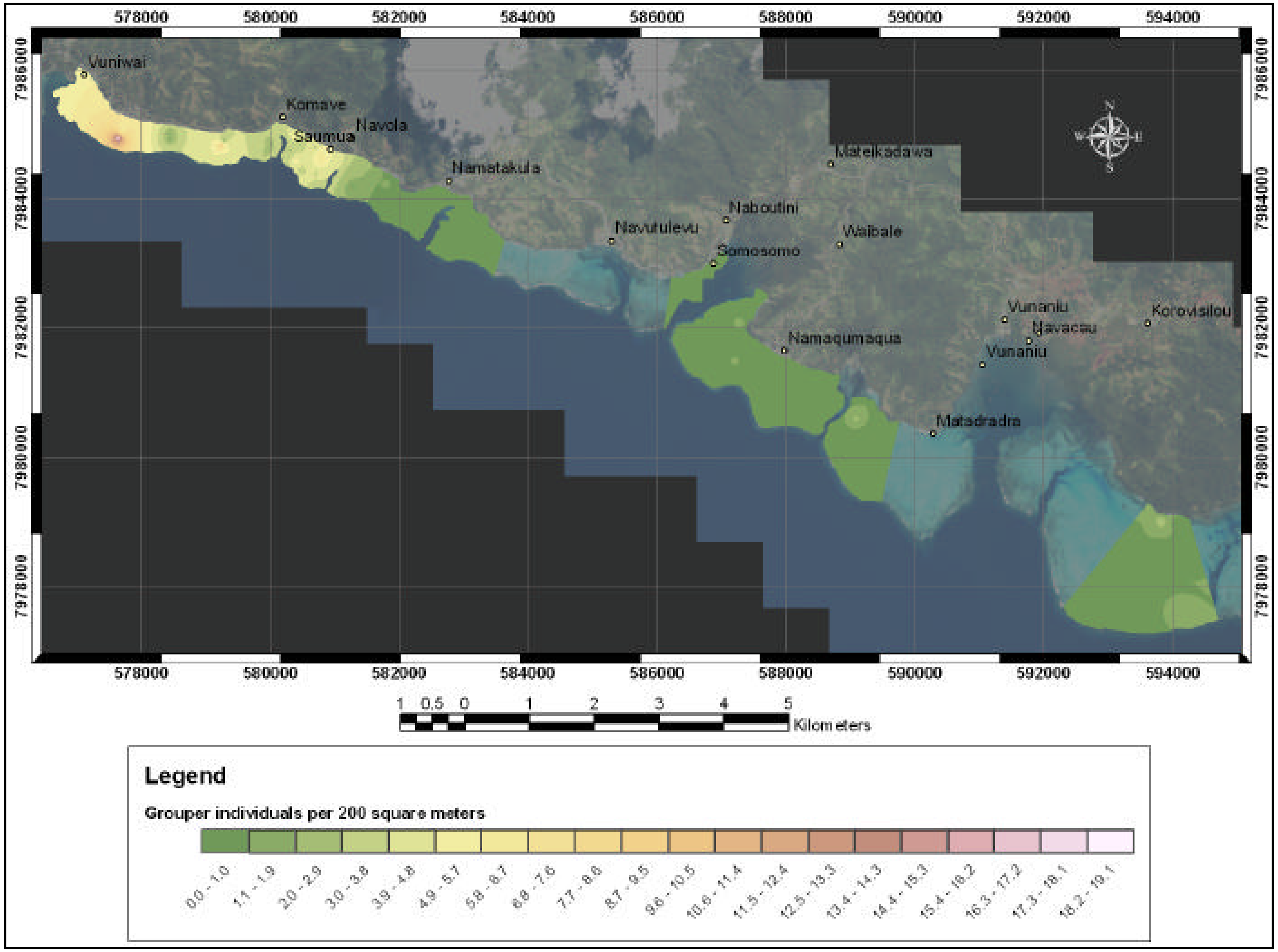

Figure 47. Density of Grouper (*Seranidae*) per 500 square metres reef area. for Section 3.

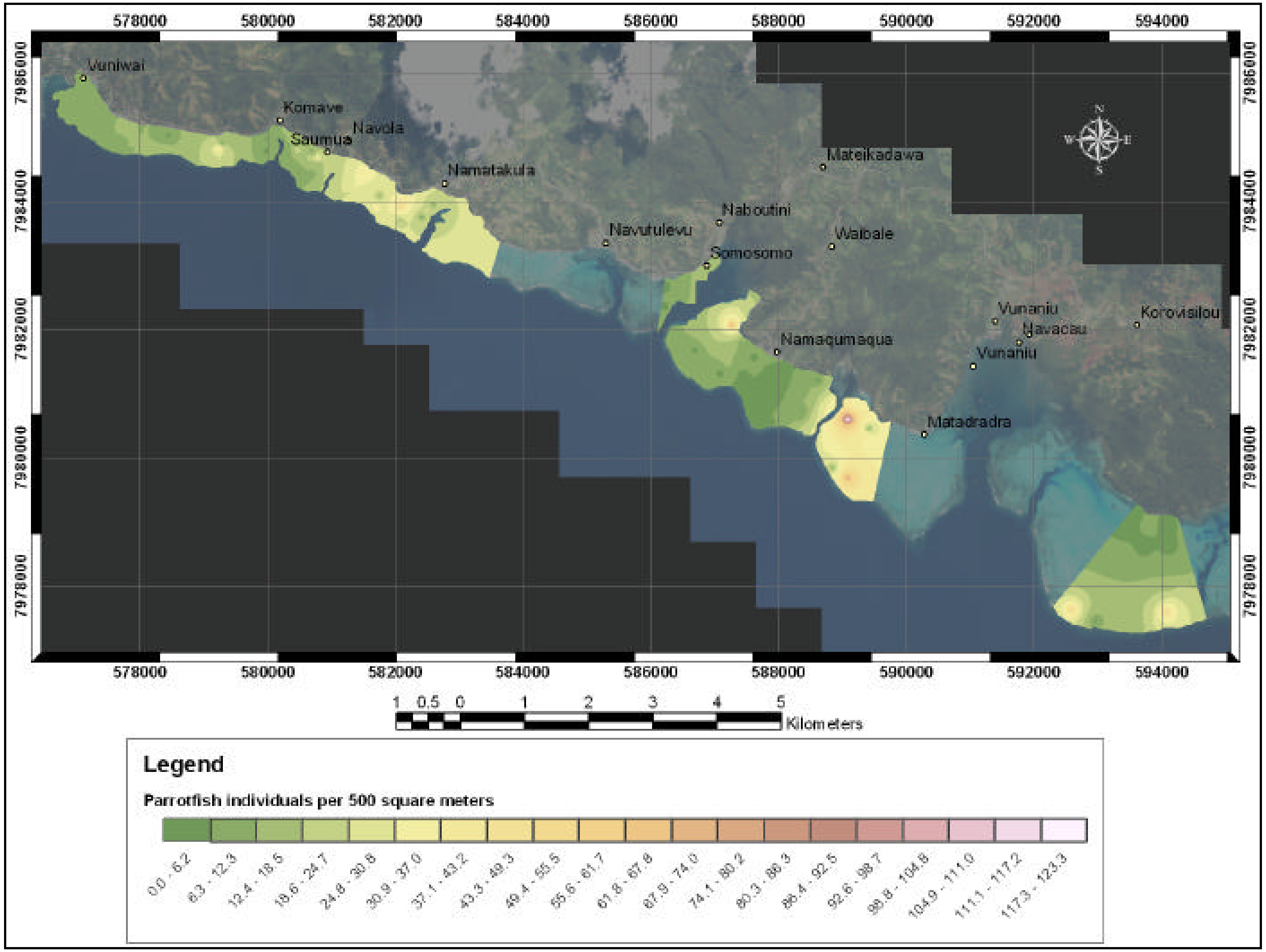

Figure 48. Density of Parrotfish (*Scaridae*) per 500 square metres reef area for Section 3.

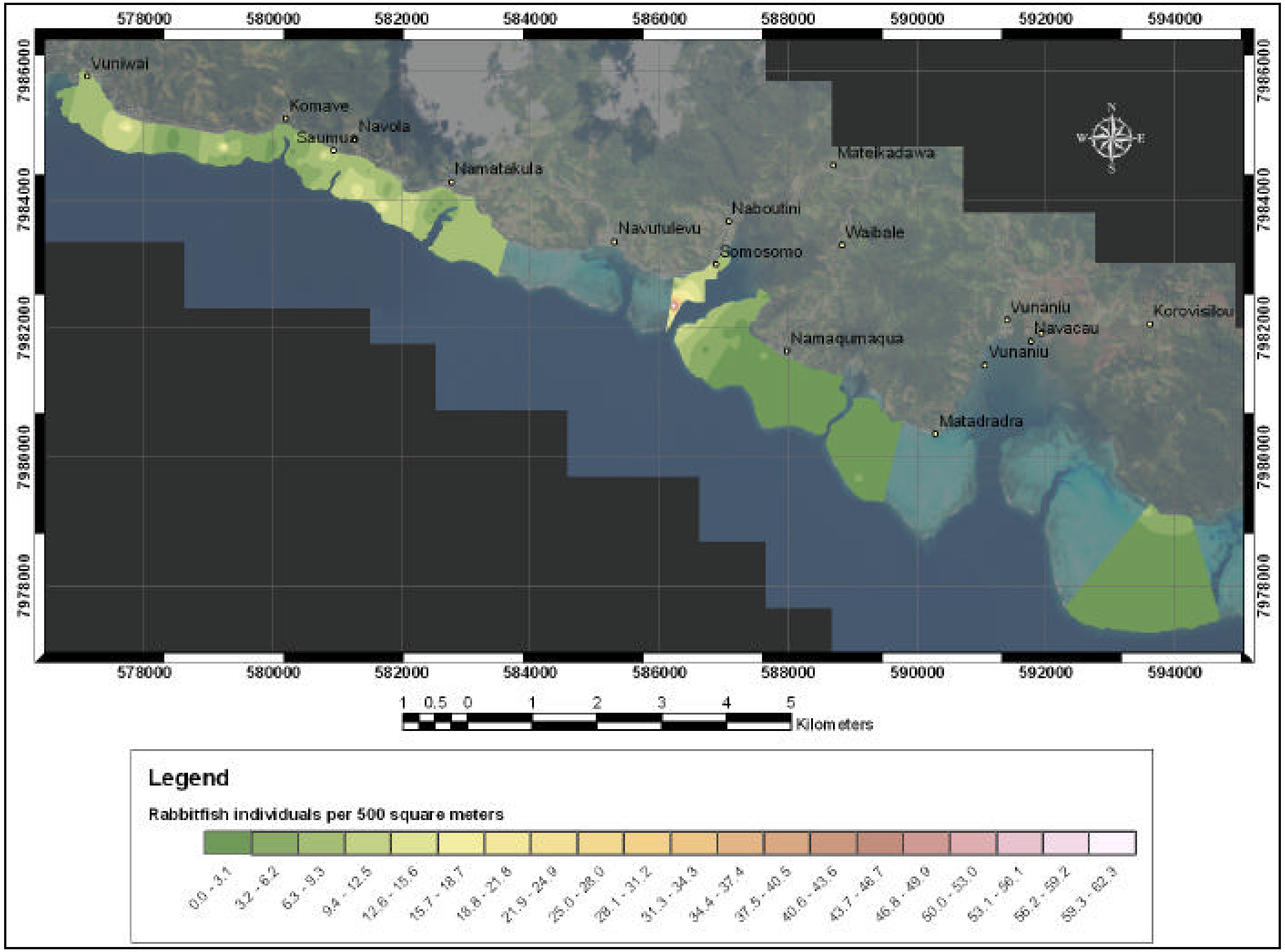

Figure 49. Density of Rabbitfish (*Siganidae*) per 500 square metres reef area for Section 3.

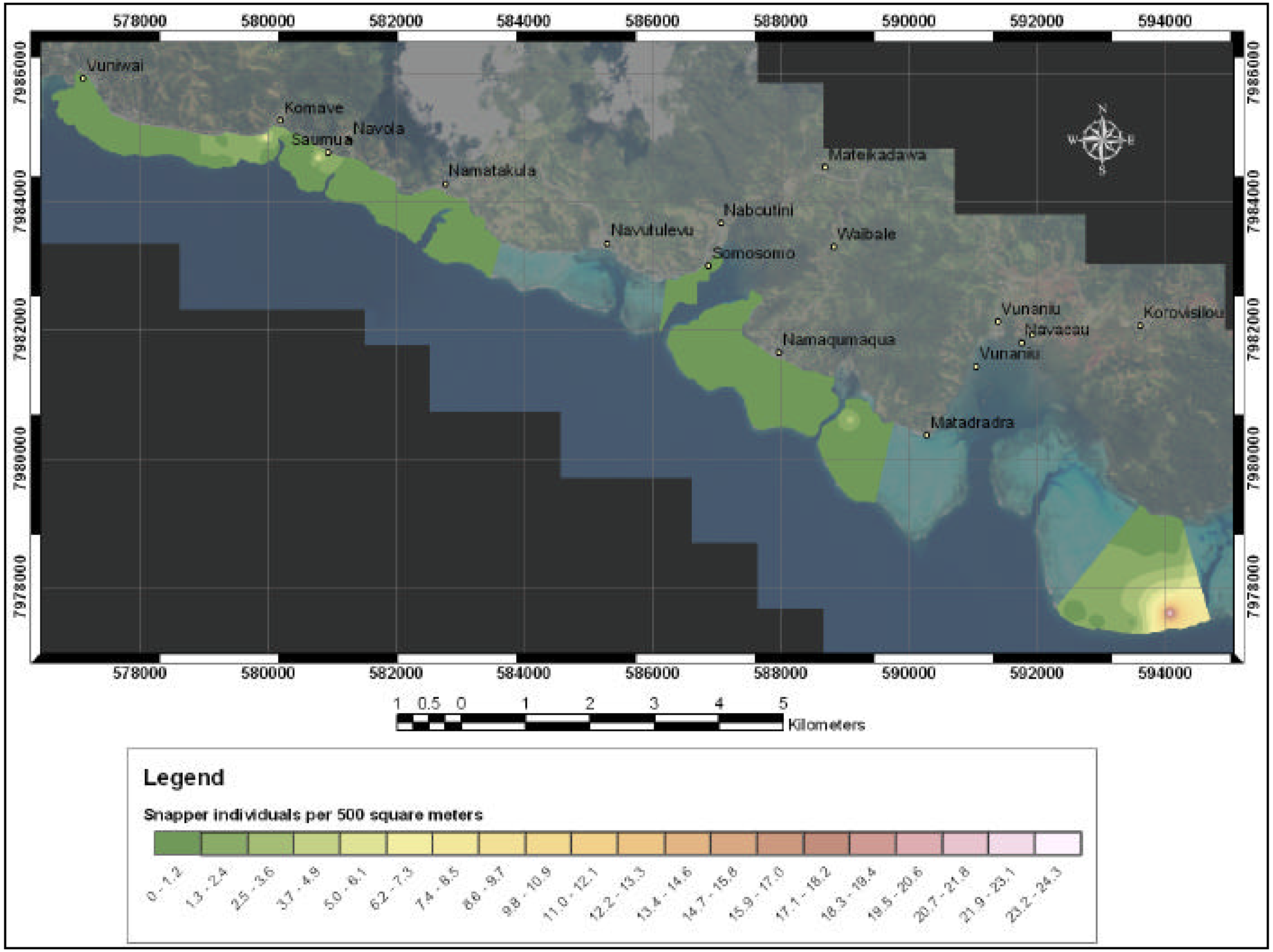

Figure 50. Density of Snapper (Lutjanidae) per 500 square metres reef area for Section 3.

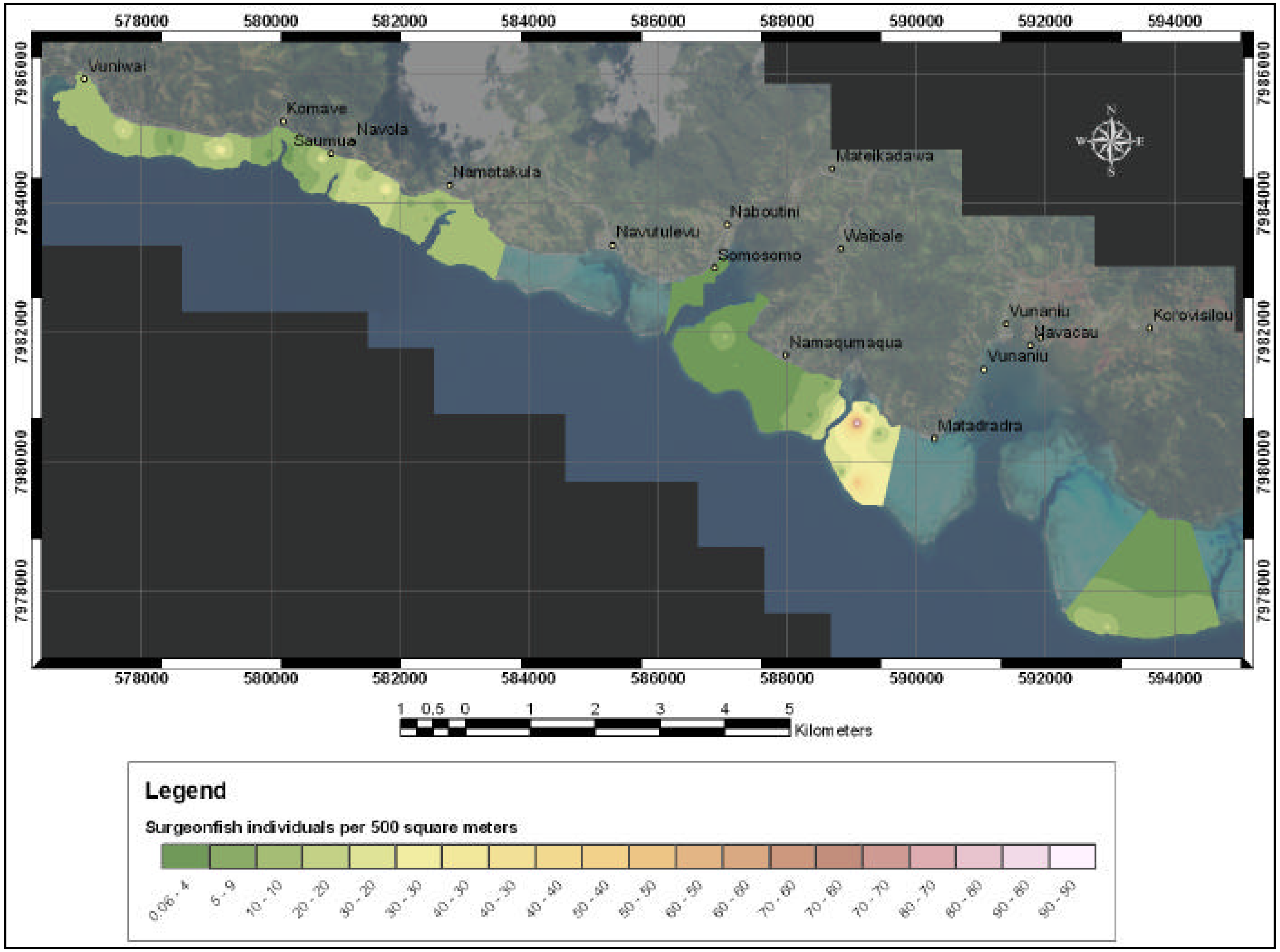

Figure 51. Density of Surgeonfish (*Acanthuridae*) per 500 square metres reef area for Section 3

Invertebrate data

Giant Clams are rare in the section, though they are seen in the reef areas east of Komave village and either side of Namqumaqua village (figure 52).

Crown of Thorns are also rare in the section (figure 53). They are noted only between Vuniwai and Komave and outside Namatakula villages.

There are very few Sea Cucumbers across the section (figure 53). A maximum density of 4.1 Sea Cucumber per 200 square metres is seen west of Namaqumaqua village, with relatively high density also seen west of Namatakula village. Density is generally higher in inner reef zones.

No Octopus are seen in the reef areas around Namaqumaqua. Elsewhere distribution is patchy with a maximum density of 1.6 individua;s per 200 square meters seen in the outlying reef area to the east (figure 55).

Numbers of Short Spined Sea Urchin are generally low across the section with densities below 3 urchins per 200 square metres across much of the section's area (figure 56). A peak density of 19 urchins per 200 square metres seen in the reef area between navola and Namatakula.

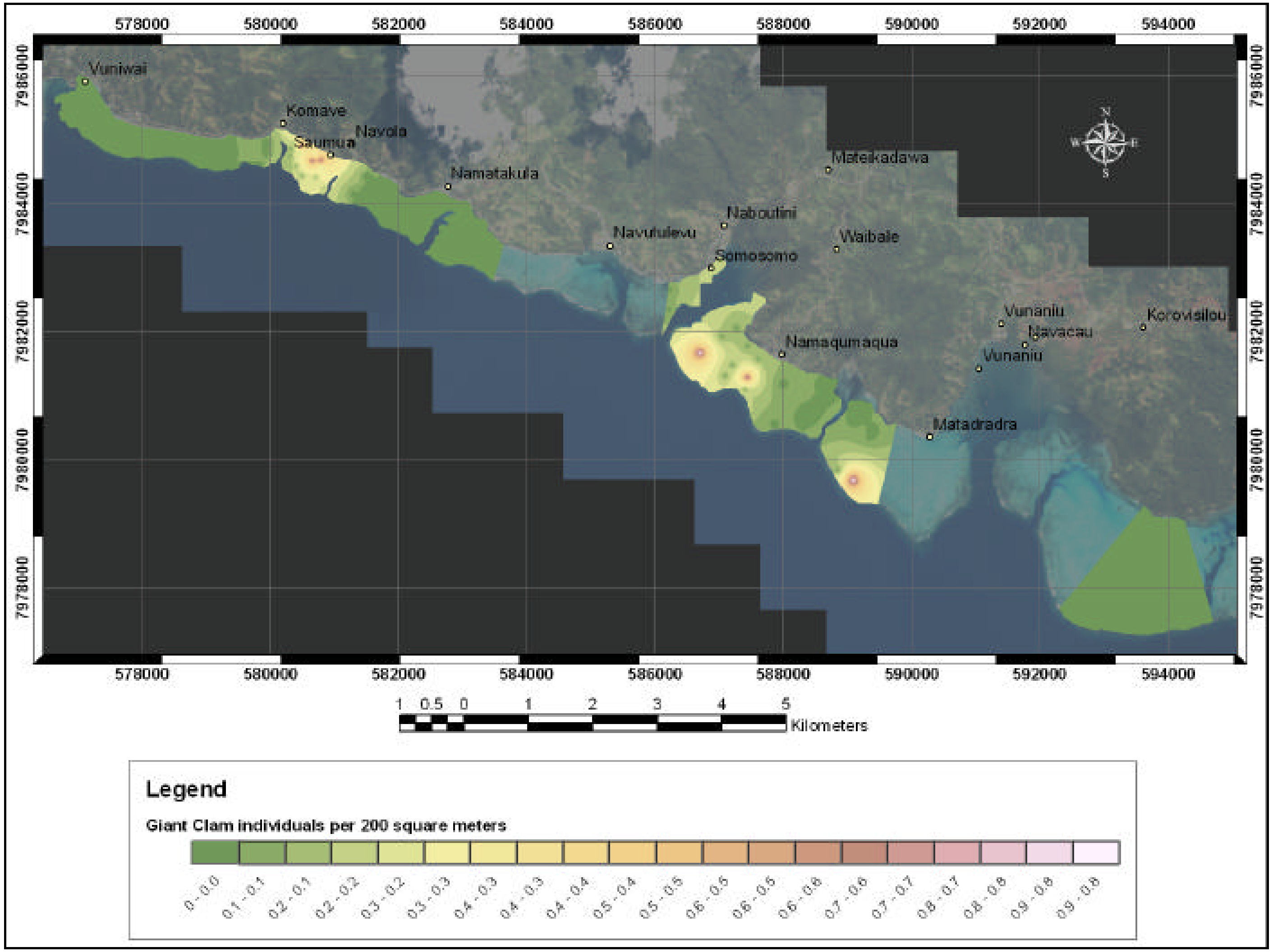

Figure 52. Density of Giant clams (*Tricadna sp*) per 200 square metres reef area for Section 3.

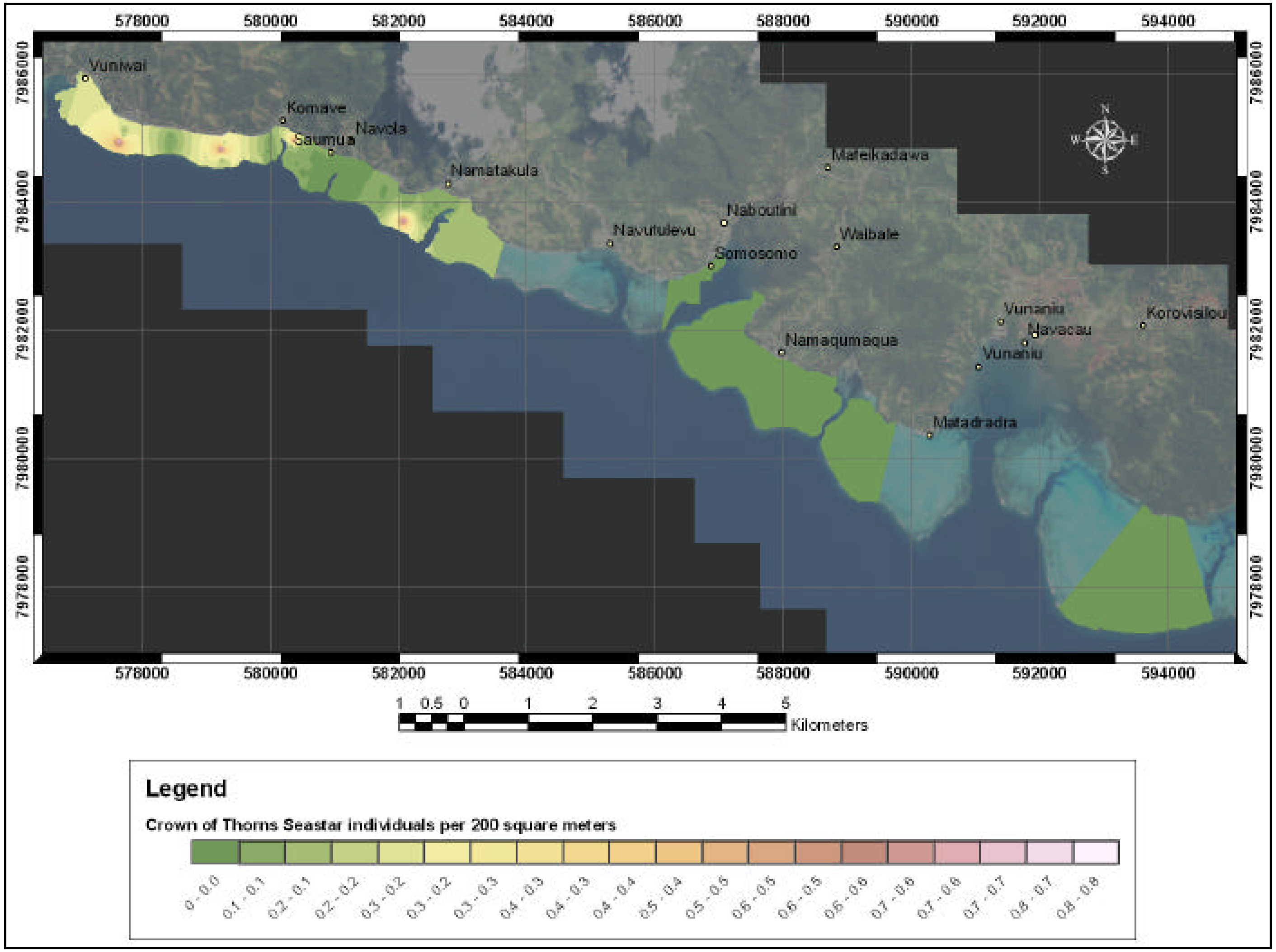

Figure 53. Density of Crown of Thorns (*Acanthaster Plancii*) per 200 square metres reef area for Section 3.

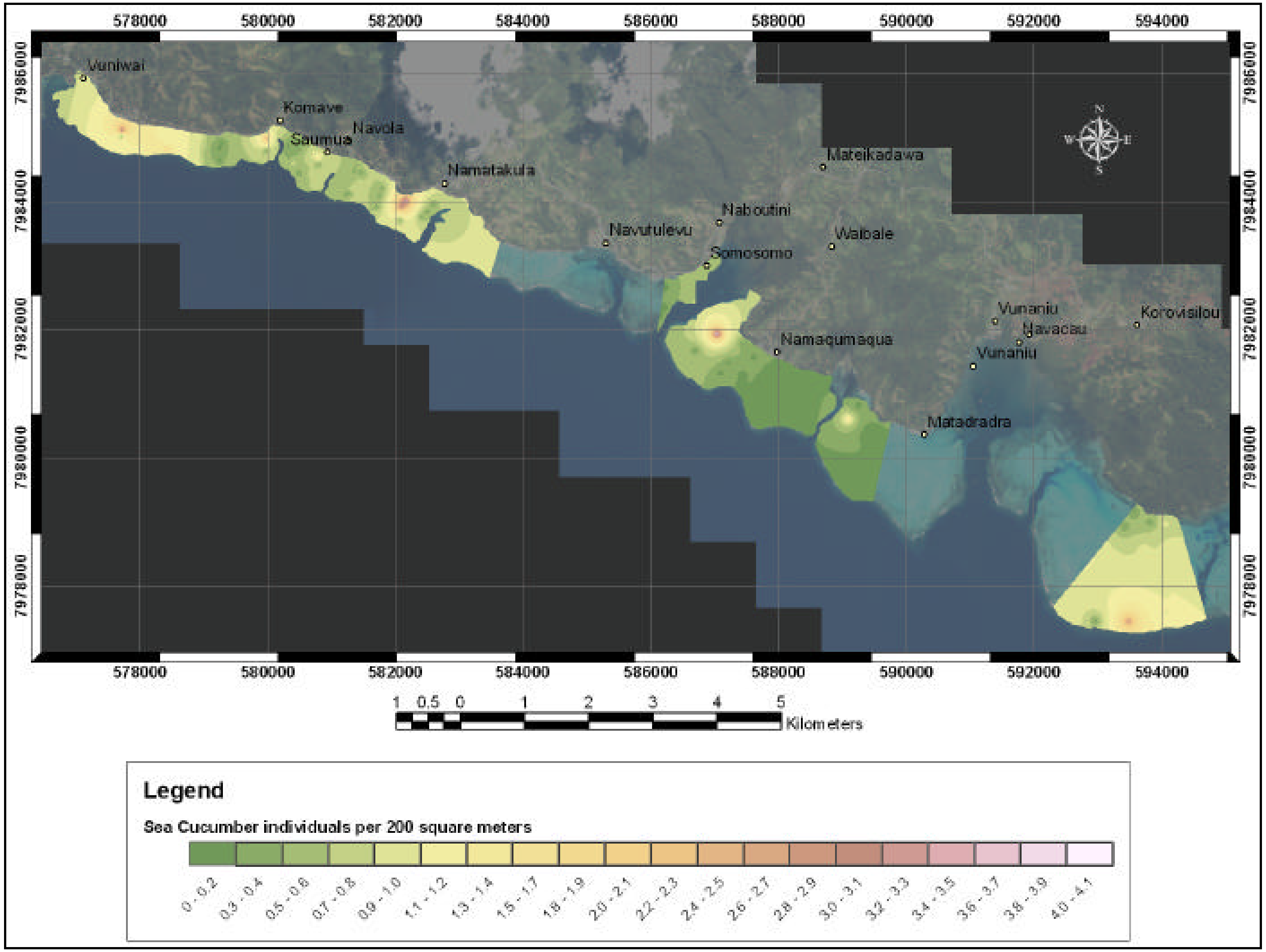

Figure 53. Density of Sea Cucumbers (*Holothuridae*) per 200 square metres reef area for Section 3.

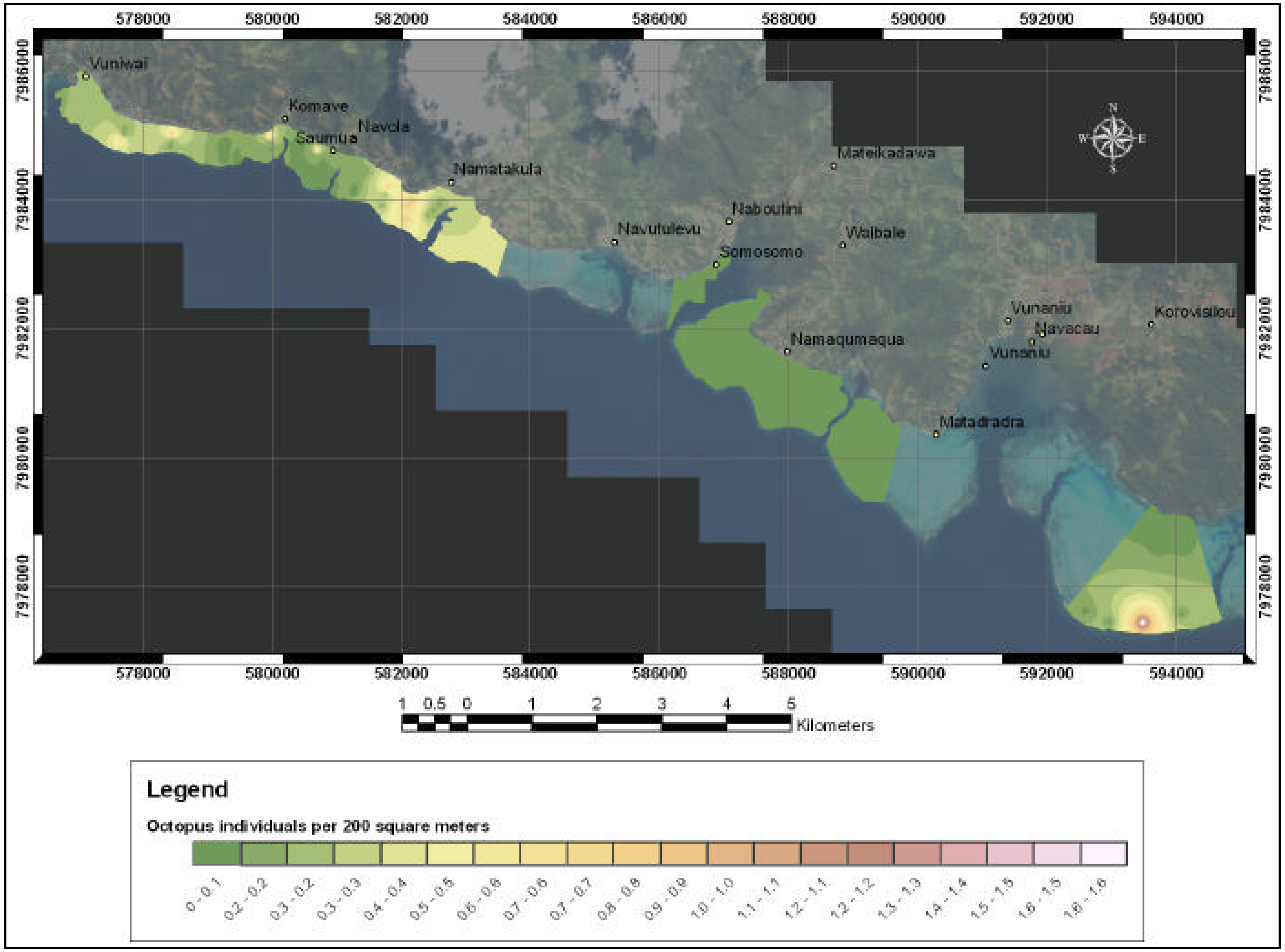

Figure 55. Density of *Octopus* per 200 square metres reef area for Section 3.

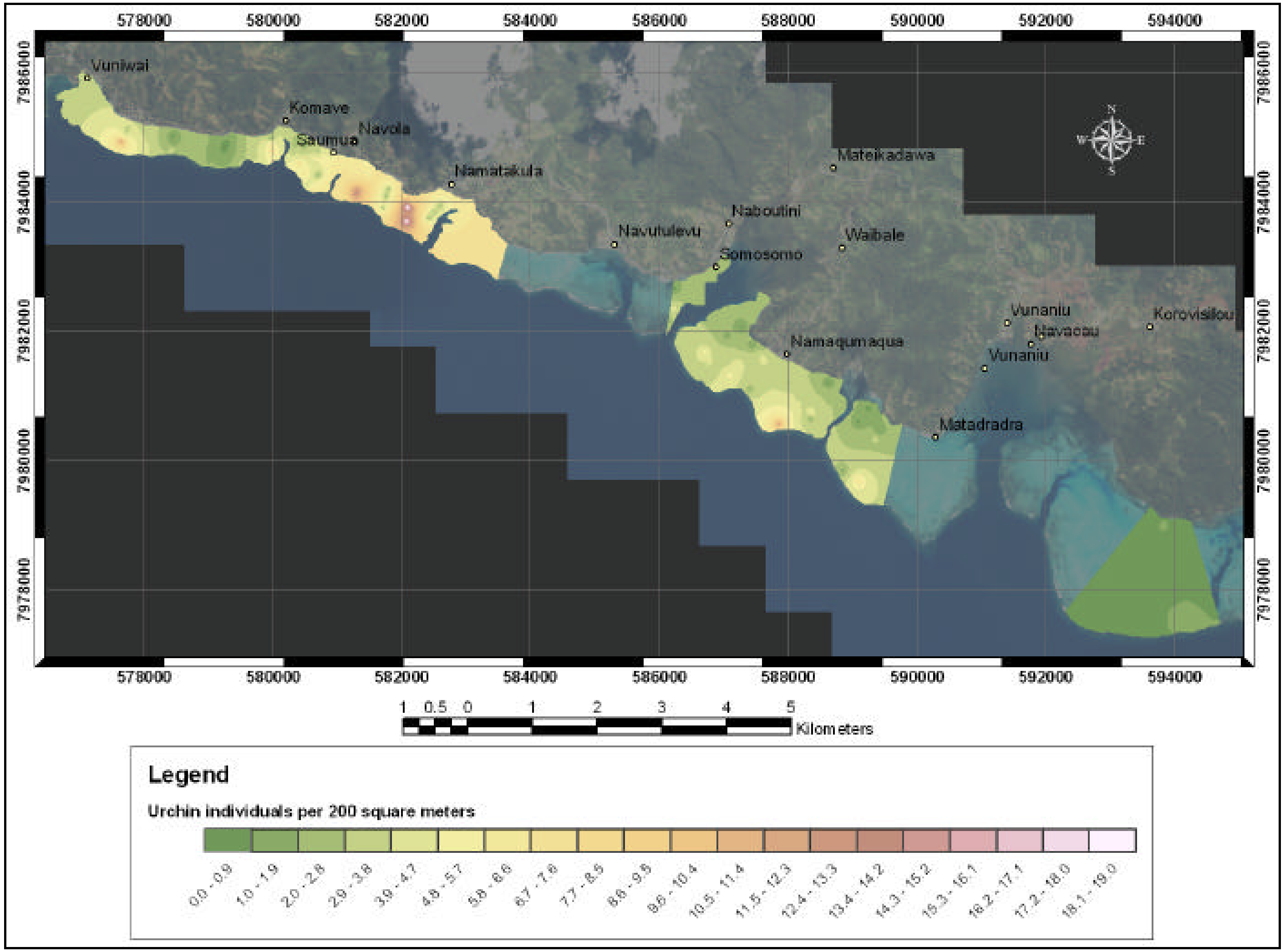

Figure 56. Density of Short Spined Urchin (*Tripneustes* sp) per 200 square metres reef area for Section 3.

6. Discussion

Species composition and abundance can be explained by interactions between species and substrate types as well by a series of anthropogenic influences.

6.1 Distribution and Abundance Interactions

As demonstrated by the contour maps in the results section, different substrates and species show marked differences in their distribution and abundance along the coral coast. Many of the distributions of fish, invertebrates, and the substrates themselves show close affiliation to one another.

As groups of primary producing organisms, coral and algae form the basis of most coral reef food webs. Though algal cover is generally high everywhere across the whole of the Coral Coast, the inverse relationship between algae and live coral cover is stark (figures 8, 9, 25, 26, 42, 43). This relationship is particularly apparent in the reef areas outside Sansana and Cuvu in section 1, around Malevu and east of Tagaqe and in section 2 and east of Namaqumaqua in section 3. Such a pattern is likely to reflect a difference in environmental conditions, most likely nutrient enrichment, and is discussed in detail in section 6.2 below.

The distribution of coral and algae ultimately depends on the provision of adequate substrate upon which to settle. There are many areas with high levels of exposed bedrock along the coast (figures 6, 24, 40). The high levels of bedrock in such regions can lead to two main conclusions; either the environmental conditions in such areas do not encourage algal or coral growth or, recruitment levels into the area are low. A comparison of benthic cover along the coast shows that high bedrock areas often correspond with areas of relatively high algal abundance and relatively low coral abundance. This can be seen in the reef areas discussed above. This pattern would suggest that algae are much better at colonising suitable substrate than coral.

It is apparent that Rubble tends to be more abundant in the outer reef zone and back from the margins of river channels and bays (figure 7, 24, 41). This pattern is to be expected as dead coral and rock is broken off from the reef crest and inner break zone and deposited in the relatively calm back reef region. The distance that rubble extends back over the back reef area is dependent on aspect relative to the prevailing wind (figure 4c) and wave conditions. Unlike bedrock, rubble does not provide a suitable stable substrate for coral and algal settlement.

Though bedrock and rubble may provide shelter for organisms, they do not contribute to energy flows between trophic levels without coral or algal settlement. An area of bedrock is more homogeneous with lower habitat complexity and lower available surface area than comparable areas of coral habitat (figure 57). This leads to a lower number of available niches for different species to exploit. An area dominated by bedrock as opposed to hard coral or algae will therefore have a lower carrying capacity and a less productive fishery. A comparison between the fish and invertebrate levels in areas of high bedrock cover but low coral cover such as the area around Namatakula (section 3) to areas with high coral cover such as the area east of Namaqumaqua clearly demonstrates this.

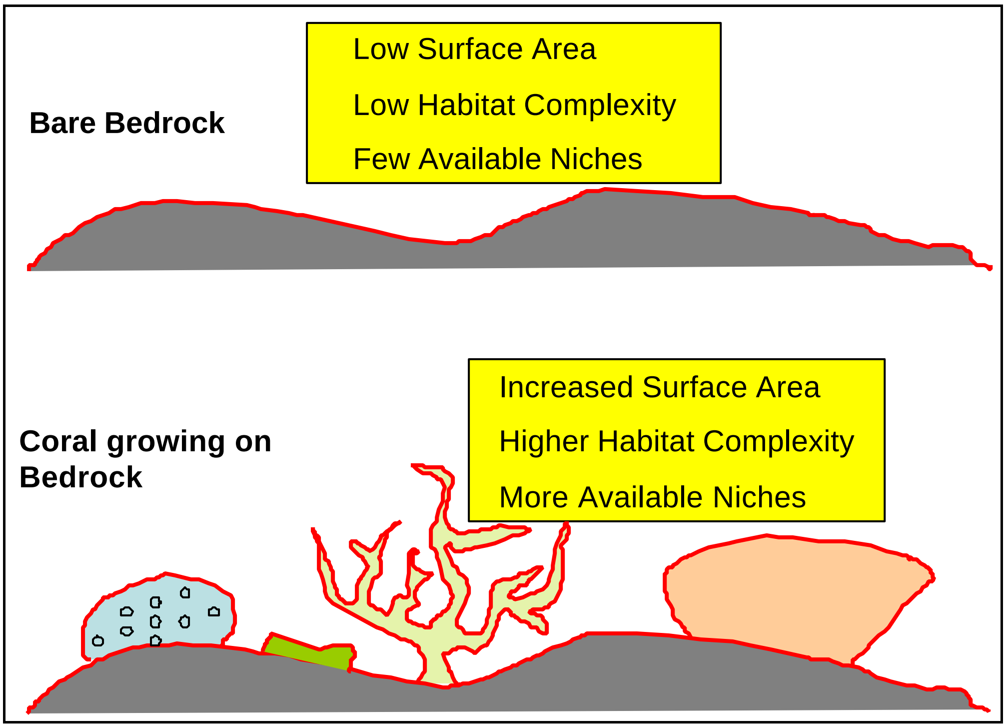

Figure 57. Simplified diagram showing affect of coral growth on surface area (red line) and thereby habitat complexity and niche availability as opposed to bare bedrock only

Though it makes up a small percentage of total reef cover, many fish and invertebrate groups show their highest abundance in or close to sections with a relatively high hard coral coverage. Live coral cover is therefore an important measure of ecosystem health. Not only does coral form the base of many food webs, but it also provides shelter for many reef organisms. Looking at figures 6 to 55 it is evident that the reef areas around Sanasana, Naidiri, Cuvu, Malevu, Taqage, Votualailai, and Namaqumaqua where coral cover is particularly dense support valuable fisheries.

A close association between Parrotfish and coral rich habitat is evident in many regions, such as around Sanasana and Cuvu in section one, Tagaqe-Nagasau, Votua laialai and east of Votua in section 2 and east of Namaqumaqua in section 3 (figures 14, 31 48). Such habitat would provide adequate coral as well as fine filamentous algae, which grows on coral rock and forms such an important part of the Parrotfish diet.

Surgeonfish are more generally distributed (figures 17, 34, 51). In addition to the above areas, the reef around Naidiri in section one, between Namada and Tagaqe in section two and the reef area west of Komave and near Navola in section three show densities of between 20 and 30 fish per 200 square metres. The majority of these areas correspond to areas of between 5 and 10% coral cover. The combined herbiverous/planctiverous diet may partly explain their more widespread distribution of this group. Surgeonfish are found at a high density of 69 fish per 200 square metres in an area dominated by rubble habitat in the outer reef zone outside of Tore (figures 7 and 17). Though observing Surgeonfish in such habitat appears rare elsewhere on the coast, this pattern of dominance over one area is common. Surgeonfish may form shoals to monopolise feeding opportunities, marginalising other herbivorous fish species in the process.

Wrasse are relatively abundant across most of the Coral Coast (figures 11, 28, 45). Food availability and diet may again be an important consideration. Most Wrasse are planktivorous or carnivorous, feeding on small invertebrates, parasites and other organisms. This may explain their more widespread distribution. Other fish which tend to feed either on larger prey, coral, or vegetable matter will therefore not compete directly with Wrasse for food. In recording numbers of fish it has not been possible to demonstrate the distribution of age classes. Though it is not clear from the evidence presented, juveniles account for a large proportion of Wrasse recorded. Given their size juvenile Wrasse may find shelter from predation in a variety of habitats including those dominated by algae as well as the outer surge habitat. Coral remains an important criterion for Wrasse distribution as many of the larger Wrasse of desirable size are seen within such regions. Larger fish must either seek shelter through shoaling behaviour, which is uncommon in Wrasse species, or through use of natural crevices and overhangs. This may restrict their range to coral rich habitat to a greater degree.

Predatory fish such as Grouper and Snapper prefer the greater protection and ambush potential of heterogeneous habitat, and are often slightly more common in coral rich areas than the surrounding reef area (figures 13,. 30, 47 and 16, 33, 50). Snapper and Grouper are however highly targeted by local fishermen. As such their abundance and distribution also appear to be dependent on local fisheries management.

Though many species may be associated with coral rich habitat, there are a few exceptions. Rabbitfish often appear at their highest densities in regions of highest algal, particularly *Sargassum*, cover. Given the scale of maps provided it is difficult to see in many areas however it can clearly seen in the reef area east of Nodaulau in section one and on the western edge of the Sovi river channel in section 3 (figures 15, 49). A degree of competitive exclusion may be occurring. Surgeonfish as described above may exclude competitive groups through shoaling activity. Whether this is indeed happening is difficult to discern, however an inverse relationship in the distribution of Rabbitfish and Surgeonfish is apparent in many areas.

Sea Urchins are abundant on the reef areas east of Nodaulau and Yadua in section one, outside of Korotogo and Votua in section two and Namatakula in section 3. In some of these areas such distribution may be connected to bedrock distribution as Sea Urchins are known to feed on the fine filamentous alga that grows on such substrate. Octopus distribution is very patchy. The highest density of Octopus on the coast is seen in the reef area west of Votua. Suitable habitat in the form of high rubble coverage may go some way to explain the high density in this region however elsewhere fishery management is likely to be more influential (see section 6.2.8 below).

As a rule, the iqoliqoli consists of algal dominated rather than coral dominated reef platform. Coral and algae, like other organisms, will grow better under different conditions. In the clear, nutrient poor waters of the tropics, coral tends to dominate suitable substrate unless these conditions are perturbed. The data therefore suggests external influences on the environment. Algae might be expected to dominate the outer surge zone, where other environmental variables such as high levels of surge and wave impact, combined with low water level may restrict coral growth. The abundance of algae over the majority of the Coral Coast is a concern.

Certain biotic variables may provide useful indicators of coral reef health. As a group, Butterflyfish depend heavily on coral as a food source. The distribution of Butterflyfish may be used to assess coral cover. The distribution of Butterflyfish agrees with the general distribution of coral along the coast (figures 12, 29, 46 and 7, 25, 42). Slight differences in distribution may be the result of different sampling techniques (see section 4). This provides an indication that coral cover occurs in small, rather than large, patches across the survey area.

Crown of Thorns, another known coralivore, again indicates such a pattern. If Crown of Thorn starfish density exceeds a critical threshold then population will begin to consume coral faster than it can grow and is considered an outbreak population. This critical density is unclear and likely to vary depending on reef type, as well as a number of other natural and anthropogenic variables. Research on the Great Barrier reef in Australia, has suggested that an outbreak may be triggered at Crown of Thorns populations of around 30 mature crown-of-thorns starfish per hectare of coral reef that has average levels of coral cover (GBMPA, 2005). For comparison, this works out as 0.6 starfish per 200 square metres. In a Malaysian marine park, a population density in the order of 6 starfish per square kilometre was found following an outbreak (Rahman and Ibrahim, 1996). This translates to a comparable density of 1.2 starfish per 200 square metres. The levels of Crown of Thorns across the Coral Coast as a whole is low, however at certain sites such as off Sanasana and Tagaqe where a density of 3.0 and 5.2 starfish per 200 square metres are seen respectively this level is vastly exceeded. It is difficult to draw meaningful conclusions in comparing data derived from the sparse coral cover of the Coral Coast with that derived for a 'hectare' or 'square kilometer' of coral reef with differing levels of coral cover. Study of the outer reef systems might be helpful in confirming how widespread the Crown of Thorns population is. Crown of Thorns may be reducing the ability of the back reef system to cope and recover from other natural and anthropogenic impacts and therefore certainly warrants monitoring and is a potential management concern.

6.2 Anthropogenic Impacts

Though not analysed directly during this study, the anthropogenic influences of nutrient enrichment, sedimentation, fishing, harvest for aquarium trade, as well as recreational use have been highlighted in the Coral Coast region (IAS[1], 2002)..

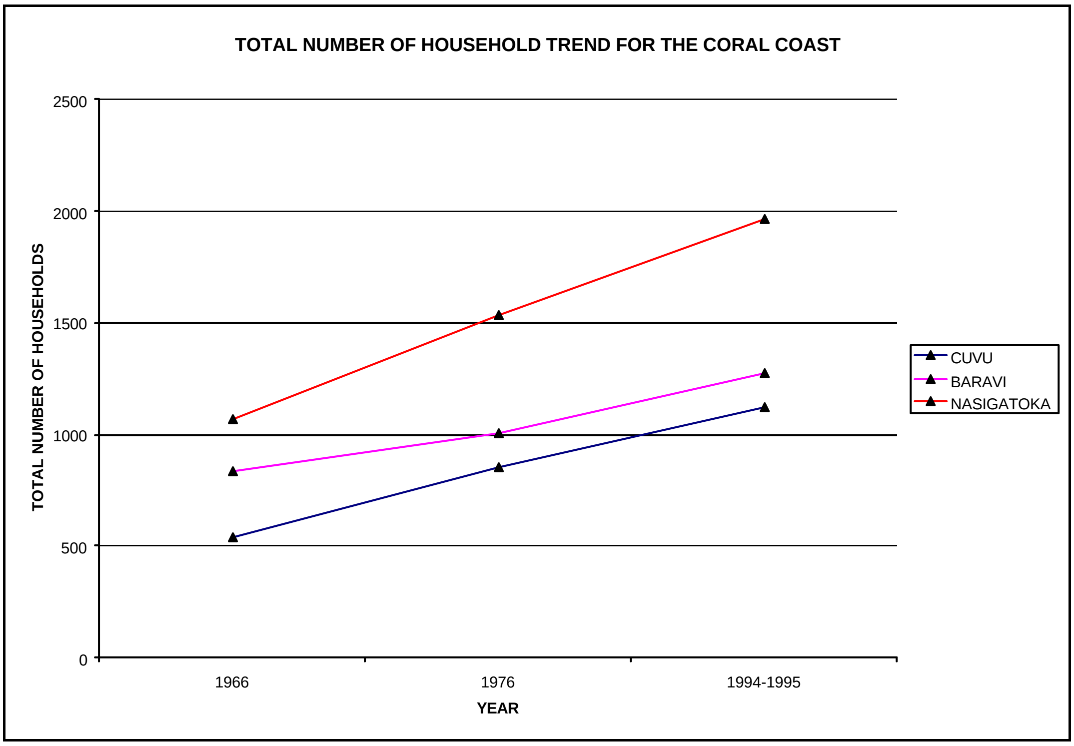

Figure 58. Graph showing trend in number of households for three legislative districts that make up the Coral Coast region. The iqoliqoli is contained within Cuvu district. (Institute of Applied Sciences-University of the South Pacific, Unpublished data).

Table 8. Population figures for some villages and towns in the Coral Coast region (Source: 1996 Census data)

District/ Tikina	Village/Town	Population
Cuvu	Yadua	336
	Rukurukulevu	249
	Sila	73
	Tore	106
	Naevuevu	324
	Cuvu	560
	Hanahana	89
Nasigatoka	Sigatoka	7862
Conua	Korotogo	380
	Malsevu	203
	Vatukarasa	450
Korolevu i Wai	Votua	260
	Votualailai	154
	Tagaqe	260
	Namada	300
Komave	Komave	200
	Navola	100
	Vucilevu	158
	Namatakula	300

Anthropogenic impacts relate directly to the population pressure in an environment. The current and trends in population levels for the Coral Coast region are highlighted in figure 24 and table 8. Between 1966 and 1995 the number of households increased steadily in all districts. It is likely that a similar pattern is true of the Serua and Malomalo Districts

Population pressure is not restricted to local villages and towns. The tourist industry of Fiji has shown a high level of growth over the same period, much of which has been concentrated on the Coral Coast. Current and future development plans in the district and surrounding region make this a very real concern.

6.2.1 Nutrient Enrichment

Nutrient enrichment leads to an increase in levels of algae and may result in a shift from coral to algae dominated reef (McCook, 1999). Algal dominated reefs have been noted to have lower fish stocks, less tourism appeal and lower levels of biodiversity. The main sources of these nutrients are human and animal waste, fertiliser, and detergent use. Algae is the dominant biotic benthic cover variable in the iqoliqoli (table 2, figure 9). This supports the view that some nutrient enrichment occurs. Low Nitrate (NO_3^-) and Phosphate (PO_4^{3-}) levels are usually the limiting factor of algal growth in tropical systems. Measures of nutrient levels are not available for the whole Coral Coast however a study of nutrients in Korolevuiwai in 2002, showed that levels of Nitrates and Phosphates outside Hideaway resort, Votua village and around river channels were above levels shown to support coral growth and therefore lead to algal growth (Mosley and Aalbersberg, 2002). The main sources of nitrate in the area have been identified as villages, pig waste and hotel wastewater in corresponding order (Thaman et al, 2005). Use of pit toilets and poor septic systems in many village communities results in nutrients leaching into the coastal system. Additionally the positioning of pigpens over and around rivers and coastal fronts leads to the direct transfer of nutrient rich effluent. Though many tourist establishments have made concerted efforts to improve their systems, some tourism businesses are still using inadequate treatment plants. The area may suffer nutrient input through inland agricultural practice. Sugar cane farming in particular is a major industry in the west of the Coral Coast region. While the Fijian sugarcane industry may not be as chemically intensive as elsewhere in the world, some chemical input does occur as well as the threat posed by siltation (see section 8.2.2).

The presence of high levels of nutrients reported above supports the findings of algal dominated reef platform reported here. Looking at section two it can be seen that there is high algae cover over the reef areas around Korotogo, Vatukarasa, Namada, Tagaqe, Votualailai and Votua villages. It is clear that much of this algal cover is concentrated around river channels, however closer inspection of algae and *Sargassum* distribution in particular does highlight small hotspots of cover on inner reef zones of Namada, and Tagaqe villages. While total algae cover remains high in all regions, there is no clear concentration of algae immediately outside of every potential nutrient source. This may be the result of a number of different natural and management scenarios.

In some cases, this may be explained by the accumulation of sand in the low energy conditions found close to shore. For example the cumulative cover of the benthic variables visually expressed in figures 5-8 does not account for the benthic cover in front of Cuvu. We can see from table 5 that 11.51% of the benthic cover of this reef area (iqoliqoli 8) is comprised of sand. A sandy habitat is transient in nature. As such, sand may periodically or permanently smother coral, algae, and bedrock substrate rendering such areas unsuitable for colonisation regardless of prevailing nutrient conditions.

One problem in determining the effects of nutrient elevation lies with a lack of oceanographic understanding. Without a detailed study of local currents, it is difficult to be clear of what the ultimate destination of these nutrients is. Nutrients sourced from within the iqoliqoli may be transported elsewhere while at the same time the iqoliqoli may be suffering from external nutrient input. The dominance of algae across the iqoliqoli may reflect runoff from agriculture and small settlements along this stretch of coastline as well as nutrients sourced from further a field. The significant concentration of algae around the margins of river channels and bays as well as the outer reef zone may be a reflection of a volume of nutrients entering the system by this route. The strong currents experienced in different regions of the reef platform mean that nutrients may be concentrated in unexpected places where eddies occur as opposed to near to obvious nutrient sources. Generally higher levels are seen in the western region that may be a reflection of the prevailing south-westerly wind as well as off shore currents.

As discussed in section 6.1, there tends to be very little exposed bedrock recorded in regions of high algal cover, suggesting that most available sites algal settlement are capitalised upon. Areas where high coral cover is seen tend to have higher bedrock levels. It is a concern that levels of coral recruitment may be too low and that coral levels are lower than their maximum potential in these areas. While the high level of coral in such areas is reassuring, algal cover predominates. Figure 59 highlights how a reef may experience a shift in prevalence of coral and algae under elevated nutrient conditions. If an area experiences regular disturbance, given that high levels of algae are already present in the region, this trend may continue. The importance of high coral cover habitat in sustaining rich fisheries has been highlighted above. Creating the conditions that tend towards coral reef establishment over algal settlement should therefore be a high priority in the management of local fisheries.

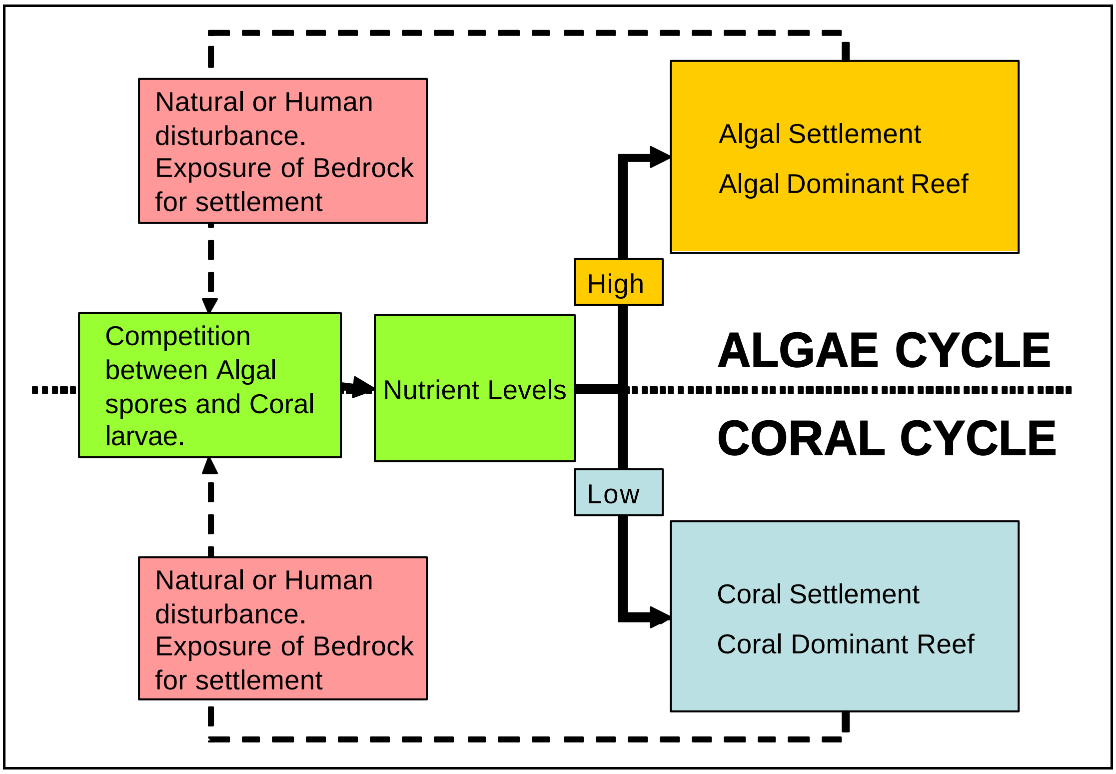

Figure 59. Influence of Nutrient levels on Coral and Algae reef development.

Though the causal link between nutrients and algal overgrowth of corals is well established, it is important to note that other factors may also be important. The abundance of herbivores in the system to graze the algae may affect reef composition (McClanahan, 1997; McCook, 1999). Phase shift from algae to coral reef may also occur if herbivorous species are overfished or in low numbers due to habitat degradation. Maintaining stocks of herbivorous groups such as Rabbitfish, Surgeonfish, Parrotfish and Sea Urchins is critical in this regard.

6.2.2 Sedimentation

Sediment brings further nutrients into the system. It may smother coral and lead to a build up of sand and mud based communities. Sediment covers feeding appendages and blocks sunlight from reaching the photosynthetic Zooxanthellae that live symbiotically within coral. Potential causes of sedimentation may include deforestation, agricultural clearance, coastal engineering and development. Removal of vegetation removes the root structure that binds the soil, preventing it from washing away when rains come. Loose soil will wash downstream with the rain and into the coastal system if natural sediment-traps such as the mangroves and seagrass beds have also been removed or damaged

Past and present sedimentation may have a significant impact on local reef communities. Heavy coastal erosion, associated with the removal of mangroves, is highlighted above and much of the same theory behind the concentration and pooling of nutrients applies to sediments. Though no specific tests of sedimentation levels were carried out in the course of this study, mud intermingled with sand as well as seagrass habitat was noted in some areas, particularly around Korotogo river mouth in section 2. The importance of seagrass habitat in encouraging the settlement of sediment should not be underestimated. Information gathered from the indigenous population suggests that sedimentation may have been a problem in the past, filling in the reef area west of Votua village. This purportedly has resulted in the filling in of deep-water channels and led to a simultaneous reduction in coral cover and fish abundance with comparatively uniform rubble substrate (figure 7). Further social and scientific study would be required to support this view however it does support the combination of variables seen here.

Generally, there was little evidence of sediments in the water or over the reef platform with visibility of between 10 and 15 metres recorded on most days (figure 4b). Given the high currents noted, it is likely that sediment is carried quickly off the back reef system and settles in river channels or over the outer reef system. Fluctuations in visibility however probably reflect increases in sediment load particularly following heavy rainfall. Through impacts to outer reef areas, sedimentation may reduce levels of recruitment into the backreef system. This in turn would reduce the likelihood of reversion back to coral reef platform in the future. Few studies have been carried out into either the effects of sedimentation, general reef health or recruitment to and from the reef area behind the break zone. Further studies would be desirable to this end. Sedimentation remains a priority for management; the potential impacts of sediment in areas peripheral to river mouths should not be ignored. Potentially damaging activities must be carefully considered and mitigated.

6.2.3 Fishing pressure

Fishing provides a vital source of food, sustaining local communities. Evidence sourced from the local community over the course of this study supports that documented elsewhere (Adams 1998; Hunt, 1999; IAS[1], 2002; Jennings and Polunin, 1995). The majority of fishing pressure along the Coral Coast is concentrated on the back reef platform, with each village or settlement concentrating its fishing effort on the reef area directly in front. Very little fish is exported from each village, but rather shared or sold between families and the village community. Opinion is divided as to how today's fishing compares with previous decades though there is a general acceptance that fishing has probably become harder, with a decline in the number and size of fish. A more in depth socioeconomic survey would be required to substantiate this. Fishing pressure must be considered a potential impact on the reef system. The higher abundance of herbivorous fish such as Surgeonfish, Parrotfish, and Rabbitfish as opposed to carnivorous fish like Grouper and Snapper may indicate the presence of over fishing. This supports the findings of Jennings and Polunin (1995[2]) who found that areas that were fished heavily tend to show greater proportions of herbivorous species as opposed to carnivorous species. Concentration of fishing pressure on herbivorous species may also contribute to an increase in algal cover as discussed in section 6.2.1. Though many people from the villages of the iqoliqoli work in outside business, many people are reliant on supplies grown or sourced locally rather than from Sigatoka town. This may exert a greater fishing pressure on the local system.

Fishing methods employed on the Coral Coast are similar to those witnessed in other subsistence and artisanal fisheries (Hunt, 1999). One of the most common fishing methods recorded in the Coral Coast involves using mask and snorkel to spear fish. The use of hand lines is also common. Spear fishing, particularly at night targets large individuals of certain species. As already discussed, the targeting of particular age classes has the potential to influence the dynamics of whole populations.

At low tide, gleaning takes place whereby people (usually women) walk out onto the reef platform in search of invertebrates such as Octopus, shellfish, edible Sea Cucumbers and Urchins. Over 50% of the subsistence catch on Viti Levu is taken by women, who are generally fishing from the shore for family consumption (Adams 1998). The widespread adoption of gleaning practices may explain the overall low numbers of all invertebrates recorded. Management of this mode of fishing is therefore potentially very important. In Yadua a small scale Beche de Mere (Sea Cucumber) fishery was reported. This region does have higher than average populations of sea cucumbers suggesting that a small-scale industry may be viable however like all fisheries it will be vulnerable to collapse if over exploited.

The targeting of young and juvenile fish is a concern for the Coral Coast. Though some fishermen reported net sizes of $3^1/_2$ inch gauge it is not clear if this is the exception or the rule. Minimum net size currently designated by Ministry of Fisheries stands at $3^1/_2$ inch and $1^1/_2$ inch (Garfish fishery only). Though the Ministry of Fisheries does publish minimum catch sizes, it is unclear to what level the size of fish harvested is regulated and it is likely that fish of all sizes and ages are taken. Many villages have designated fish wardens however in reality the fishery remains managed mainly by the traditional community pressure mechanism. Much of the back reef area where fishing effort is concentrated functions as a nursery for juvenile and sub-adult populations. By continuing to target young and immature fish the result is that few make it to full adult size. The knock on effect targeting specific age classes has on the dynamics, reproductive output and recruitment of populations is well documented and could explain some of the patterns in general low fish abundance witnessed.

Seine netting is another fishing method utilised. This involves a team of fishermen making a wide circle, which is then constricted forcing the fish within into a tight shoal, which can be stunned and netted. This method not only impacts the reef directly as fishermen walk over and beat the reef to herd fish, but also has the disadvantage of being unspecific in the species targeted.

Use of *Derris*, known locally as 'Duva', root was witnessed sporadically along the Coral Coast, however it is not clear to what degree it continues to be used. Though localised, Duva is unspecific in its target organism and its use is rightly discouraged under Fijian law. There was no evidence of dynamite fishing the use of cyanide or other destructive fishing types on the Coral Coast.

6.2.4 Harvest for the Aquarium trade

Live rock is a commodity highly prised by the aquarium trade due to its aesthetic qualities and role as a biofilter. Live rock refers to bedrock or coral rubble with a growth of red coralline algae on its surface. The potential damaging effects of 'Live Rock' extraction have been documented for other geographic areas and work is currently under way by the Marine Aquarium Council to examine the specific impact along the Coral Coast. This report will offer a more comprehensive review of the level of impact associated with this industry than is contained here though the benthic community composition data collected in this report could and should be used as a basis for further impact assessment programmes. 'Live Rock' continues to be harvested along the Coral Coast in the reef regions either side of Vatukarasa village, though has been discontinued elsewhere. The data presented indicates high levels of algae and low levels of coral in these areas (figures 25, 26). As discussed above this implies elevated nutrient conditions. Given the inevitable disturbance caused during live rock extraction, the opportunity for algae to settle and become dominant is provided (figure 58).

Over the past five years there has been a shift in emphasis along the coast with a number of villages now cultivating artificial or 'cultured live rock'.

Local opinion suggests that there is little collection of fish for the aquarium trade along the Coral Coast. There were some reports of collection in Serua district though it is unclear of what species. Collection at Badara Inn in Korotogo was discontinued in 2002.

6.2.5 Coastal construction

Though the economic and social benefits of development are often clear, the environmental impact on land and marine systems is often harder to see and quantify. Land reclamation and dredging activities to ensure deep-water access may increase sediment load if not carefully considered and controlled. Any increase in the resultant population may lead to increase nutrient loading and demands on local fish stocks as discussed previously. Construction projects can range in size from the building of single houses and sheds to the building of large resorts and villages. The potential damage of projects clearly depends on their size and frequency. With the dominance of the tourism industry in the region the majority of large-scale development in the region concerns the building of tourism facilities. Examples of current or planned construction projects include plans to develop Natadola bay to the west as a major resort complex providing accommodation as well as a host of leisure activities, a new resort near Tagaqe village (the excavation for this has begun since the collection of data), extensions at Naviti resort and the building of a church in Votualailai. Other developments are planned at various locations along the coast. The degree to which such construction projects will cause increased sediment loading of nearby reefs is unknown.

6.2.6 Recreation

A large number of tourists also make use of the iqoliqoli. This is mainly concentrated outside of the resorts. The following activities may occur over the back reef platform: swimming, snorkelling, glass bottom boat rides, kayaking, sailing, fishing, and reef walking. SCUBA diving is largely concentrated in the channels and outside the break zone. Most resorts and operators have taken steps to minimise the impact of these activities on the ecosystem. Natural channels are often used for boat access; the reef area that activities are allowed within may be controlled, as well confining activities to high tide.

6.2.7 Pollution

Pollution is a concern throughout the Coral Coast. Villagers use the shoreline and seafront as a place to dump rubbish. Non-biodegradable rubbish such as plastic takes a very long time to degrade and may smother coral heads or choke marine animals. Agricultural and industrial chemicals and poisons may leach into the marine system and are a potential threat to the Coral Coast resources.

6.2.8 Current Management

The previous sections have concentrated largely on often-negative anthropogenic impacts. There have been many positive steps towards the sustainable management of local marine resources.

Fisheries Management

Marine organisms provide the single greatest source of protein in the diet of local villages. Most fish caught locally are consumed locally. As such individual communities have particularly high stakes in their own local fishing grounds, the practice of designating areas as protected or ‘Tabu’ and the benefits of this management approach are evident in many areas along the Coral Coast. The designating of an area as Tabu does not reveal what kind of protection it affords.

The position of Tabu areas may be seen in figure 60. Tabu areas have been mapped from a variety of sources ranging from GPS readings, field observations as well as outside sources. While some Tabu, such as the Korotogo Tabu have been in place for over five years, the Vatukarasa Tabu has only been in place since January 2005. Generally, areas designated as Tabu are not fished and the waters remain ‘still’ from human activity. This is not always the case however, for example, the Tabu at Tagaqe allows hotel recreational activities within it, and is also used for bathing and washing. This is common at other sites where the hotels fall within the Tabu areas.

A number of Tabu areas have recently moved position. While the reef area under Tabu at Vatukarasa is shown, data was collected for this area before its designation. This therefore does not allow analysis of its efficacy. Prior management of this area includes the rotational opening and closing of areas of the reef for live rock harvest, though it is believed fishing was not regulated as part of this approach. The Yadua Tabu has covered its current position in front and east of the village for less than a year and previously occupied a position west around the point. The Malevu Tabu was recently extended by approximately 5 km to allow spear fishing but not net fishing within this zone. The Tagaqe Tabu has moved eastwards to incorporate the channel and some of the habitat beyond. These extensions have been incorporated into figure 60. In early 2005, the communities of Cuvu, were planning on extending their MPA area eastwards. This has yet to be confirmed.

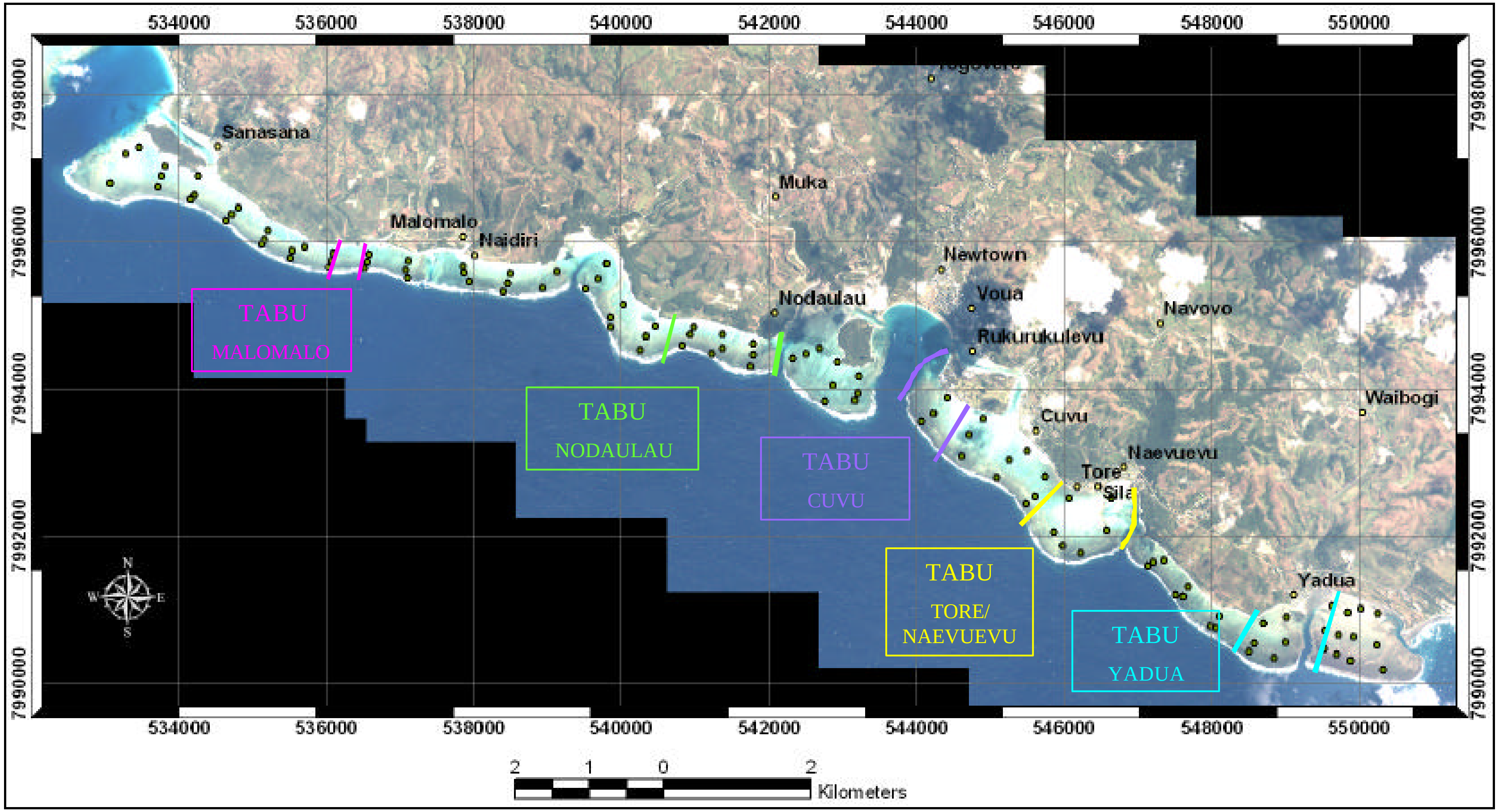

Figure 60 (a). Approximate position of Marine Protected ('Tabu') Areas in Section 1, April 2005. Source: Unpublished PCDF data, CCC GPS and field data.

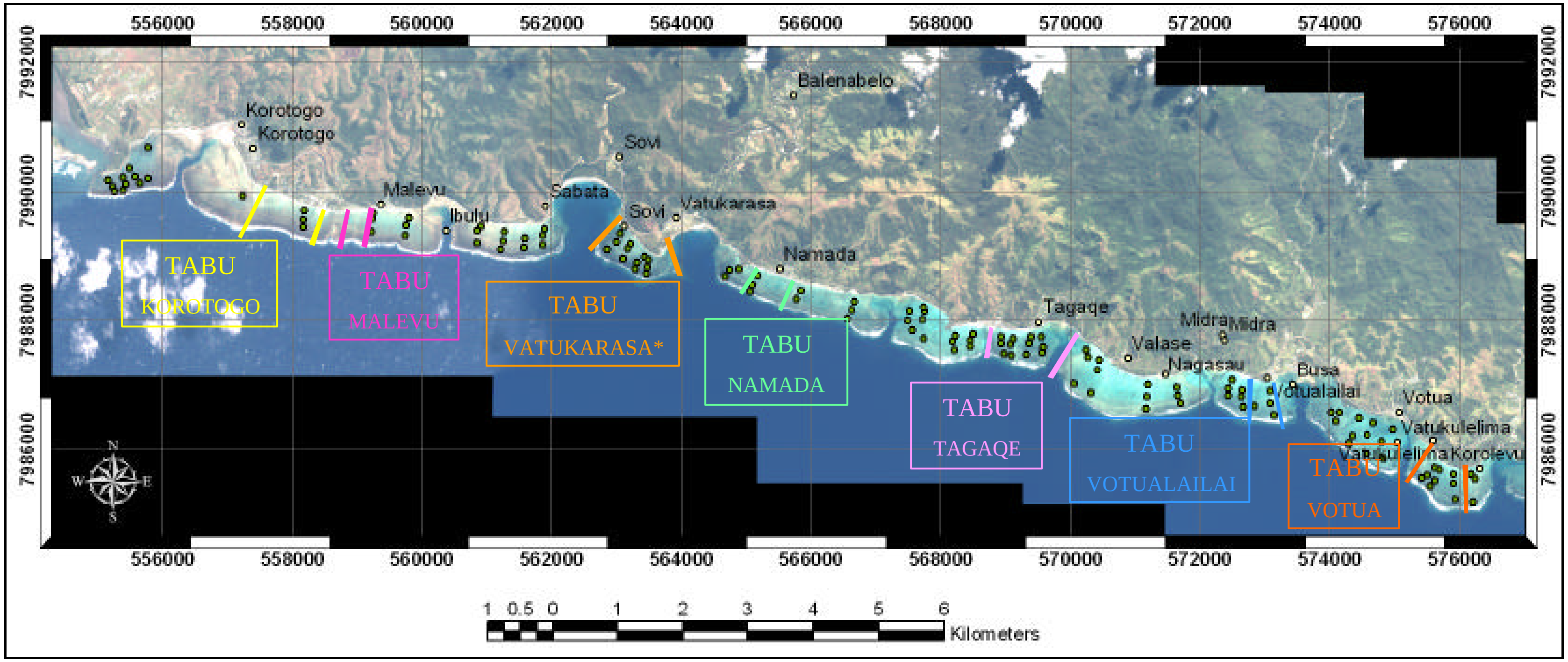

Figure 60 (b). Approximate position of Marine Protected ('Tabu') Areas in Section 2, April 2005. Source: IAS and CCC GPS and field data, unpublished. *Position of Vatukarasa Tabu unknown within described area.

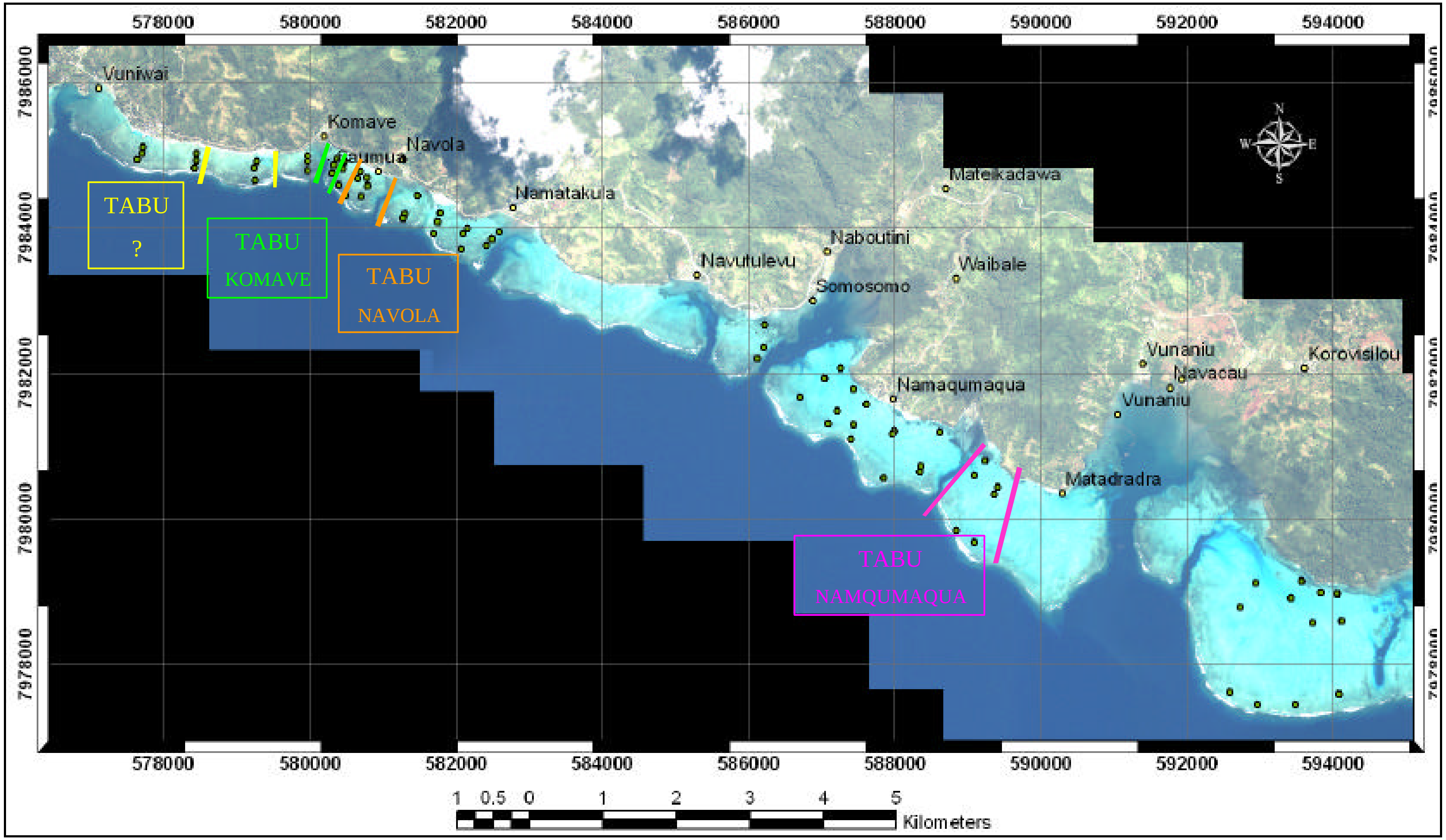

Figure 60 (c). Approximate position of Marine Protected ('*Tabu*') Areas in Section Three (April 2005). Source: CCC field data. Positions of Tabu areas described relative to prominent landmarks, therefore may not reflect exact position.

The presence of the Tabu system is probably having a positive impact on the density of food fish and invertebrates along the Coral Coast. Fish density tends to be greatest within Tabu areas. In the Namaqumaqua Tabu, there is a clear concentration of most fish groups within the Tabu area. Even groups such as Wrasse, which are usually widely distributed, are heavily concentrated within this area. The refuge provided within the Tabu is highly important to local fish stocks. There is a clear concentration of many fish and invertebrate species within the Tabu of Cuvu, Korotogo, Malevu, Votualailai, and Votua. Many Octopus are recorded within Tabu areas. This is particularly noticeable within the Tagaqe Tabu, which has a much higher density than is typical in the surrounding reef area. Though fish stocks in the Komave region are generally low compared to the rest of the coast, there are notable local increases in the population of Surgeonfish and Parrotfish in the Tabu areas west and east of Komave. It is clear that most areas of habitat with highest quality coral habitat lie within current Tabu boundaries. Given the time frame that most Tabu areas are managed for before moving it is likely that this is the result of sound judgement and advice to local communities in positioning these Tabu areas rather than as a direct benefit of the Tabu designation. Though no transects were run within the Tabu area, the Malomalo Tabu appears to have had less of an effect on local fish stocks. This area is both small and positioned over substrate with a lower coral cover. It is difficult to say whether the fish and invertebrates are distributed because of Tabu management or the carrying capacity of the habitat contained. It is likely to be a combination of these factors and demonstrates the benefits of managing such high value areas.

The Fiji Locally Managed Marine Areas (FLMMA) network is active in the iqoliqoli. FLMMA involves both government and non-government agencies in Fiji. Through FLMMA villages have been working to develop Resource Management Plans within Korlovevuiwai and more recently Komave Districts. Communities develop the capacity to make management decisions through the addition of scientific knowledge to their traditional knowledge of marine lifecycles and dynamics. Villages improve their capacity to monitor and make decisions about their marine environment. Monitoring schemes for the Tabu areas currently occur once a year and concentrates on a few easily recognisable food species such as Parrotfish. There are plans to increase the frequency and scope of this monitoring across the iqoliqoli.

All villages involved in the FLMMA scheme report an increase in size and abundance of fish within their Tabu areas, which is borne out by their monitoring surveys. A strong correlation can be seen between fish and invertebrate populations commonly fished with the position of Tabu areas. The evidence presented supports that found during FLMMA monitoring and general observation by local communities that the size and abundance of fish within Tabu sites is greater than outside and supports their use as a management option to feed the wider area via spill over effects. Volunteer fish wardens have been appointed in order to monitor and where necessary enforce the fisheries management along the Coral Coast. In reality, however most enforcement continues along the traditional community pressure mechanism.

Other Management Initiatives

Communities and resource users of the Coral Coast region have made a commitment to the Integrated Coastal Management (ICM) approach. Currently this relates to the populations of Conua, Korolevuiwai and Komave district, though there have been recent commitments to extend the work to encompass the rest of the survey region. Members of the Institute of Applied Science (IAS) from the University of the South Pacific, Suva provide much of the technical knowledge required by such an approach. Academic study from within IAS is channelled towards the knowledge requirements of the region. FLMMA works within the group helping in the management of marine resources directly. OISCA, a Japanese NGO is active in the field of coastal regeneration and among other projects, they aid with mangrove, coral and clam regeneration projects. Other Governmental and Non-Governmental Organisations have been active in areas peripheral to the main ICM region. These include the Ministry of Fisheries, which has been involved in MPA management decisions in the Serua district, Partners in Community Development Fiji (PCDF) who are involved with allied work in the Cuvu region, and World Wildlife Fund (WWF) who have carried out some educational activities in Malomalo district. Provincial government are also actively involved.

The ICM group has placed a high priority on wastewater management. The majority of effort has been concentrated over Korolevuiwai, though there is a steady progression to extend this work area. Current efforts lie with reducing the volume of nutrients entering the system through the relocation of piggeries away from water sources and the exploration of methods for managing the waste. There are now examples within the initiative of alternative management systems for human waste through use of natural composting and wetland systems. These can be found at Tagaqe village and Crusoe's resort (Namaqumaqua).

Given the combined local and tourist population in the area between Korotogo and Malevu it would be expected that algae would heavily dominate this reef region. Examinations of figures 25 and 26 reveals that this area actually contains some of the highest coral cover on the coast. It is known that Outrigger, the largest resort on that strip of coastline has installed a pipe system to take its waste away from the Outrigger to the Sigatoka sewerage plant. A number of the other resorts have also attached themselves to this system. This is an encouraging sign of the value of removing nutrients from the system. It is important to remember that removal of nutrients from one area may however be creating or increasing the problems in another area if it is not adequately dealt with. A pump station at Korotogo was vandalised in the past, whether this resulted in leaching in to the system at Korotogo is unknown.

Initiatives are in place to tackle the threats of sedimentation such as through the planting of mangrove species (principally *Rhizophora* sp.) around river mouths. Development of alternative community industries is encouraged for example the community based cultured live rock industry as opposed to natural rock extraction is being undertaken in Tagaqe village. The issues of waste management are addressed through combining village and hotel collection as well as the roadside bin system seen at Namada. Development and other population pressures are addressed through the inclusion of all stakeholders in the programme. There remains a long way to go in achieving the desired objectives however steady progress is being made.

While some of the above activities have been instigated by the agencies working in areas peripheral to the main ICM area, nutrient reduction has been less central to activities, with the noted exception of the installation of a wetland management system at the The Fijian resort (Rukurukulevu). Management activities have concentrated more on restorative projects such as mangrove planting, the building of fish houses in an attempt to encourage fish to aggregate, and Crown of Thorns removal operations.

6.3 Marine Resource Management

With the reversion of *iqoliqoli* ownership back to the local indigenous communities, the onus of local resource management is set to change. The role of Government departments and associated agencies will be to provide the framework within which community decision-making can operate. Management of the marine resources of the Coral Coast is a complex undertaking but imperative if resource stocks are to be secured for future generations. A series of impacts on Coral Coast are apparent from the data collected and serve to highlight the need for a number of management activities in the area.

It is vitally important to understand the source of problems affecting local inshore fisheries. As discussed above, the main management concerns of nutrient enrichment, and fishing pressure relate to the whole region. Sedimentation, coastal development, and recreational use are also of concern, though more localised in effect. There are however active steps that can be taken to mitigate such concerns, and encourage the process of natural and human- assisted restoration. Ultimately good management can lead to an increase in the carrying capacity of an area as well as its inherent stability.

Management of stocks on a local level for local consumption is often effective as impacts on the system may be easier to both identify and manage. There may however be situations where the source of problems is external to a local areas management remit. Communication between different communities, local businesses as well as relevant government and non-government organisations is important in finding solutions to these issues.

6.3.1 Fisheries management

Overfishing

The problem of overfishing can be tackled both directly and indirectly. Removal of fish before they are reproductively mature needs to be managed. Fish should not be removed below certain sizes. To this end use of nets with too small a gauge is discouraged. The Ministry of Fisheries publishes minimum catch sizes for fish (appendix 2). These size limits could be used as a guide to local communities in their management of individual iqoliqoli to increase the size and reproductive capacity of fish populations. The reasoning behind these sizes however needs to be assessed and conveyed to local communities to enable management practices to be adapted accordingly. Other potential methods of managing overfishing include limiting how much effort individuals put into fishing. This could include how many trips they may make, and/or how long they may spend on these trips.

The FLMMA approach has proven successful, not just in Fiji, but also as part of the world wide Locally Managed Marine Areas programme. It is vitally important that communities develop the capacity to manage their marine resources efficiently with minimum external input. Since the instigation of the FLMMA programme, villagers in Korolevuiwai have created a team of individuals made up from the various communities to conduct the required monitoring for the whole region. Though there are obvious strains to resources, it is desirable that this approach spreads to the rest of the Coral Coast.

One explanation proffered within local communities for the comparative health of the Votualailai area is that a high proportion of the village are employed in resorts and as such fish less. Communities should be encouraged to supplement their diet with alternative sources of protein thus reducing the requirement for fish in the diet. It is important for local communities to development additional village industries to spread tourism derived revenue into local communities via non conventional routes.

Tabu or Marine Protected Area management

Identification of areas for management as Tabu or Marine Protected Area (MPA) is an important step in managing human activities, safeguarding ecosystem health and fish stocks for future generations. In a no-take Tabu area fish will live longer and grow to a larger size. Larger fish tend to produce more eggs and offspring than smaller fish. As population increases even more eggs and offspring will be produced, swelling the population further until the carrying capacity of the area is reached. At this point fish will move out of the area or 'spillover' and replenish the surrounding fishing grounds.

Other potential benefits of Tabu areas include an increase in intrinsic value of the marine ecosystem for tourism.

Many factors must be considered in designating areas for protection. The composition of the benthic community in an area is of critical importance as it forms the basis of communities in terms of nutrient source and shelter. Though some coral reef species show strong special affiliation living within distinct home ranges, many species are ephemeral, and move between patches of habitat. As already discussed, coral cover is the best indicator that an area is of value due to its links with important food species and the shelter it provides. The protection of the most productive habitat will yield better returns. In early 2005, the communities of Cuvu, through the provincial office were planning on extending their Tabu area. This would have the benefits of bringing into the Tabu additional coral rich habitat, which can only add to the functioning of the MPA. Based on the available information, the current position of most Tabu sites appears justified. To what degree current fish stocks are reliant on the Tabu system is uncertain however the opening up of these areas to Fishing pressure could be potentially damaging. The Tabu area of Namaqumaqua for example contains the vast proportion of the iqoliqoli's fishstocks. If this area is lifted, these stocks are unlikely to divert to another Tabu set up elsewhere and stocks will quickly be diminished. Fish population across the Coral Coast may be dependent upon the comparative health and resources of these areas. Continued Tabu management in these areas is therefore vital.

Size is an important criterion. An area of between 20 to 25% of available reef area is thought to be necessary for the successful functioning of an MPA or Tabu area. Across much of the Coral Coast this level is achieved, however there is very little area under management in the Malomalo region, and Tabu designation in Serua district overall is known to be low.

One important consideration when positioning MPAs or Tabu sites is to identify source and sink areas. A source area will feed planktonic, juvenile larvae of benthic organisms which once settled will provide habitat complexity into sink areas. Knowledge of currents is important in this regard, as coral, invertebrates, and many fish have planktonic stages in their lifecycle whose dispersal is dependent on these.

Protection of the areas from which animals are dispersing will lead to the best results in terms of spill over and regeneration of the surrounding area.

The protection of spawning aggregation sites should be included in resource management plans. Many families of reef fish will aggregate in order to spawn and are particularly susceptible to overfishing at these times. While smaller fish tend to aggregate on the back reef and lagoon area, other important food fish will aggregate on outer reef slopes, in reef channels, promontories and drop offs.

While Tabu or area protection can be used to manage whole ecosystems, it can also be used to manage certain target fisheries. The link between the position of Tabu areas and the number of Octopus has been highlighted above. Communities could decide what species they want to specifically manage in their *iqoliqoli*. No take areas, seasonal closure (for example to protect spawning aggregations) and management of other activities are all options that should be considered. Such decisions however bring with them increased problems in terms of enforcement to ensure that they function as management methods.

One critical attribute of a successful MPA or Tabu management system is the inclusion of a realistic time frame. While many Tabu have been in place for over five years, Tabu may be put in place or lifted for a number of different reasons. Bearing in mind that many species take a long time to reach maturity, an area is unlikely to function as a source area, feeding peripheral fisheries if it is lifted and moved every few years. Some species of parrotfish for example can take up to 10 years to reach reproductive maturity and reproductive output increases with successive years after this point. Tabu should be committed enough to achieve this longevity yet flexible enough to adapt to changes in impacts and iqoliqoli use.

Despite the positive reports from FLMMA and this survey as regards to Tabu areas, some fishermen continue to report a decrease in catch size. This pattern suggests that while numbers are increasing, fish are failing to reach large size. Juvenile fish may come from external source areas. Tabu must remain in place for a long enough time frame (indefinitely) for fish size to increase. Care must be taken however to ensure that these regions continue to function and do not become degraded through undue care and poor management.

Though theoretically simple, many of these management actions are often difficult to put into practice. Current management, making use of traditional Tabu is important in achieving an increased, more stable population. The development of a plan that identifies the community's needs, pressing concerns and possible management approaches is an important step. Such a plan needs to extend beyond a list of planned activities, giving weight to the value, steps required and a suitable time frame in which to achieve specific aims. One management concern as discussed above is the degree to which current strategies are monitored across much of the region. Particularly in the light of ongoing development and population pressure, communities need to know what the current state of their marine resources is and whether management is working. Monitoring fish catches may only partially tell the story as an area may be overfished without an apparent drop in catch levels until subsequent years. This is particularly true with net fishing where there is the capacity to remove whole shoals of fish from a population. Monitoring both inside and areas peripheral to Tabu areas would be good long term aim though does put requirements on resources.

6.3.2 Managing other impacts

Nutrient enrichment

In terms of marine resources, the carrying capacity of the Coral Coast is currently compromised by impacts peripheral to the marine system. Management of nutrient enrichment sources is of major importance for long-term sustainability of the region. Algal reef dominance due to nutrient enrichment is a large concern. High value coral reef habitat will support a greater abundance and diversity of marine life.

In section 2 and part of section 3, communities have made commitments to nutrient reduction through the ICM approach. Nutrient removal by the Outrigger resort between Korotogo and Malevu could be the reason behind the relatively high coral cover seen in this area. This should provide inspiration towards further efforts. Testament must be paid to the advances made, however tangible results have yet been realised along much of the Coral Coast. It is still very early on in the process and further work and advancement in this area will be imperative in reducing nutrient enrichment and algal dominance.

Though the level of technical support may not currently be available in all districts, the extension of the ICM approach is encouraging. Nutrient enrichment should not be seen as simply a localised problem. Dependent upon currents and other parameters nutrients may accumulate in and from areas peripheral to the local system. This collective responsibility requires a collective solution. The exchange of ideas, approaches, and ethos is encouraged. The provincial office has an important role in the communication and facilitation of these ideas and practical solutions.

While not without value there are a number of activities involved in restocking of marine areas, such as coral replanting, that without having solved this problem may only provide short-term benefits. Such activities represent a huge investment in time and other resources without any long-term guarantee for return on what is put in. As discussed previously, under elevated nutrient scenarios any bedrock exposed during environmental disturbance is likely to return to algae dominated reef. Large waves remain frequent events and anthropogenic impacts a continuing concern. This therefore works against the long-term viability of encouraging coral settlement through these activities. Removal of the impact of nutrients, while safeguarding and promoting existing coral areas reefs will encourage the return to the coral cycle and renewed reef generation.

Sedimentation

The continued planting of mangroves around river and stream mouths is encouraged as a means to reduce sedimentation through natural settlement and management. Mangroves have additional benefits in helping to filter out pollutants, providing nursery habitat for fish and a source of timber if harvested sensibly. Though propagules may travel long distances, generally the reproductive and dispersal abilities of mangroves are much less than coral and algae. Replanting of mangroves can kick start this process through vegetative growth and the ultimate creation of local source areas. Many of the mangrove planting projects are still in their infancy. These must be allowed time to develop into a mature and dense mangrove stands. Planting should continue to the extent that sedimentation levels demand. River channels often form the boundaries between neighbouring management units. Good communication between these communities is therefore imperative to ensure responsibility as well as benefits are shared.

Areas of seagrass should be protected from disturbance even if they lay outside of existing Tabu areas. Such areas will naturally spread if allowed to grow undisturbed. Seagrass forms an important link with mangroves and other inshore habitat and should be protected accordingly.

Development and Recreation

Development and recreational use is best managed through communication between stakeholder parties. The local community should take care to establish a good relationship with other stakeholders coming into the area to ensure that their concerns and desires are addressed. Environmental Impact Assessment and consultation are an extremely important part of the process. Development provides high value alternatives to the reliance on marine resources however should not be encouraged at the expense of the health and long-term viability of the iqoliqoli.

6.3.3 Other Marine industries

Live Rock and Cultured Live Rock

Other marine industries provide a means to reduce the reliance on current fish stocks. The practice of ‘live rock’ extraction continues in Vatukarasa village, but concerns have been expressed as to its long-term viability. The ongoing research by the Marine Aquarium Council will be instructional in that regard. The practice of cultured live rock harvest holds potential however it currently comprises only a small proportion of Fiji’s live rock exports. Markets would need to expand to ensure long-term industry viability. In essence, cultured live rock offers a good opportunity for low impact income generation

7. Synopsis

Given the disparity of management across the Coral Coast region, a synopsis of the management concerns as they relate to each section has been provided.

7.1 Section 1: Current and Future management

The issues of nutrient enrichment and potential overfishing are of great concern for the health within this section. Increased education and training is required, particularly in the more isolated Malomalo district that has received less in the past. It will be necessary to develop a considered management plan to provide the framework for future management. A greater emphasis must be placed on the management of nutrient impacts. The influence of inland agricultural practices is likely to have a greater level of impact on the system. Inland communities and industries must therefore be included in the management approach. Sediment mitigation measures should therefore continue apace. Similarly, there is a need for the instigation of steps towards the management of marine resources in the form of establishing Marine Protected Areas or Tabu sites. Designation in the Malomalo district currently appears inadequate and poorly located, while those within the Cuvu district appear better designed. Communities across the region require training in marine monitoring in order to inform management decisions. In order to allow fish to mature and achieve the maximum benefit out of Tabu and other marine management, it is important to take a long-term view. The local community should look to the members groups of ICM, FLMMA as well as other experienced parties in neighbouring areas in achieving these aims.

7.2 Section 2: Current and Future management

The importance of the environmental and management solutions described during this report has been well documented in this section through ICM activities, and a clear objective driven management plan is in place. Management should continue along the outlined plan. Continued capacity building within local populations towards sustainable management objectives is encouraged with the extension of activities into the districts of Komave and Conua alongside ongoing initiatives within Korolevuiwai. Finding solutions to the nutrient enrichment problems will ultimately rely on finding cost effective solutions to waste management. Efforts towards this ultimate goal must continue. Local communities and businesses must continue to work together towards achieving long-term objectives. The issue of live rock harvest at Vatukarasa stands out as an environmental concern within this section. The ongoing work of the Marine Aquarium council will be important in determining the future of this industry. In the event of its closure, alternative livelihoods must be sought. Such an action would increase pressure on the already limited local marine resources and must therefore be addressed.

7.3 Section 3: Current and Future management

As described in section 7.2 above, an increase in the level of ICM and allied input to Komave district is desirable. The communities of Serua district would benefit substantially through increased capacity building and training. Given the inaccessibility of these communities this has proven difficult in the past, however this should not be seen as an insurmountable barrier. The impact of nutrient enrichment must again be addressed in this region. Steps taken at Crusoe's resort are an example to other businesses and communities along the coast of possible approaches. Sediment mitigation measures should again continue apace. Current Tabu designation appears to be well distributed within the area of study. Without additional data informing otherwise, the current Tabu designation should be maintained in order to ensure future rewards.

8. Conclusion

Local communities remain dependent on the marine environment for a large proportion of daily sustenance. The distribution of fish, invertebrate and benthic classes is uneven across the coral coast region. The combination of an increased population as well as more efficient fishing gear impacts further upon these resources. A high level of algae cover implies that a high level of nutrient enrichment also occurs. Nutrient enrichment appears the greatest problem facing fisheries management though perhaps the hardest to manage. The issues of nutrient enrichment and potential over fishing are of great concern for the health of the region.

Steps towards management of the regions resources have been taken however the emphasis and intensity of approach varies. Many areas have developed management plans, however these vary in their objectives and priorities. It is important that all plans incorporate a realistic but detailed sequence of objectives for attaining desired goals with sufficient longevity allowed within the plan to achieve these aims. Marine Protected Areas or Tabu sites have been established in many of the in shore fisheries. There is a tendency however for these areas to lifted and moved after short intervals. This does not allow such areas to maximise their management potential. The ICM and FLMMA approaches encourage the incorporation of the above values into community and resource management through an integrated communicative process and strong emphasis on a local community driven approach. Nutrient enrichment and fisheries management are placed high on the list of priorities. The continuation and extension of this approach to resource management is encouraged.

One of the tenets of the ICM approach is that important management decisions should be based on research rather than supposition. The data presented here has not been exhaustively analysed. Further research is necessary to identify among other issues, the source and destination of nutrient flows, patterns in fishing pressure, recruitment of biotic populations, migration patterns within and between populations and additional system impacts. This data set provides a strong basis for such research and will aid present and future management decisions.

9. Recommendations

Recommendations are provided towards future management of the Coral Coast region.

1. Encourage and expand the use of the data set towards improved resource management in the Coral Coast region.

2. Support and enable studies and initiatives highlighted above. For example looking at nutrient management and factors important in the planning and management of Tabu areas such as recruitment and source/sink studies.

3. Follow the examples and experience set by the Integrated Coastal Management (ICM) and Fijian Locally Managed Marine Areas (FLMMA).

4. Include all stakeholders in major management decisions as a realistic means to manage and address natural resource and coastal zone concerns towards long-term improvement over short-term gain

5. Develop plans that identify the community's needs, pressing concerns and possible management approaches. Such a plan needs to extend beyond a list of planned activities, giving weight to the value, steps and time required in achieving specific aims

6. Continue and increase awareness and education programmes. Efforts are required in reducing the volume of nutrients entering the system. This could include moving pigpens away from watercourses and coastal fronts and managing pig waste as a primary step in this process.

7. Continue to manage fisheries through use of the Tabu approach. Current location is a concern in some cases and may require relocating. Once effectively placed Tabu sites should be allowed to develop to their capacity.

8. Encourage, educate, and assist in different fisheries management options as a means to increase overall fish size and abundance. These might include restrictions on size, target species, season, and effort.

9. Support and enable alternative means of income and sustenance as a way of lessening the fishing pressure on the back reef area, provided the environmental impact of doing so is minimal. These might include tourism tours and expansion of pastoral agriculture.

10. Review current Environmental, Land Management, and Fisheries Law for Fiji. Legislation should aid local communities through reducing environmental impacts and providing the legislative framework within which resources can be managed.

11. Provide, encourage, and arrange appropriate awareness activities to develop understanding of the reasoning behind legislation in order to engender community support for it.

11. Appendices

Appendix 1: References

Adams, T. (1998). The interface between traditional and modern methods of fishery management in the Pacific Islands. *Ocean and Coastal Management* 40: 127-142.

Coral Cay Conservation. (2005[4]). Fisheries Resource Assessment Report: Korolevuiwai iqoliqoli, Viti Levu. Fisheries Research Division, Fiji.

Coral Cay Conservation. (2005[10]). Yavusa Ketenamasi, Leweitaqalulu, Tacini, Nalotawa and Leweiasiga in the District of Malolmalo, Viti levu. Fisheries Research Division, Fiji.

Darwall, W.R.T. and N.K. Dulvy. 1996. An evaluation of the suitability of nonspecialist volunteer researchers for coral reef fish surveys. Mafia Island, Tanzania A case study. *Biological Conservation* **78**: 223-231.

Erdmann, M.V., A. Mehta, H. Newman and Sukarno. 1997. Operational Wallacea: Low-cost reef assessment using volunteer divers. *Proceedings of the 8th International Coral Reef Symposium* **2**: 1515-1520.

GBMPA (Great Barrier Reef Marine Park Authority) Environmental Status: Crown of Thorns Starfish http://www.gbrmpa.gov.au/corp_site/info_services/publications /sotr/cots/ Accessed 2nd July 2005.

Green, ASP (1980) Wave Height and Periodicity: Measurements on the Coral Coast of Viti Levu

Harding, S., Lowery, C. and Oakley, S. 2002. Comparison between complex and simple reef survey techniques using volunteers: is the effort justified? *Proceedings of the 9th International Coral Reef Symposium*.

Hodgeson, G. (1999). A global assessment of human effects on coral reefs. *Marine Pollution Bulletin* 38, 345-355.

Hunt, C. (1999). Fiji's fisheries: their contribution to development and their future. *Marine Policy* 23(6): 571-585.

Hunter, C. and Margos, J. (1992) Methodology for involving recreational divers in long term monitoring of coral reefs. *Pacific Science* **46**. 381-382

IAS[1]. (2002). Sustainable coastal resources management for Fiji: A background paper prepared for the Fiji national workshop on Integrated Coastal Management. . Institute of Applied Science (IAS), University of the South Pacific. (Unpublished).

IAS[2]. (2002). Coral Coast ICM News. Issue 1, September 2003. Institute of Applied Science (IAS), University of the South Pacific.

Jennings, S and Polunin, NVC, (1995). Comparative size and composition of yield from six Fijian reef fisheries. *Journal of Fish Biology* 46: 28-46.

Jennings, S and Polunin, NVC. (1995[2]). Effects of fishing effort and catch rate upon the structure and biomass of Fijian reef fish communities.

McCook, L.J. (1999). Macroalgae, nutrients and phaseshifts on coral reefs: scientific issues and management consequences for the Great Barrier Reef. *Coral Reefs* 18, 357-367.

McClanahan, T.R. (1997). Primary sucession of coral reef algae: Differing patterns of fished versus unfished reefs. *Journal of Experimental Marine Biology and Ecology* 218, 77-102.

Morton, J. & Raj, U. (1980). The Shore Ecology of Suva and South Viti Levu, Institute of Marine Resources, University of the South Pacific, Fiji

Mumby, P.J. and A.R. Harborne. 1999. Development of a systematic classification scheme of marine habitats to facilitate regional management and mapping of Caribbean coral reefs. *Biological Conservation* **8**: 155-163.

Rahman, R.A., Ibrahim, S.N.S., (1996). Pulau Redang Marine Park Malaysia.The National Advisory Council for Marine Parks and Marine Reserves; The Department of Fisheries Malaysia

Ryland, J.S (1981) Reefs of Southwest Viti Levu and their Tourism potential. Proc. *4th International Coral Reef Symposium* Manila 1: 293-298

Sanchez, S., (1999) Hydrodynamic Impact Assessment of Natadola Beach, SOPAC Training Report 83.

Thaman, R.R., Tawake, A., Thaman, B., Niukula, J. (2001) Change over time and current status of the Coastline, reef and Biological Organisms in Yanuca Channel: preliminary findings.

Thaman, B., Robadue, D., Ricci, G. (2005). Strengthening a nested system of coastal Management in Fiji: Progress and lessons learned towards integrated Integrated Coastal Management on the Coral Coast and their implications for national policy. Institute of Applied Science, University of South Pacific.

Veron, J.E.N. (2000) Corals of the World, 3 Vols. M.Stafford-Smith (Ed.) Australian Institute of Marine Science Monograph Series

Vuki, C., L.P. Zann, M. Naqasima and M. Vuki. (2000). The Fiji Islands. Pages 751-764. *In:* C. Sheppard (Ed.) Seas at the millennium: an environmental evaluation. Elsevier Science

Wells, S.M. 1995. Reef assessment and monitoring using volunteers and nonprofessionals.University of Miami.

Appendix 2:

Recording forms showing Data variables recorded

TARGET FISH

		SECTION A	SECTION B	SECTION C	SECTION D
Butterflyfish	1				
(Big) Long-Nosed	2				
Klein's	3				
Vagabond	4				
Pyramid	5				
Eastern Triangle	6				
Latticed	7				
Redfin	8				
Chevroned	9				
Saddled	10				
Threadfin	11				
Teardrop	12				
Longfin Bannerfish	13				
Masked Bannerfish	14				
Humphead Bannerfish	15				
Pennant Bannerfish	16				
Angelfish	17				
Regal	18				
Bicolour	19				
Emperor	20				
Blue-girdled	21				
Dusky	22				
Semicircle	23				
Lemonpeel	24				
Surgeonfish	25				
Convict	26				
"Ringtail" spp.	27				
Brushtail tang	28				
"Bristletooth" sp.	29				
Sailfin tang	30				
Mimic	31				
Unicorn spp.	32				
Tuna/ Mackerel	33				
Narrow-banded king mackerel	34				
Fusilier	35				
"Blue and yellow" sp.	36				
Bluestreak	37				
Damselfish	38				
Blue-Green Chromis	39				
Black Bar Chromis	40				
Other "Chromis" sp.	41				
Threespot dascyllus	42				
Humbug dascyllus	43				
Reticulated dascyllus	44				
Whitebelly	45				
Staghorn	46				
Talbot's demoiselle	47				
Blue devil	48				
Lemon	49				
Golden	50				
Black	51				
"Anemone fish" sp.	52				
"Sergeant" sp.	53				

		SECTION A	SECTION B	SECTION C	SECTION D
Wrasse	54				
Diana's hogfish	55				
Mesothorax hogfish	56				
Humphead	57				
Red-banded	58				
Checkerboard	59				
Twotone	60				
Crescent	61				
Sixbar	62				
Jansen's	63				
Cigar	64				
Bird	65				
Rockmover	66				
Blackedged thicklip	67				
Cleaner	68				
Sling-jaw	69				
Goatfish	70				
Half-and-half	71				
Two-barred	72				
Dash-and-dot	73				
Multibarred	74				
Blackstriped	75				
Yellowfin	76				
Triggerfish	77				
Redtooth	78				
Orangestriped	79				
Clown	80				
Blackbelly Picassofish	81				
Pinktail	82				
Scythe	83				
Halfmoon	84				
Picasso	85				
Moustache / Titan	86				
Groupers	87				
Flagtail	88				
Peacock	89				
Humpback	90				
"Honeycomb" sp.	91				
Lyretail	92				
Saddleback/ Chinese coral	93				
Leopard Coral	94				
Soapfish	95				
Anthias	96				
Parrot Fish	97				
Bumphead	98				
Bicolour juv.	99				
Spinecheek	100				
Twoline	101				
Snapper	102				
Two-spot	103				
Black-and-white	104				
Bluelined	105				
Twinspot	106				
Fivelined	107				
Paddletail	108				

TARGET FISH (CONT)		SECTION A	SECTION B	SECTION C	SECTION D
Rabbitfish	109				
Foxface	110				
Pencil-streaked	111				
Uspi	112				
Dartfish	113				
Blackfin	114				
Cardinalfish	115				
Pyjama	116				
Blackstriped	117				
Puffer	118				
Blackspotted	119				
Goby	120				
Sphynx	121				
Brownbarred	122				
Toby	123				
Spotted	124				
Blenny	125				
Yellowtail poison fang	126				
Bicolour	127				
OTHER MAJOR FAMILIES					
Jack / Trevally	128				
Sweetlips	129				
Barracuda	130				
Moorish Idol	131				
Emperor	132				
Spadefish / Batfish	133				
Porcupine	134				
Trunk / Box / Cowfish	135				
Squirrelfish / Soldierfish	136				
Filefish	137				
Lionfish	138				
Scorpionfish / Stonefish	139				
Lizardfish	140				
Hawkfish	141				
Sandperch	142				
Sharksucker	143				
Needlefish	144				
Pipefish	145				
Trumpetfish	146				
Moray Eel	147				
FURTHER SPECIES					
______					
______					
______					
______					
______					

TARGET INVERTS			SECTION A	SECTION B	SECTION C	SECTION D
Annelid Worms						
Segmented Worms		141				
Feather Duster		142				
Christmas Tree		143				
Anthropoda : *Crustacea*						
Shrimps		145				
Spiny Lobster		146				
Crab		147				
Mollusca :						
Gastropods:	Abalone	148				
	Murex sp.	149				
	Conch	150				
	Cowrie	151				
	Triton	152				
	Cone Shell	153				
	Drupella sp.	154				
	Limpet	155				
	Topshell	156				
	Nudibranch	157				
	Worm Snail	308				
	Other	158				
Bi-Valves:	Oyster	159				
	Giant Clam	160				
	Other Clam	161				
	Other	162				
Chiton		163				
Cephalopods:	Cuttlefish	164				
	Squid	165				
	Octopus					
Echinodermata:						
Sea Stars:		166				
Acanthaster planci (COT)		167				
Linkia laevigata (Blue)		168				
Nardoa sp. (Brown)		169				
Culcita novaeguineae		170				
Protoreaster nodosus		171				
Choriaster granulatus		172				
Other		173				
Brittle Star		174				
Feather Star		175				
Basket Star		176				
Sea Urchin:	Short Spine	177				
	Long Spine	178				
Sea Cucumber:						
Synaptid		179				
Other		180				
H. edulis		301				
H. scabra		302				
H. noblis		303				
H. fuscogilva		304				
Bohadshia marmorata		305				
Actinopyga mauritana		306				
Stichopus chlorinatus		307				
Tunicate (Phylum Chordata)		181				
	______					
Bryozoan (Phylum Bryozoa)	______					
	______					
FURTHER SPECIES:						
______						

Dead Coral	5	
Rubble	6	
MICRO-ALGAE		
Cyano-Bacteria: Blue-Green	7	
MACRO-ALGAE		
Chlorophyta: Green	8	
Green Filamentous	8	1
Ventricaria sp.	8	2
	8	3
Bornetella sp.	8	4
Finger - *Neomeris* sp.	8	5
Grape - *Caulerpa* sp.	8	6
Calcified - *Halimeda* sp.	8	7
- *Tydemania* sp.	8	8
Spongy *Codium* sp.	8	9
Phaeophyta: Brown	9	
Dictyota sp. (Flat-Branched)	9	10
Padina sp. (Fan Blade)	9	11
Lobophora sp. (Blade/Ruffle)	9	12
Hydroclathrus sp.	9	13
Turbinaria sp. *(Pyramid)*	9	14
Brown Filamentous	9	15
Sargassum sp. (Bladder)	9	16
Rhodophyta: Red	10	
Encrusting coralline algae	10	17
Galaxaura sp.	10	18
Amphiroa sp.	10	19
Jania sp.	10	20
Red Filamentous	10	21
Sheet	10	22
Gracilaria sp.	10	23
MARINE PLANTS		
Sea Grass	11	
Thalassia sp.	11	24
Halophila sp.	11	25
Mangroves	12	

Branching	13	29
Encrusting	13	30
Lumpy	13	31
Rope	13	32
Vase	13	33
Octocorallia: Soft Coral Forms	14	
Deadman's Fingers	14	34
Leather	14	35
Tree	14	36
Pulsing	14	37
Sea Fan	14	38
Sea Whip	14	39
Bamboo	14	40
Organ pipe	14	41
Flower	14	42
Other Cnidarians	15	
Black Coral	15	43
Anemone (Sea and tube)	15	44
Zoanthid	15	45
Jellyfish (Medusa)	15	46
Hydroid	15	47
Corallimorph	15	48
HARD CORAL		
Life Forms		
ACROPORA:	16	
BRANCHING	17	
ENCRUSTING	18	
SUBMASSIVE	19	
DIGITATE	20	
TABULATE	21	
NON-ACROPORA:		
BRANCHING	22	
ENCRUSTING	23	
FOLIOSE	24	
MASSIVE	25	
SUBMASSIVE	26	
MUSHROOM	27	
OTHER:		
FIRE (*Millepora*)	28	
BLUE (*Heliopora*)	29	

Seriatopora hystrix	52
Stylophora pistillata	53
Stylophora mordax	54
Acroporidae	
Bottlebrush *Acropora* sp.	55
"Foliose" *Montipora* sp.	56
Poritidae	
Massive *Porites*	57
Porites cylindrica	58
Porites nigrescens	59
Porites rus	60
Goniopora / Alveopora sp.	61
Agariciidae	
Pavona clavus	62
Pachyseris speciosa	63
Pachyseris rugosa	64
Fungiidae	
Ctenactis echinata	65
Herpolitha limax	66
Polyphyllia talpina	67
Upsidedown bowl	68
Oculinidae	
Galaxea sp.	69
Pectiniidae	
Pectinia lactuca	70
Mycedium elephantotus	71
Mussidae	
Lobophyllia sp.	72
Faviidae	
Favia sp.	73
Favites sp.	74
Diploastrea heliopora	75
Echinopora lamellosa	76
Caryophylliidae	
Euphyllia sp.	77
Plerogyra sp.	78

Dendrophylliidae	
Tubastrea micrantha	81
Turbinaria reniformis	82
Merulinidae	
Hydnophora sp.	83
Merulina scabricula	84
Miscellaneous	
Brain: Small	85
Medium	86
Large	87

BACKGROUND INFORMATION

Data Identifyer	____	Start Easting	____
Reef Unit	____	Start Northing	____
Transect Number	____	End Easting	____
Transect Section	____	End Northing	____
Survey Date	____	Wind Strength (1-6)	____
Start Time	____	Wind Direction (from)	____
End Time	____	Current Strength (none, weak, mod, strong)	____
Marshall	____	Current Direction (Towards)	____
Fish Recorder	____	Horizontal vis	____
Invertebrate Recorder	____	Temperature	____
Point data Recorder	____	Salinity	____

SURFACE IMPACTS

Algae	☐	Litter	☐
Driftwood	☐	Nets	☐
Surface sewage	☐	Other impacts	____

UNDERWATER IMPACTS

Bleaching	☐	Coral disease	☐
Coral Damage	☐	Litter	☐
Other impacts	____		

ACTIVITIES

Gleaning	☐	Line Fishing	☐
Coral Harvesting	☐	Snorkelling	☐
Spear Fishing	☐	Swimming	☐
Net Fishing	☐	Reef Walking	☐
Boating	☐	Other activities	____

Appendix 3

Minimum Fish Catch Sizes

Ministry of Fisheries

SIXTH SCHEDULE
(Regulation 18)
(Minimum size limits for fish)

Common Name	*Fijian*	*Family*	*Genus*	*Minimum Length (mm)*
Barracuda	Ogo	*Sphyranidae*	*Sphyrona*	300
Crevally, Trevally, Pompano	Saqa (excluding vilu/saqa)	*Carangidae*	*Caranx*	300
Grey Mullet	Kanace	*Muglidae*	*Mugil*	200
Glassperch, Aholehole	Ika Drake	*Ducilidae*	*Duels*	150
Ketang, Spinefoot Rabbitfish	Nuqa	*Siganidae*	*Siganus*	200
Long-jawed Mackeral	Salala	*Scombridae*	*Rastrelliger*	200
Longtom, Garfish, Greengar	Saku Busa	*Belonidae*	*Belone*	300
Milk Fish	Yawa	*Chanidae*	*Chanos*	300
Mojarra	Matu	*Gerridae*	*Gerres*	100
Parrotfish	Ulavi	*Callyodontidae*	*Scarichthys*	250
Pouter, Slimy, Soapy, Peperek	Kaikai	*Leiognathidae*	*Gazza*	100
Rock Cod, Grouper, Salmon Cod	Donu, Kawakawa, Kavu (excluding small red spotted cod)	*Serranidae*	*Serranus*	250
Sea Bream, Pig-faced Bream	Kawago, Dokonivudi, Musubi	*Lethrinidae*	*Lethrinus*	250
Small Sea Bream	Kabatia, Kake	*Lethrinidae*	*Lethrinus*	150
Small Sea Bream	Sabutu	*Lethrinidae*	*Lethrinus*	200
Surgeon Fish	Balagi	*Hepatidae*	*Hepatus*	200
Surmullet, Goatfish, Whiskercod	Ki, Ose	*Mullidae*	*Mulloidichthys*	150
Snapper	Damu	*Lutjanidae*	*Lutjanus*	300
Unicorn-fish, Leather Jacket	Ta	*Hepatidae*	*Naso*	300