FIJI CORAL REEF CONSERVATION PROJECT

KADAVU ISLANDS

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EXECUTIVE SUMMARY

- Much of Fiji's wealth is generated by its extensive marine resources, which provide, for example, protein based food from fishing and income from tourism. However, a suite of factors currently threatens the ecological balance and health of many of Fiji's reef ecosystems.

- Following on from the work conducted by CCC in the Mamanuca Islands as part of the Fiji Coral Reef Conservation Project (FCRCP), CCC were engaged in May 2005 to assist in coral reef assessment and management in the Kadavu Islands.

- Fieldwork in northern Kadavu commenced in March 2006 using a quantitative version of CCC's baseline technique that allows a level of information to be collected that is appropriate to management decisions makers and facilitates the use of remotely sensed imagery and Geographic Information Systems to represent the coral reef systems.

- This fieldwork data acquisition concentrated on the fringing, lagoonal and seaward facing reefs of the Great Astrolabe Reef in the northern part of the Kadavu Island archipelago.

- Survey progress during the first six months of the project has included 340 survey dives on 77 survey stations completed on three main reef types in northern Kadavu (island fringing reefs, lagoonal and outer ribbon reefs) at four depth bands.

- As a part of the dataset has been collected to date only preliminary inferences can be drawn from the results presented in this report. Contour maps outlining the main attributes of the coral reef system indicate the areas of high coral cover, fish and invertebrate density for the area surveyed.

- Results indicate that the coral reefs in the region are generally in a pristine condition, particularly for seaward facing slopes of the main ribbon reef. There were a few locally attributable anthropogenic impacts on lagoonal and fringing reefs, although these were considerably lower in occurrence that observed in the more developed Mamanuca Islands. However, if considerable development occurs in northern Kadavu , these impacts are likely to increase in both distribution and intensity.

- The field data indicates that the outer reef slopes of the northern part of the Great Astrolabe Reef are of high ecological importance with a diverse and abundant ecosystem in terms of the benthic community and fish assemblages associated with them.

- Preliminary coral reef areas recommended for management in the area surveyed are:
    - The northern tip and north-western section of the Great Astrolabe Reef – high cover of hard corals, abundant and diverse populations of reef fish and the presence of rare species such as the Bumphead Parrotfish.
    - The south-west section of the Great Astrolabe Reef – high invertebrate diversity and high densities of food-fish families.
    - Fringing reefs along the north coast of Vanuakula Island – highest recorded densities of rare and often targeted invertebrates (Giant Clams and edible Sea Cucumbers).

- Further recommendations for the project and the northern Kadavu region are also provided below:

Recommendation 1- CCC recommends that the KQMST take the lead role in the implementation of Marine Protected Areas in conjunction with the existing network of qoliqolis in the Kadavu Islands

Recommendation 2- CCC to act, if invited, in an advisory capacity to support the appointed lead agency in the process of Marine Protected Area implementation. To provide assistance in areas such as the development of a monitoring scheme and educational workshops aimed at the integration of MPAs.

Recommendation 3- To seek support from all levels of administration to forward the development of a legislative framework as a sound platform for MPA implementation

Recommendation 4- Evaluate sources of infrastructure support for MPAs. Infrastructure needs to include patrol bases, offices and community education and environmental interpretation facilities

Recommendation 5- Conduct specific and targeted workshops to inform all stakeholders of the importance of Marine Protected Areas and conservation

Recommendation 6- Data and recommendations derived from CCC's work are not definitive. Using techniques such as the GIS developed for this and subsequent reports, all stakeholders to be invited to a consultation process to refine MPA location and function.

Recommendation 7- Undertake studies on the socio-economic and demographic factors that may affect successful MPA implementation. The findings of these studies will assist in defining suitable MPA sites as well as providing a feedback-monitoring programme to detail the success of implemented MPA programmes

Recommendation 8- Establish a monitoring programme to identify changes in the coral reef communities of the northern Kadavu region in collaboration with local stakeholders and communities

Recommendation 9- Promote Adaptive Management -Any MPAs and management planning needs to be dynamic in order to respond to feedback from both socio-economic and biological monitoring programmes

1. INTRODUCTION

Fiji is one of the wealthiest countries in the South Pacific, partly because of its extensive marine resources, which provide important services such as protein from fishing and income from tourism. The country is made up of approximately 844 volcanic islands and is dominated by the Viti Levu and Vanua Levu platforms which account for 87% of the total land area (Vuki *et al*., 2000). Fiji has a moderate tropical climate with well-developed coral reefs around all of the islands.

Although the tropical forests and coral reefs of Fiji are of vital importance, both ecologically and economically, they are threatened by rapid economic and population growth. Fiji's natural forests are now under serious threat from land-use conversion activities such as logging and agricultural development (Spalding *et al*, 2001). Similarly, the countries' coral reef ecosystems are being adversely affected by a range of anthropogenic activities including over-fishing, destructive fishing, sedimentation, eutrophication and pollution, which has resulted in extensive loss of coral reefs and inducement of coral diseases. Recent coral bleaching events and storm damage have exacerbated these effects by acting synergistically to reduce reef health further. Such impacts represent substantial long- and short-term threats to the ecological balance and health of reef ecosystems which, if left unchecked, will ultimately lead to reduced income for coastal communities and other stakeholders relying on fishing and marine-based tourism.

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-scientist', 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*., 2000). 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.

2. Project Background

2.1 The coastal zone of Fiji

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 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, a 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).

Conservation in Fiji has been limited in the past because of conflicts between proposed Marine Protected Areas and local communities' ownership of customary fishing rights. Marine reserves have, therefore, until recently been limited to several privately owned sanctuaries where, for example, resorts have reached an agreement with the holders of fishing rights. Expansion of this network of reserves could be achieved by payment of adequate compensation to those who currently own the rights and rely on them for their livelihoods. There is also a growing network of locally owned and managed MPA's 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 Kadavu Island Group and Great Astrolabe Reef

The Kadavu island group lies 45 nautical miles south of Viti-Levu (Figure 1). It is comprised of Kadavu, the fourth largest of Fiji's islands, and 7 smaller islands: Ono, Dravuni, Vurolevu, Namara, Buliya, Yaukuvelevu, and Vanuakula. Ono is the largest of the seven, with an area of 30 km^2. The barrier reef surrounding these islands was named the Great Astrolabe Reef by French explorer Dumont d'Urville after he nearly lost his ship, the Astrolabe, to this reef in 1827. In the 1870's Kadavu was almost selected as the site for the capital of Fiji, due to the once thriving whaling business. Today the island group is home to 12,000 native Fijians living in 72 traditional village communities. The main livelihoods for the local communities population are subsistence agriculture and fishing, with tourism becoming more important in recent years and set to increase in economic importance. Local produce, non-native pine and seafood are exported to mainland Viti-Levu and beyond to meet increasing demands for cash income.

The Great Astrolabe Reef, known locally as Cakau Levu (the big reef), is classified as an oceanic ribbon reef and surrounds a large lagoon of almost 300 km^2 to the north of the main island of Kadavu. This lagoon contains a number of islands, including Dravuni where CCC operations are currently based at the field research station facilities operated by the Marine Studies Programme (MSP) of the University of the South Pacific (USP). The main reef and lagoon are considered as a marine environment in relatively pristine condition, impacted only by low human populations on the small islands (Morrison and Naqasima, 1999). To the north of the Great Astrolabe Reef lies the North Astrolabe Reef also known as Solo Reef.

Both the Great Astrolabe and the North Astrolabe Reefs contain a variety of marine habitats. Lagoon depths range from very shallow to 40 metres, and include rock, sand/sediment and seagrass beds, as well as patch reefs. Dense coral growth has been reported on the windward sides of the smaller islands in the main lagoon. Seagrass beds can be found on the leeward coast of Dravuni and some of the other islands. Mangroves and mud flats also exist on Kadavu and Ono Islands.

There are three major passes into the Great Astrolabe,. The outer reef falls steeply to 30+ metres, followed by gentle sediment and rubble covered slopes to a depth of over 65 metres. In some areas parts of the reef have separated from the broad crest and formed pinnacles with valleys in between them. Depths in these valleys are as shallow as 5-10 metres. Beyond this the reef wall drops more than 1.6 km to the ocean floor.

The North Astrolabe, a circular atoll barrier reef, has previously been recommended for development as a marine reserve and park. Its use is controlled by the mataqalis on Dravuni Island. The reefs fall steeply to 35 m. or more before the first bench, although the northeast corner has numerous pinnacles with shallow passes between them into the lagoon.

The Great and Northern Astrolabe Reefs fall within two traditional fishing grounds or qoliqolis. The first qoliqoli (Ko Ono 1) encompasses the northern part of the Great Astrolabe Reef and the lagoon and is fished by communities living on the islands of Dravuni, Bulia and Ono. The second qoliqoli (Ko Ono 2) consists of the reefs and lagoon of the Northern Astrolabe Reef and is fished only by the Dravuni island community.

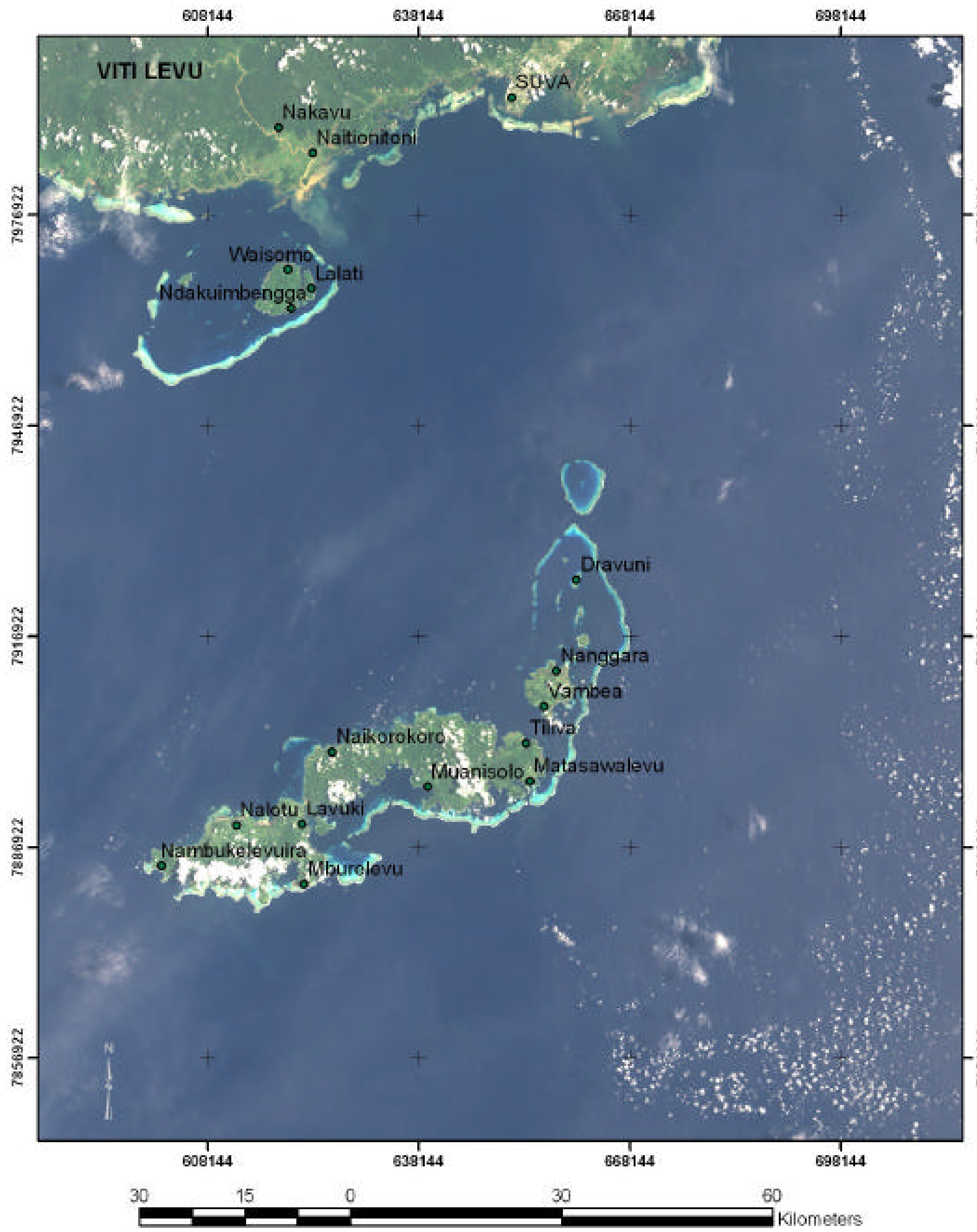


Figure 1. **The Kadavu island group located to the south of Viti Levu.**

2.3. Aims and Objectives

2.3.1. Project Activities and Timetable

Two sections are highlighted within the work-plan timetable – Data acquisition and Management and Counterpart Training/Conservation Awareness.

Data Acquisition and Management (Table 1)

Systematic surveys of all reefs within the project area from Solo reef in the north to Ono Island in the south for key biological criteria such as corals, reef fish and invertebrates that are indicators of biodiversity and health of the reefs in the area. Overlay collected data into a GIS package to highlight key hotspots of biodiversity. This will be accomplished by using UK recruited volunteers, and local counterparts to survey the reefs using the *CCC Baseline Survey Technique*.

Assess the main environmental impacts on the coral reefs of the northern part of the Great Astrolabe Reef from including the coastlines of the islands within the Astrolabe lagoon. Again, this will be carried out using divers that have been trained during the *CCC Skills Development Programme* (Table 4)

Counterpart Training and Conservation Awareness Programmes (Table 2)

The main objectives of counterpart training and raising conservation awareness will be addressed by the following actions:

Counterpart Training

Scientific and SCUBA training for project counterparts and regional representatives. This will empower both local and regional communities to undertake their own reef monitoring and educational tours for fishermen and local children

1. Training for Community Fish Wardens

In close collaboration with the Kadavu Qoliqoli Management Support Team (KQMST) CCC will provide training in scuba diving and reef resource survey and assessments, including MPA-orientated and practical scientific training in data acquisition, management, analysis and synthesis. Training will be offered primarily to each of the 30 or so communities at Kadavu

2. Training scholarships for USP students

Provide four-week training scholarships for USP students. The training programme will be similar to those offered to Community Fish Wardens but with an expanded curriculum in the technical components of data processing and management

Table 1. **Planned activities for the *Kadavu Conservation Project March 2006 - September 2007.* - Marine Surveys.**

ACTIVITY - Marine																			**ASSUMPTION**
Data Acquisition and Management	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	
1. Development of a comprehensive classification scheme for Kadavu reefs	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Local partners facilitate CCC staying at various satellite locations to enable sites further a field to be surveyed. Surveys carried out with all equipment functioning correctly. Local GIS facility identified and collaborates with on-site activities.
Baseline surveys – GIS database updates (ongoing)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
2. Recommendations																		•	Marine Protected Area recommendations to be accepted and actioned by all stakeholders
Initial application of protected area boundaries and zoning schemes associated with these areas.																			Co-operation of all stakeholders, identification of implementing agency, external funding sources
3. Reporting																			
Updates on web		•		•		•		•		•		•		•		•		•	Data are made available to CCCUK staff.
Summary reports			• *		• *		• *		• *		• *		• *		• *		• *		* Update reports to be produced as and when Baseline transects in an area completed

Table 2. **Planned activities for the *Kadavu Conservation Project March 2006- September 2007*. - Outreach activities.**

ACTIVITY	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	ASSUMPTION
Counterpart Training																			Appropriate individuals are identified
Baseline surveys	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Counterparts are fit to dive and make themselves available. Funds made available by counterparts to travel to and from the CCC operations base.
Report Production	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Reporting to Ministry of Tourism
Conservation Awareness																			
Village visits							•												
Schools visits	•	•	•								•	•	•	•	•				Acceptance of local schools to facilitate visits by CCC staff.
Report Production								•										•	All materials are made available to CCCUK staff.
Collaboration with KQMST	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	KQMST sustain monitoring initiatives

Coral Reef Awareness Programme

1. Marine Awareness Field Trips

Marine awareness field visits to the CCC base on Dravuni will be provided for parties of children from each community, where they will be provided with interactive reef awareness educational activities, including snorkelling excursions to local coral reefs.

2. Resort Support

Staff of local tourism resorts will be provided with skills training opportunities in order to enhance their guests appreciation, enjoyment and understanding of the importance of healthy coral reefs in protecting income and livelihoods for local communities and stakeholders alike.

Establish a schools curriculum for conservation education by participating and joining schools in the northern Kadavu area with presentations, classes and interactive practical sessions on the local marine environment. Production of educational posters will provide an initial resource to help promote reef conservation at an early stage.

Establish a formalised 'diver briefing' lecture for the local dive community to make tourist divers more aware of the fragile nature of the coral reefs of The Kadavu Island Group.

Training of local project counterparts and stakeholders will concurrently with the CCC survey programme when applicable. Educational days involved the CCC Project Scientist travelling between the CCC project base camp, and local communities in the northern Kadavu region. CCC field science staff will give lectures and practical demonstrations of the importance of mangroves, seagrass beds and coral reefs. A beach clean up will also be organised each time a school or community is visited.

The scientific, training and outreach programme on each CCC project is co-ordinated by the CCC Project Scientist (PS) and Science Officer (SO). The primary responsibilities of the PS are to train volunteers and local counterparts in marine life identification, survey techniques and other supporting skills and to co-ordinate and report upon all field survey programmes. The PS is also responsible for representing CCC at in-country meetings and conferences and ensuring the data are precise and consistent. The SO works closely with the PS and the role involves teaching, survey planning and co-ordinating data management. Both the PS and SO will work with full-time CCC-UK staff on data analysis and report writing and dissemination.

2.3.2 Habitat mapping and Geographic Information Systems

One of the major planned outputs of the Kadavu phase of the FCRCP is a detailed marine habitat map for the northern Kadavu region. Coastal habitat maps are a fundamental data requirement in establishing coastal management plans (Cendrero, 1989). In the context of conserving reef diversity, habitat maps provide an inventory of habitat types and their statistics (Luczkovich *et al*., 1993; Spalding and Grenfell, 1997), the location of environmentally sensitive areas (Biña, 1982), allow representative networks of habitats to be identified (McNeill, 1994), identify hotspots of habitat diversity, permit changes in habitat cover to be detected (Loubersac *et al.*, 1989), and allow boundary demarcation of multiple-use zoning schemes (Kenchington and Claasen, 1988). Furthermore, the conservation of marine habitats may serve as a practicable surrogate for conserving other scales of diversity including species and ecosystems (Gray, 1997). In essence, coastal habitats are manageable units and large-scale maps allow managers to visualise the spatial distribution of habitats, thus aiding the planning of networks of Marine Protected Areas and allowing the degree of habitat fragmentation to be monitored. As Gray (1997) states, a mosaic of marine habitats must be protected if complete protection of biodiversity is to be achieved.

Habitat maps are generally created using remotely sensed imagery, such as satellite images or aerial photography, in combination with field data. Despite limitations such as cloud cover and limited water penetration (typically <25 m), remotely sensed imagery has the advantage of facilitating the cost-effective extrapolation of field data to large spatial scales. For example, a 'Landsat' satellite image covers an area of 185 km by 185 km, much larger than could be covered by survey divers alone. Satellite imagery consists of rows of square 'pixels', typically covering hundreds of square metres, that are characterised by the reflectance of blue, green and red light. Field data can then be used to characterise each 'spectral signature'. For example, if field data shows that a pixel with a high reflectance of red light is present in an area of habitat type A, computer software can be used to classify each pixel with a high reflectance of red light as habitat type A. Repetitions of this process for each habitat type will rapidly generate a map of habitat distributions across the whole satellite image. Readers are referred to Green *et al*. (2000) for further information on remote sensing for tropical coastal management.

In addition to the creation of the habitat map, one of the main planned outputs for the FCRCP is the creation of a fully integrated Geographic Information System (GIS) on the coral reef resources of the northern Kadavu region. Essentially, a GIS is visual representation of a database that allows user to query the data set and display the results in a graphical representation. Data entered into a GIS is geographically and spatially linked in that each data point in the underlying database is linked to a point in space on the ground and also in the system display. A fundamental inclusion of any GIS is a base map or image over which data can be laid; in the case of the FCRCP, a satellite image is used. GIS have the great advantage in that the data they include is firstly linked to geographically identifiable sites as well as allowing data representations to be made graphically; a medium which is far more easily interpreted than a list of numbers in a conventional database.

Habitat map production for the northern Kadavu region is not covered by this progress report as the dataset is not yet substantial enough to undertake a full analysis. An initial detailed habitat map will be produced toward the end of the first year of data collection on Kadavu.

3. METHODS

3.1 Survey strategy

Since the area encompassed by the Kadavu Phase of the FCRCP is extensive the survey strategy focused on gathering detailed data from a wide range of geographical locations in order to build up a solid baseline of coral reef information. The main aim was to generate data from a broad range of habitat types that represent most reef types of the area and hence provide solid recommendations for coral reef management and potential MPA designation in the northern Kadavu region.

3.2. The Concept Of 'Survey Stations'

During the first six months of the project, CCC volunteers collected data from a series of 'survey stations', which correspond to a particular geographic position located on the range of reef types (inner barrier, outer barrier and fringing lagoonal) depending on area shown in Figure 2. Surveys at each site will generate a standardised data set that will facilitate characterisation of each area and also powerful comparisons at a range of spatial scales. A total of 405 stations were designated for potential surveying during the Kadavu Project (Figure 2).

One survey technique was used during the surveying period covered by this report: quantitative CCC baseline transects for habitat mapping and assessment of reef status.
Firstly, *CCC Baseline Survey Technique* transects were surveyed to provide general data on each habitat type present. The exact number of transects at each site was constant with four 40 metre transects completed at four depth bands. In addition to these key techniques, further data such as compiling species lists and assessing water quality will be undertaken concurrently.

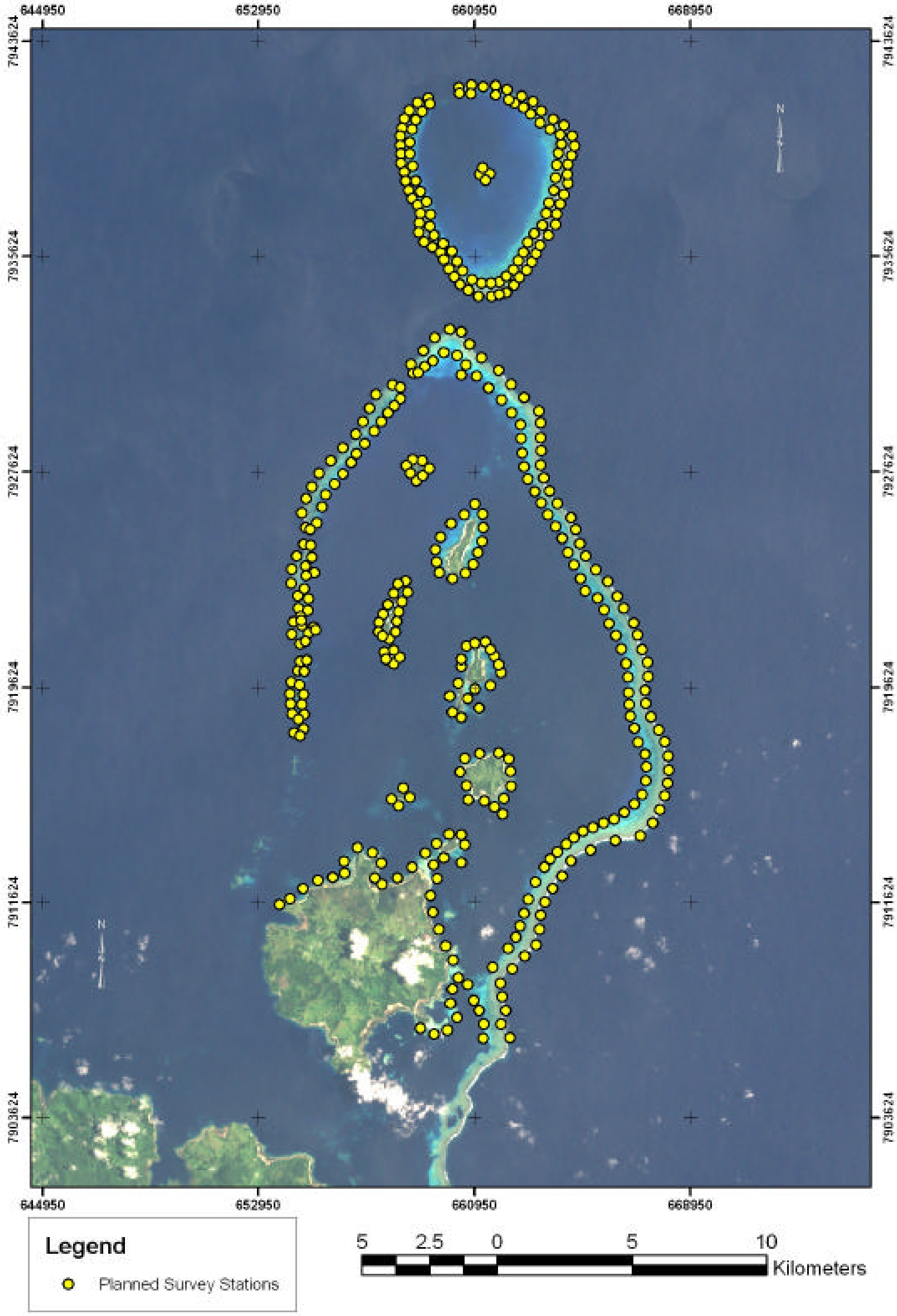


Figure 2: Position of the planned survey stations for the Kadavu Project

3.2 Volunteer training

Efficient and effective training is a vital component of any volunteer programme in order that participants quickly gain the required identification and survey skills that allow them to collect accurate and useful data. During the Kadavu Project, CCC used an intensive two-week training programme, which is outlined in Table 3. The programme was designed to provide volunteers, who may have no biological knowledge, with the skills necessary to collect useful and reliable data. The primary aim of the lecture programme was to give volunteers the ability to discern the specific identification characteristics and relevant biological attributes of the species that they would encounter during their diving surveys. The training programme was co-ordinated by the Project Scientist (PS) and Science Officer (SO) and involved two lectures and two dives or snorkels each day along with de-briefings and evening audio-visual presentations. Volunteers were also encouraged to snorkel and utilise identification guides to ensure a thorough understanding of the information provided in the lectures.

An important component of the training schedule was a series of testing procedures to ensure that each volunteer had reached a minimum acceptable standard. Hence the training programme concluded with a series of tests, which ensured that the volunteers had reached an acceptable standard of knowledge. These tests used both 'flash-cards' or slides and in-water identification exercises for corals and fish. Furthermore, to assess the quality of data collected by CCC volunteers during actual survey work, two validation exercises were undertaken. The benthic validation exercise used a test transect survey set up and thoroughly surveyed by the PS and SO to collate a reference data set. During Phase 1, test transects were conducted in buddy pairs with one person recording coral and the other soft corals, invertebrates and algae (as performed by Divers 3 and 4 during surveys; Section 3.3). During Phase 2, each person surveyed the transect line as during an actual Reef Check transect. Data were then transferred to recording forms and entered into a spreadsheet where the results from each pair were compared to the reference using the Bray-Curtis similarity coefficient (Equation 1; Bray and Curtis, 1957).

Equation 1:

$$\text{Bray - Curtis Similarity, } S_{jk} = \left[1 - \frac{\sum_{i=1}^{p} \left| X_{ij} - X_{ik} \right|}{\sum_{i=1}^{p} \left(X_{ij} + X_{jk} \right)} \right]$$

Where X_{ij} is the abundance of the *i*th species in the *j*th sample and where there are *p* species overall.

Since it is impossible to compare volunteer fish data to a reference, validation of fish surveys were conducted by measuring the consistency between pairs of surveyors. It is then assumed that if surveyors are consistent they are also accurate. Therefore, both divers within a buddy pair independently survey the whole fish list and each surveyor fills out their own survey form and enters it onto a spreadsheet. As with the benthic validation, the pairs of results were compared using the Bray-Curtis similarity coefficient. These assessments were similar to the critical assessment conducted by CCC in Belize in 1993 to test the accuracy of volunteer divers conducting baseline transect surveys (Mumby *et al*., 1995).

Table 3. **CCC Skills Development Programme timetable for CCC volunteers during the Fiji Coral Reef Conservation Project in Kadavu.**

	Day +1 (Sat)	Day +2 (Sun) No diving	Day +3 (Mon)	Day +4 (Tue)	Day +5 (Wed)	Day +6 (Thur)	Day +7 (Fri)	Day +8 (Sat)	Day +9 (Sun) No diving	Day +10 (Mon)	Day +11 (Tue)
⇩AM	**Transfer** New vols (i.e. trained scuba divers) to Castaway **Survey dive** (Trained Volunteers only - see note 2) **Orientation** ▶Welcome & tour of facilities ▶Expedition life & duties ▶General health & safety ▶CCC rules & regulations **Practical** ▶Scuba kit allocation ▶PADI AOW Elective Dive: PPB (6m) with new diver volunteers	**Lecture 2** ▶Dangerous animals! **Safety briefs** ▶PADI MFA: Ac mods 1+2 ▶O_2 therapy ▶PADI tables & quiz (OW mods 4+5) ▶CCC dive standards ▶Radio use ▶Emergency procedures ▶Boat safety ▶Boat marshalling ▶Use of boat safety kit	**Lecture 3** ▶Intro to coral reef ecology **Practical** ▶Reef orientation (scuba-18m) ▶ **PADI AOWD Training** Elective Dive 3 (18m)	**Lecture 6i** ▶Hard coral ID – target grps **Practical** ▶Hard coral ID (scuba-18m) **Lecture 6ii** ▶Hard coral ID	**Lecture 11i** ▶Fish families and species ID **Practical** ▶Fish ID – Families (18m) **Review** ▶Fish ID – Families	**Lecture 11iii** ▶Fish ID – target species **Practical** ▶Fish ID – target species (scuba-18m) **Review** ▶Fish ID – target species	**Lecture 13** ▶Invert. ID **Practical** ▶Invert. ID (scuba-18m) **Review** ▶Invert. ID	**Lecture 15** ▶Intro to CCC Reef Survey Technique **Practical** ▶CCC Reef Survey methods (dry run) ▶CCC Reef Survey methods practice (scuba-18m) **Review** ▶CCC Reef Survey technique	**Review** ▶ID – coral, fish, inverts & algae **ID skills evaluation** ▶Inverts & algae (slides & samples) ▶Inverts & algae (snorkel)	**Lecture 17** ▶CCC data validation **Skills refresher** ▶Benthic validation (scuba-18m)	**Review** ▶ID – hard & soft corals **(a) Skills validation** ▶Coral trail (16m)
⇩PM	**Safety briefs** ▶PADI RD: Ac mods 1+2 **Practical** ▶PADI RD: OW exc. 1 (surface only) ▶OW exc. 2 (3m)	**Lecture 10** ▶Marine plants & algae **Practical** ▶Marine plants & algae ID (snorkel) ▶Specimen ID – reference collections	**Lecture 4** ▶Intro to hard coral biology **Practical** ▶ID - coral life forms (scuba-16m) **Review** ▶Coral life forms	**Lecture 7** ▶Soft coral and sponge ID **Practical** ▶Hard/soft coral ID (scuba – 16m) **Review** ▶Hard/soft coral ID	**Lecture 11ii** ▶Fish ID – target species **Practical** ▶Fish ID – target species (16m) **Review** ▶Fish ID – target species	**Practical** ▶Fish ID – target species (scuba-18m) **Review** ▶Fish ID – target species	**Review** ▶ID – coral, fish, inverts & algae **Practical** ▶ID – coral, fish, inverts & algae (scuba-16m) **Self-revision** ▶ID – coral, fish, inverts & algae	**Lecture 16** ▶Intro to Survey forms, habitat classifications & use of abundance scales **Practical** ▶Practice survey (scuba-16m) ▶Data entry onto CCC forms	**Practical revision** ▶ ID – all fauna and flora (snorkel)	**Skills validation** ▶Coral trail (scuba-16m)	**Review** ▶ID – fish **Skills validation** ▶Fish (scuba-10m) **Review** ▶Validation assessment
EVE	**Lecture 1** ▶Fiji **Review** ▶Expedition Skills Training schedule	**Review quiz** ▶CCC health & safety regulations ▶CCC dive standards ▶Emergency procedures ▶Local culture & customs	**Lecture 5** ▶Coral biology and taxonomy	**Lecture 8** ▶Intro to fish ecology & behaviour **Lecture 9** ▶Intro to GPS	**Review** ▶Coral & fish ID (pictionary) **Lecture 12** ▶Ropes & knots	**Review** ▶Coral, fish and algae ID (pictionary) **Review** ▶GPS & knots	**ID skills evaluation** ▶Corals **Lecture 14** ▶CCC data: analysis & use	**Safety brief** ▶Night-diving procedures **Practical** ▶Optional night-dive (12m)		**ID skills evaluation** ▶Fish (slides)	**ID skills evaluation** ▶Re-takes (if required) **Lecture 18** ▶Other survey methods

Table 3 (continued). CCC Skills Development Programme.

	Day +12 (Wed)	Day +13 (Thurs)	Day +14 (Fri)	Day +15 (Sat) End of training
⇩ AM	**Skills validation** **Retakes if required (fish or coral)** **review** **Coral and soft coral ID**	**practice CCC Reef Survey dive** **shore dive/boat dive** Followed by Data entry	**Data collation – practice CCC Reef Survey dive** **Validation retake if required** **ID skills evaluation if required**	Recreational dive – location as decided by volunteers **Departures** ▶2 week volunteers **PADI DM*** ▶Topic 1
⇩ PM	**Practice CCC Reef Survey dive from boat** **Lecture 19** ▶Data entry to CCC computer database – (groups of 4)	**Practice CCC Reef Survey - shore/boat dive** **Followed by Data entry** **PADI MFA*** ▶Mods 3+4	**Practice CCC Reef Survey dive** Validation retake if required Graduation! Congratulations on completing the CCC Skills Development Programme **PADI MFA*** ▶Mods 5+6	Recreational dive – location as decided by volunteers **PADI DM*** ▶Topic 2–pt1
EVE		**Lecture 20** ▶Marine reserves **retakes of ID skills if required**	**Lecture 21** ▶mangrove ecology **retakes of ID skills if required**	**Lecture 22** ▶threats to the reef Optional night dive **Party night**

3.3 Baseline transect technique

The Kadavu Project utilised a new quantitative version of the standard baseline survey techniques developed by CCC for the rapid assessment of biological and physical characteristics of reef communities by trained volunteer divers. Following an intensive training programme, CCC's techniques have been shown to generate precise and consistent data appropriate for baseline mapping (Mumby *et al.*, 1995). All surveys were co-ordinated by the PS and SO to ensure accurate and efficient data collection.

CCC's standard baseline transect survey technique utilised a series of plot-less transects, perpendicular to the reef, starting from the 28 metre contour and terminating at the reef crest or in very shallow water. The revised version of the survey technique used at Kadavu utilised quantitative surveys at 4 pre-set depth bands referred to surface (2m depth), shallow (6m), medium (12m) and deep (16m) transects to record benthic composition (percentage cover), reef fish and macro-invertebrate density along the designated reef contour. Benthic and fish surveys were focused on life forms or families along with a pre-selected number of target species that were abundant, easily identifiable or ecologically or commercially important. Stony corals were recorded as life forms as described by English *et al.* (1997) and selected corals were identified to species level. Fish were generally identified to family level but in addition, important target species were identified. Sponges and octocorals were recorded in various life form categories. Seaweeds were classified into three groups (green, red and brown algae) and identified to a range of taxonomic levels such as life form, genera or species.

For each depth band one buddy pair of divers completed surveys for benthic cover, targeted reef fish and invertebrates. Each survey station therefore required 8 divers in 4 buddy pairs and could usually be completed in one boat trip. This has a distinct advantage of completing a site in one trip eliminating the need for surface or sub-surface marker buoys to mark the station for subsequent surveyors. At each depth band a 40 m length of thin polypropylene line weighted every 50 cm with a small lead tag was laid along the reef parallel to the reef slope. The tape was laid by Diver 2 with Diver 1 staying slightly ahead in order to survey reef fish along a 40 x 5 x 2.5m corridor. Once the measuring tape was laid and the fish survey completed the buddy pair swam back along the tape to record benthic composition and invertebrate density. Diver 1 records selected invertebrates present in a 40 x 1 metre belt while Diver 2 records the benthos or substratum under the tape at 50 centimetre intervals for a length of 40 metres giving a total of 80 points per transect. Details of the benthic categories and targeted fish and invertebrates are provided in Appendix 1.

The positions of the survey sites were fixed in advance using a satellite image (LANDSAT 7 acquired on 04/02/2001. Source: Global Land Cover Facility; http://www.landcover.org.) and GIS software (Erdas Imagine). During the survey, the start positions of the 'surface' and 'medium' depth transects were recorded using a handheld GPS unit.

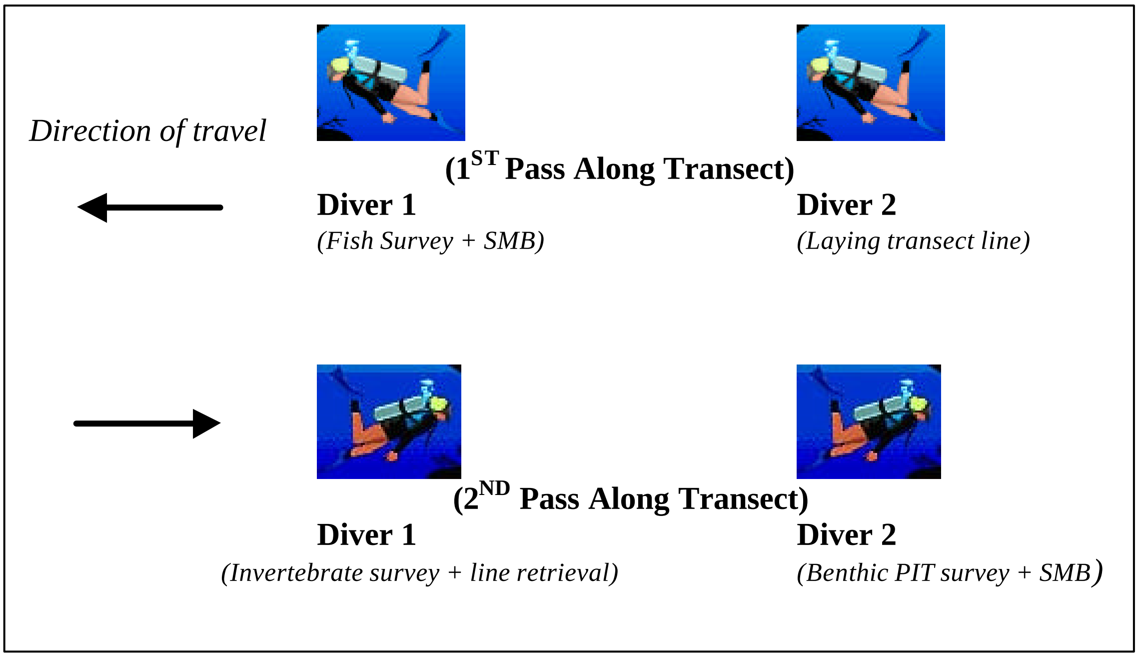


Figure 3. Schematic diagram of a baseline survey dive team showing the positions and data gathering responsibilities of two divers. Details of the role of each diver are given in the text.

During the course of each survey, certain oceanographic data and observations on obvious anthropogenic impacts and activities were recorded at depth by the divers and from the surface support vessel. Water visibility, a surrogate of turbidity (sediment load), was measured. Horizontal visibility through the water column was estimated by the divers while underwater. Survey divers also qualitatively assessed the strength and direction of the current at each survey site. Direction was recorded as one of eight compass points (direction current was flowing towards) and strength was assessed as being 'None', 'Weak', 'Medium' or 'Strong'. Similarly, the boat marshall on the survey boat qualitatively assessed the strength and direction of the wind at each survey site. Direction was recorded as one of eight compass points (direction wind was blowing from) and strength was assessed using the Beaufort scale.

Natural and anthropogenic impacts were assessed both at the surface from the survey boat and by divers during each survey. Surface impacts were classified as 'litter', 'sewage', 'driftwood', 'algae', 'fishing nets' and 'other'. Sub-surface impacts were categorised as 'litter', 'sewage', 'coral damage', 'lines and nets', 'sedimentation', 'coral disease', 'coral bleaching', 'fish traps', 'dynamite fishing', 'cyanide fishing' and 'other'. All information was assessed as presence / absence and then converted to binary data for analysis. Any boats seen during a survey were recorded, along with information on the number of occupants and its activity. The activity of each boat was categorised as 'diving', 'fishing', 'pleasure' or 'commercial'.

3.4 Data analysis

Note on Map outputs: all maps presented in this report are displayed on a Universal Transverse Mercator (UTM) grid (zone 60, Southern Hemisphere). Throughout, a WGS84 Geodetic Datum is use for projection.

Note on statistical analyses: as the current dataset is incomplete with data for only a small proportion of the survey stations available we shall not undertake multivariate statistical comparisons for the reef parameters collected but rather present univariate statistics and complete a more detailed analysis when a more substantial dataset has been collected.

3.4.1 Oceanographic, climate and anthropogenic impact data

Data for underwater visibility, the strength and direction of currents and wind, natural and anthropogenic impacts were summarised graphically and via univariate statistics. Data were either summarised for the whole project area or for each of the main reef types as appropriate.

3.4.2 Benthic data

Data for benthic composition is presented as mean percentage cover in both tabulate and graphical form for the three main reef types surveyed (fringing, inner barrier and outer barrier reefs) and for four depth bands.

3.4.3 Fish and invertebrate data

Fish and invertebrate data were summarised graphically and via univariate statistics. Data were either summarised for the whole project area or for each main reef type and depth band. Direct counts of fish and invertebrates can be converted to densities per unit area of reef such as density per hectare of reef area (density / ha).

3.5 Preliminary Mapping of Biological Characteristics.

As this report is an intermediate update on survey progress to date (March – September 2006) the final analysis to produce a habitat map for the whole area to be surveyed cannot be produced at this stage. However we can present preliminary maps for the main biological characteristics of part of the Kadavu reef system that has been surveyed up until September 2006.

A Landsat 7 ETM+ satellite image produced by the U.S. Geological Survey (USGS) was purchased for use in the FCRCP. Landsat 7 carries the Enhanced Thematic Mapper plus (ETM+) sensor in support of research and applications activities. Further details are available from the USGS website[1]. The image was acquired on 4th February 2001. Source: Global Land Cover Facility; http://www.landcover.org.)

[1] http://eosims.cr.usgs.gov:5725/DATASET_DOCS/landsat7_dataset.html

Prior to the image being used in the production of preliminary maps, a three-fold correction and masking technique was carried out.

The initial step of the process was to atmospherically correct the image. The process of atmospheric correction accounts for the angle at which the sun was at the time of the capture of the image, commonly referred to as sun zenith angle. The model used, called the MsixS model, is a radiative transfer model that accounts for the path of light from the subject (coral reef) to the satellite sensor through the atmosphere, and the influence of interference of the atmospheric gases on the reflected light (Green *et al.*, 2000). The resulting corrected image was then at a stage where the influence of the atmosphere had been removed and instead the reflected light had simply passed through a vacuum.

The second image processing stage was to mask areas of land from the image that were not to be used in the classification of reef areas in the habitat map. The masking technique employed calculates a ratio between bands 1 and 5 in the satellite image (infra-red and blue areas of the spectrum respectively). The methodological background to such a technique is based on the difference in absorption of light of different wavelengths in water; with infra-red being absorbed entirely by very shallow water and therefore none being reflected and blue light being reflected by all but the deepest and most turbid water bodies. The resulting output image clearly differentiates between areas of land and sea and was used to identify areas of the image containing land and then to subsequently use these as a mask to remove land areas from the image. Removal of land areas in this manner has the advantage that the remaining water bodies containing the target coral reef areas can then assume a much wider range of colours in the image and therefore can aid in the process of correctly identifying different habitat classes comprising the coral reef.

The final stage in the pre-processing of the Landsat image prior to classification was to perform a water column correction technique with the aim to remove the effect that the overlying water column has on the spectral composition of the light reflected by the coral reef. The purpose behind the employment of this technique is that frequently the effect of the water column on the attenuation of light from a coral reef target is far greater than the difference in reflected light caused by the different coral reef types; upon which the classification of habitats is based. The particular technique employed is known as the Lyzenga or band ratioing technique (Lyzenga, 1981). The first step in this process was to extract values of irradiance from sites known from field data to have similar reflectance values prior to the interference of the water column on the reflected light. In this instance, sand sites of different depths were chosen throughout the image. Once these values of light intensity have been log transformed, they can be used to produce ratios of the bands present in the Landsat sensor. In this technique, ratios of the following Landsat bands were calculated; 1/2, 1/3, 2/3. Plotting radiance values from each band against the band to which they are being ratioed and then extracting information on both the gradient and y-intercept of the regression line around these plotted points allows for the calculation of a value representative of the differential effect of the water column between these two bands. The final step was then to use these values to perform a calculation on the bands comprising the image data to produce one depth invariant band for each of the band ratios used. The resulting depth invariant bands were now representative not of the reflectance characteristics of the underlying target coral reef together with the interference of the water column overlying them, but instead only represent the reflectance values of the coral reef target itself. The use of water column corrected imagery in the classification and production of habitat maps has been shown to produce a statistically significant increase in habitat map accuracy (Green *et al*., 2000).

An unsupervised classification, where the computer classifies each pixel into a number of classes prior to the user overlaying field data, was chosen in preference to a more traditional 'supervised classification'. During a supervised classification field data are used to classify the raw spectral signatures of each pixel i.e. areas with a high reflectance of blue light are classified as habitat C. All pixels with a high reflectance of blue light are then classified as habitat C and so on for each habitat type. The process of unsupervised classification simply places each pixel of the satellite image into one of a user defined number of bins based on its reflectance characteristics across the entire spectrum sampled by the remote sensor. Overlaid onto the resulting output image was then the GPS coordinates of survey transect sections classified into each benthic class. Using this information, each of the classes identified by the image processing technique could be assigned to one of the benthic classes to produce the final habitat map. This technique of marrying field data with that information collected by the remote sensor is a form of visual interpretation.

Ideally, a supervised classification would be used to produce the habitat map, however, due to issues of spectral confusion the resulting output maps were of lower accuracy that the map produced by unsupervised classification and visual interpretation described in the previous paragraph. Accordingly, the unsupervised classification technique was used throughout to produce the output habitat maps.

An accuracy assessment was carried out on the output map to ensure its consistency throughout. This assessment was conducted using the output map and then locating sites of known habitat classification from 150 field collected data points. If the map indicated the site to be the same habitat as that indicated by the field data, then this site was given a score of 1; if classified incorrectly, the site was given a score of zero. By simply producing a ratio of correctly classified points to incorrectly classified ones; an assessment of overall accuracy was obtained.

3.6 Environmental Awareness and Community work

3.6.1 Kadavu Qoliqoli Management Support Team

CCC has been actively engaged in Kadavu since June 2005 and has maintained a staff team assisting the Kadavu Qoliqoli Management Support Team (KQMST). The KQMST are subdivision of the FLMMA (Fiji Locally Managed Marine Areas) network.

KQMST was set up in early 2005 to help the local communities of Kadavu set up and manage MPAs (Marine Protected Areas) within their qoliqolis (traditional fishing grounds) with the primary aim of providing a better livelihood for future generations. In this area most of the MPAs have been set up in the 18 months since KQMST was established, however a few have been established for much longer. Kandavu has 33 qoliqolis and 26 MPAs, hence nearly every qoliqoli has an MPA - an achievement that in itself is great news and is not repeated in many other countries of the world. CCCs staff team have been assisting the KQMST undertaking surveys to compare the condition of the coral reefs in fished and non-fished areas (Marine Protected Areas). Additionally, CCC has been involved in training of the core KQMST team, enhancing the techniques that are used to provide a more holistic approach to the collection of data as well as presenting the scientific findings of the studies undertaken to each of the communities that have custody of the qoliqoli.

3.6.2. Training for Community Fish Wardens

Objective: Provide training in scuba diving and reef resource survey and assessments, including MPA-orientated and practical scientific training in data acquisition, management, analysis and synthesis. Training will be offered primarily to each of the 30 or so communities at Kadavu.

A total of 10 Community Fish Wardens were successfully trained in scuba diving, reef assessment and monitoring, and data management. Eight of the participants were from Lau and were provided through collaboration with WWF while two were local participants from Dravuni Island village. The names of the WWF participants were Ilaitia Vakatawa, Jone Halafi, Juita Vakau, Ana Takayawa, Feskato'a Elizabeth, Isimeli Salote, Soqo Mere and Sauya Valu with Raijeli Bola and Rusila Pone being the Community Fish Wardens from Dravuni.

Fijian Community Fish Wardens Raijeli Bola (foreground left) and Rusila Pone (one back from foreground right) undergoing training in fish identification skills.

Community Fish Warden Raijeli Bola receiving one-on-one training in the identification of hard coral by Amy Tamblin (Community Liaison Officer)

3.6.3. Training scholarships for USP students

Objective: Provide four-week training scholarships for USP students. The training programme will be similar to those offered to Community Fish Wardens but with an expanded curriculum in the technical components of data processing and management

To date, a total of four USP students successfully enrolled onto and completed the CCC technical training scholarships. In addition to these activities held by CCC at its base of operations on Dravuni Island, two one-week workshops have been conducted by CCC science staff at the University aimed at increasing technical capacity within the University graduates to enable coral reef conservation activities to be widened.

3.6.3 Reef Awareness Field Trips

Objective: Marine awareness field trip visits to the CCC base at Kadavu will be provided for parties of children from each community, where they will be provided with interactive reef awareness educational activities, including snorkelling excursions to local coral reefs

Six sets of snorkelling equipment have been purchased to date. Each class at Dravuni Island primary school has to date been given a minimum of 12 hours contact time with the Community Liaison Officer. Topics covered in the sessions have included the importance of coral reefs to the socio-economic well being of the community, basic coral reef ecosystem ecology and the links between coral reefs, seagrass beds and mangroves. In addition to these theoretical classroom-based sessions, each class has been taken on a four guided snorkel tours around the reef adjacent to Dravuni Island to assist in the understanding of the interdependencies of the reef inhabitants and some of the factors that can influence coral overall coral reef health.

One of the classes from Dravuni Island primary school that has been included in the coral reef awareness programme.

School children from Dravuni Island primary school following an amateur dramatics presentation given to the community on the importance of coral reefs to the continued well-being of the community.

As part of the nation wide 'splash for trash' and international 'dive into Earth days', all of the school classes included in the programme had a class-room based session on the threats posed by solid waste pollution in the marine environment together with steps (such as recycling) that can be taken to reduce this problem. Practical work on these days included beach and foreshore cleanups. As a result of these programmes and with the assistance of CCC, recycling bins have now been sited at key locations throughout the community and with the assistance of Yaukuve Island resort, the solid waste collected is now transferred to the mainland for recycling.

School children from Dravuni Island primary school making a poster at the start of the national splash for trash activity.

4. RESULTS

4.1 Survey Progress

Of the 405 survey stations originally outlined, a total of 77 stations were completed between March and September 2006 (Table 4). The start positions of all baseline survey stations completed are shown in Figure 3. Between March and September 2006 a total of 340 survey dives were conducted along 308 transects. This equates to approximately 254 survey team hours, and with one baseline survey team consisting of two divers, 508 man-survey-hours. With baseline surveys collecting species abundances of approximately 300 target species and categories, volunteers taking part in the assessment of Kadavu reefs have made 76,200 *in situ* recordings to date.

Surveying activity has focussed on completing the more difficult survey stations when possible which has resulted in stations on the outside of the main ribbon reef making up the majority of completed sites during the survey period.

Table 4. Summary of Survey Progress at Kadavu: March - September 2006

Survey Station Type	No. Completed	No. Planned	Proportion completed (%)
Fringing	15	109	13.76
Inside Atoll*	0	49	0
Outside Atoll*	0	56	0
Inside Ribbon	17	103	16.50
Outside Ribbon	45	88	51.14
Total	**77**	**405**	**19.01**

* = Atoll refers to the northern most reef (Solo Reef)

All of the data derived from these survey stations have been analysed and reported in this document. Preliminary maps have focussed on one depth band (‘Shallow’ or 6 ± 1 m) to reduce the total number of maps in the report. Comparison between the depth bands surveyed has been completed for the main biotic and abiotic characteristics selected. A preliminary comparison between reef types is also presented although sample number is rather variable between reef types (Table 4).

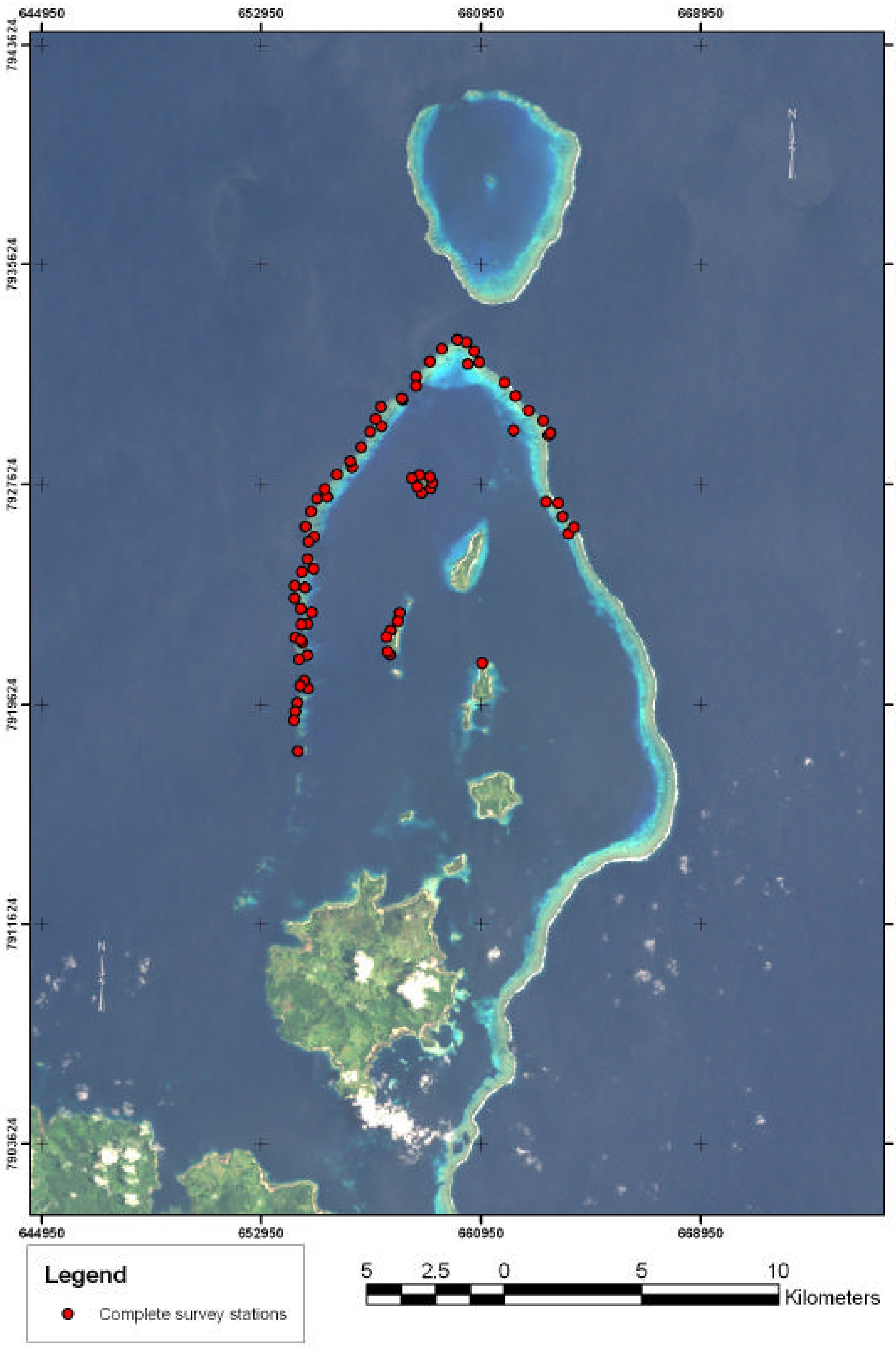


Figure 3: **Map of the project area indicating the survey stations completed between March and September 2006.**

4.2 Oceanographic, Climate and Anthropogenic Impact Data

4.2.1 Underwater Visibility

Mean values for underwater horizontal visibility, recorded by survey divers, are shown below (Figure4). Visibility was generally high on the reefs surveyed and was greatest on the seaward facing sides of the main ribbon reef (19 – 21 m). The lowest visibility was recorded on fringing reefs (13 – 17 m). Horizontal visibility also consistently decreased with increasing depth for all reef types. Variations in visibility measurements within reef type were greatest for fringing reefs at the surface depth band (S.E. = 1.89).

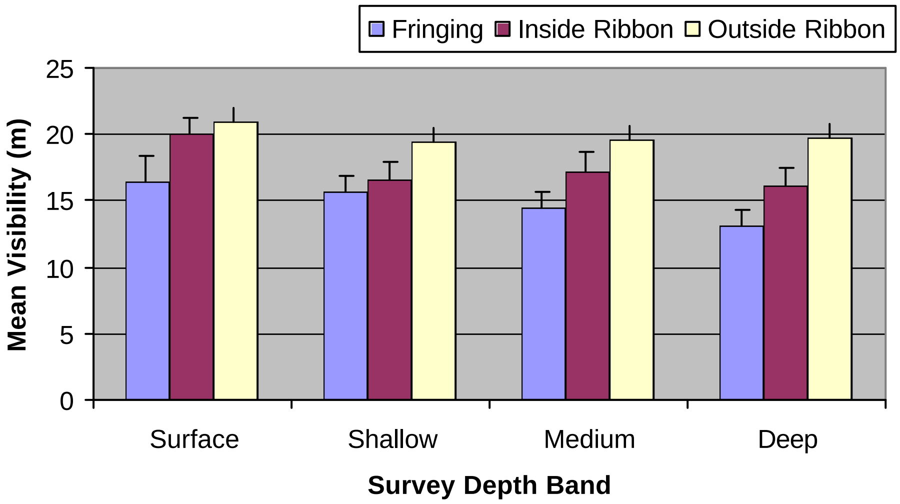


Figure 4 Horizontal underwater visibility recorded by survey divers for three reef types and four depth bands (Mean values + Standard Error).

Sample sizes: Fringing = 15; Inner Ribbon = 17; Outer Ribbon = 45.

4.2.2 Wind Strength and Direction

The direction and strength of prevailing winds during the first seven months of the Kadavu Project are presented in Figure 5. Estimates of wind were recorded on 93.5% of surveys with the remaining 6.5% experiencing calm weather (no wind). Northeasterly winds were most prevalent with 28.17% of all recordings. Two-thirds of all recordings originated from the east (all easterlies combined). Wind strength was generally light, with 86.11% of observations between 1 and 3 on the Beaufort scale.

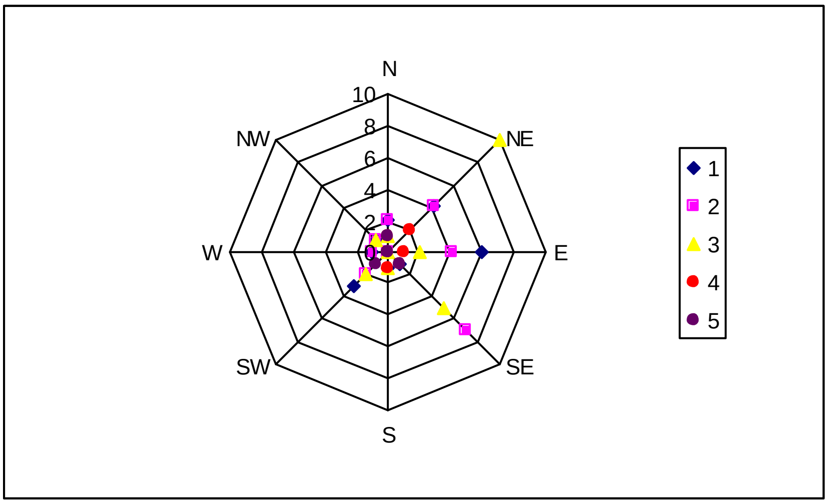


Figure 5 Radar diagram showing the prevailing winds recorded during the first 7 months of the Kadavu Project.

Points represent the frequency of occurrence of combinations of wind direction and strength. Symbols represent wind strength measured using the Beaufort scale.

4.2.3 Current Strength and Direction

Recordings of current direction and strength during the first seven months of the FCRCP in Kadavu are summarised in Figure 6. Currents were observed on 62% of surveys on a scale of weak to strong. No current was observed during the remaining 38% of surveys. Current direction varied considerably during the study period but was predominantly from the north, south, west and southwest. Generally currents were light with 72.34% of observations recorded as weak in strength. Only 8.5% of surveyors recorded a strong current.

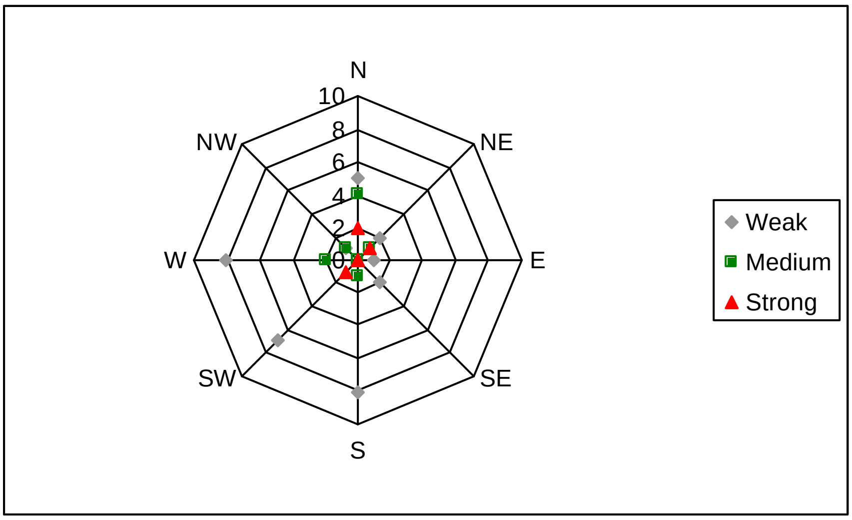


Figure 6 Radar diagram showing mean underwater current recorded in the northern Kadavu Islands between March and September 2006.

Points represent the frequency of occurrence of current strengths from different directions. Symbols represent current strength on a scale of weak to strong.

4.2.4 Surface Impacts

Surface impacts recorded over the first seven months of the FCRCP in Kadavu are presented in Figure 7 for the three reef types surveyed. All surface impacts were recorded at low levels (<7% frequency). The most commonly recorded impact was the 'Other' category, followed by litter and macroalgae with very little driftwood seen. No fishing nets or sewage were recorded during the surveys.

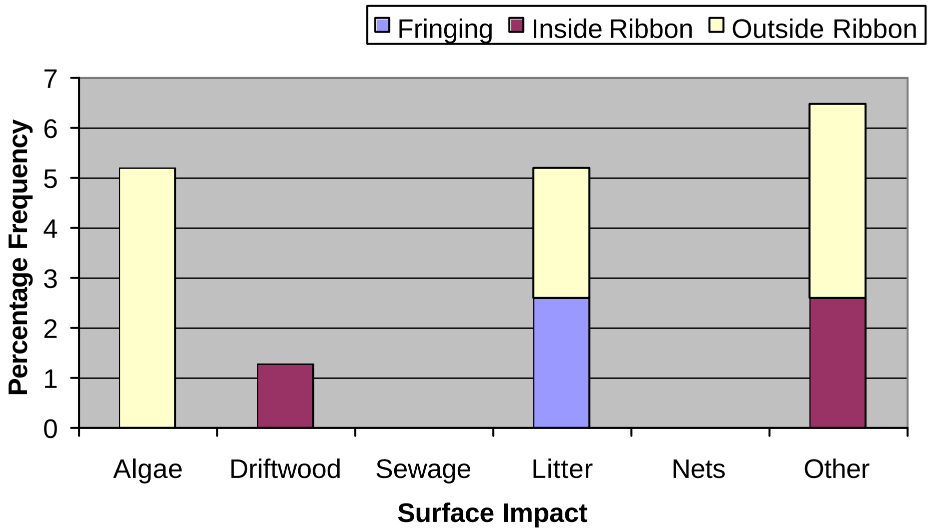


Figure 7 Frequency of observation of surface impacts recorded at Kadavu.

4.2.5 Sub-surface Impacts

Figure 8 shows the relative frequency of sub-surface impacts for the three main reef types. The most frequently observed impacts were to hard corals, namely damage, bleaching and disease, which were recorded at all reef types. Coral damage was observed more often on the seaward side of the ribbon reef and on fringing reefs. Coral bleaching was recorded more often on the ribbon reef than on fringing reefs whilst coral disease was seen more often on fringing reef sites. Occurrence of litter was low and relatively similar between reef types whilst one observation of sedimentation was recorded for fringing reefs as 'Other'.

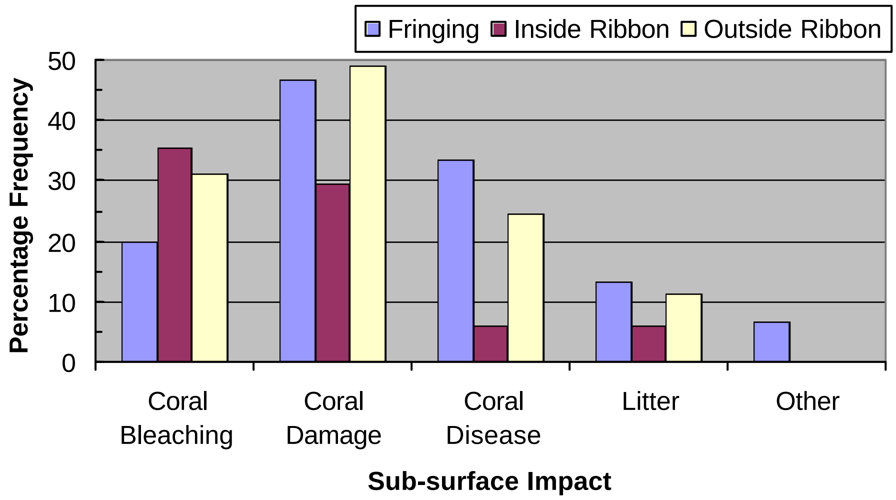


Figure 8 Relative Frequency of Sub-surface Impacts for three reef types in the northern Kadavu region.

4.3 Baseline Biophysical Surveys

4.3.1 Benthic Composition

In this section we provide information on the main types of biotic and abiotic substrata present at the four depth bands and for three main reef types that have been surveyed to date, fringing reefs, the inner side of the main barrier or ribbon reef in the main lagoon (inner barrier) and the outer side of the ribbon reef (outer barrier). Table 5 shows the mean values for six benthic categories at each depth band and for each main reef type. Sample number was similar for fringing and inner barrier sites (15 and 17 stations respectively) but considerably higher for outer barrier sites (45 stations).

In terms of abiotic substrata, available bedrock decreased with increasing depth for all reef types. Bedrock was highest at fringing reefs sites and made up more than half of available space (55%) at the surface depth band (2 metres) for this reef type. Low levels of bedrock were recorded on inner barrier sites where sand dominated the abiotic substrata particularly at the medium and deep bands (12 and 16 metres). Percentage cover of sand was also high on fringing reefs below 6 metres. Coral rubble cover was low on the outer barrier sites with the highest level recorded at 16 metres depth (6.7%). For the inner barrier reef, rubble was considerably higher, reaching almost 20% at the shallowest survey band (2 m).

For the selected biotic components (Table 5) macroalgae levels were low and generally less than 10% at all reef types and depth bands. The highest algal cover of 12.97% was recorded on outer barrier reefs in shallow water (2m). Mean crustose coralline algae cover was very low on fringing reefs (<2%) and also low on inner barrier reefs (<7%). Higher cover of coralline algae was recorded on outer barrier reefs but was still less than 14% for any depth band. Live hard coral cover was considerably higher on outer barrier reefs than on the other two reef types reaching a maximum mean value of 33.56% at the shallow depth band (6 m).

Hard coral cover did not exceed 10% at any depth band for fringing or inner barrier reefs and was highest in shallow water.

Table 5 **Mean Percentage Cover of selected Benthic Categories for four depth bands and three reef types of the Great Astrolabe Reef.**

Fringing (n = 15)	Bedrock	Rubble	Sand	Coralline Algae	Algae	Live Hard Coral
Surface	54.92	5.50	10.92	2.17	2.00	10.00
Shallow	22.75	11.08	40.67	0.25	2.25	5.08
Medium	22.75	10.83	35.75	1.08	6.42	7.33
Deep	12.25	12.25	32.42	1.58	5.08	9.58
All Depths combined	**28.17**	**9.92**	**29.94**	**1.27**	**3.94**	**8.00**

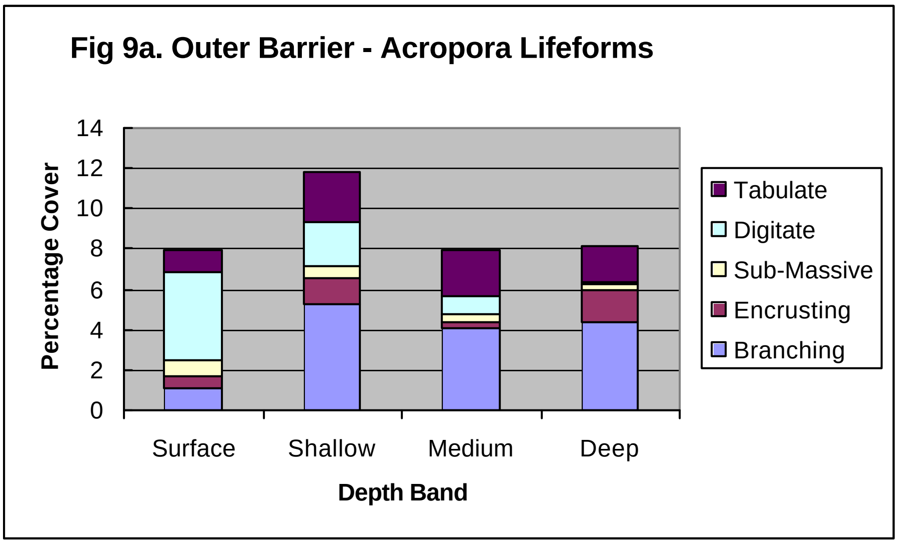
Inner Barrier (n = 17)	Bedrock	Rubble	Sand	Coralline Algae	Algae	Live Hard Coral
Surface	27.21	19.93	12.79	6.47	3.46	9.41
Shallow	8.90	14.19	49.26	1.62	8.60	5.51
Medium	5.74	11.40	68.24	0.66	5.22	2.87
Deep	2.79	10.29	65.44	1.99	8.38	3.24
All Depths combined	**11.16**	**13.95**	**48.93**	**2.68**	**6.42**	**5.26**

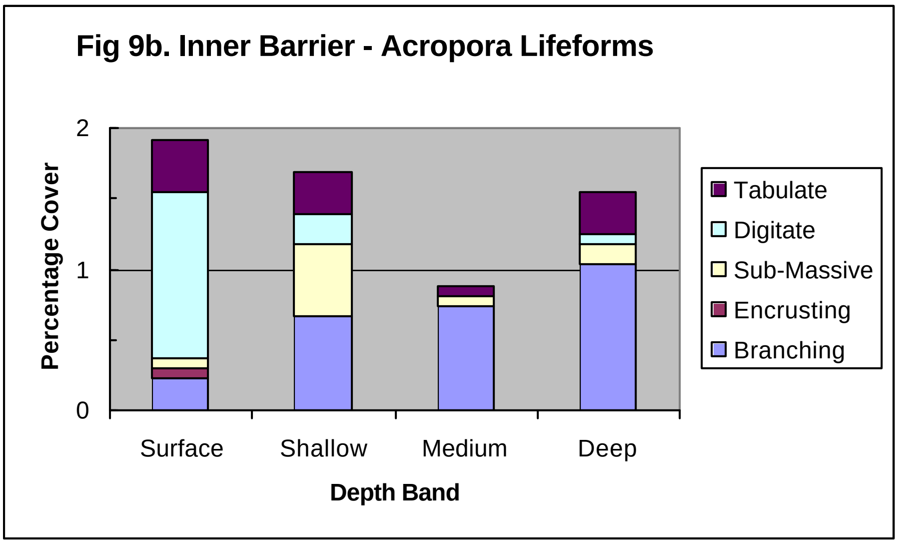
Outer Barrier (n = 45)	Bedrock	Rubble	Sand	Coralline Algae	Algae	Live Hard Coral
Surface	37.53	1.69	0.72	9.11	12.97	23.33
Shallow	25.19	1.03	0.89	13.89	7.78	33.56
Medium	23.03	5.97	2.47	11.69	6.50	30.00
Deep	21.28	6.72	3.14	13.00	9.81	29.44
All Depths combined	**26.76**	**3.85**	**1.81**	**11.92**	**9.26**	**29.08**

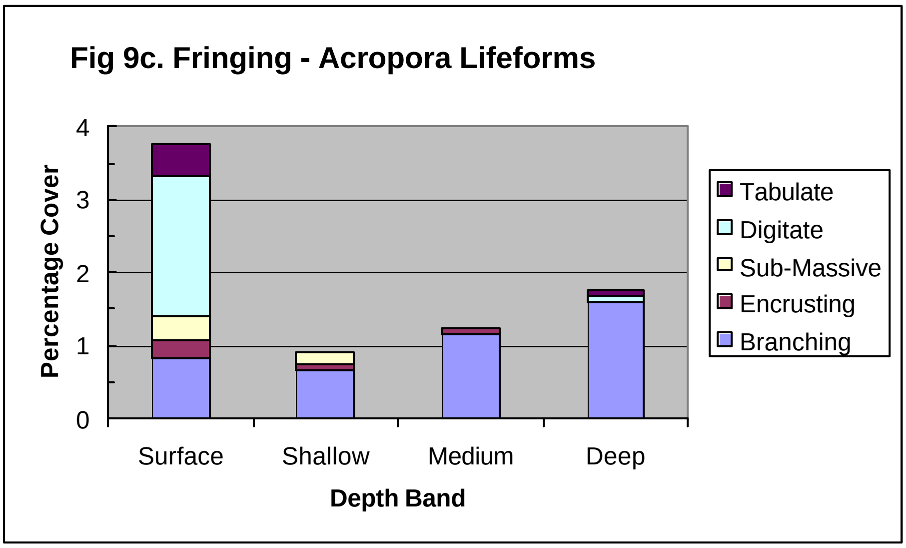
Figure 9 below shows the mean cover of *Acropora* corals at each reef type for the five main lifeforms of this genus.

The three graphs indicate that mean cover of *Acropora* corals is generally low for all reef types in the area surveyed to date. *Acropora* cover was highest on Outer Barrier sites (Fig 9a.) ranging from 8.06% (2m depth) to 13.97% (6 m depth). Total cover of *Acropora* was very low on the Inner Barrier (Fig 9b.) and did not exceed 2% at any depth band. Fringing reefs fared slightly better with *Acropora* cover reaching 3.75% in very shallow waters (2m).

Figure 9. ***Acropora* coral cover at four depth bands for three reef types in northern Kadavu.**







In terms of *Acropora* lifeforms, digitate corals were dominant in shallow waters followed by branching and tabulate forms. As depth increased the proportion of branching *Acropora* generally increased, particularly at inner barrier and fringing reef sites. Encrusting *Acropora* was most prevalent on the Outer Barrier, recorded at very low levels on fringing reefs but generally absent on inner barrier sites. Tabulate *Acropora* corals were either rare or absent at the depths surveyed on fringing and inner barrier reefs.

A plot of Non-*Acropora* corals for the main lifeforms (Figure 10) firstly indicates that mean cover of Non-*Acropora* hard corals is considerably greater than for *Acropora* corals for all reef types (Figures 9 and 10). Secondly cover of non-*Acropora* corals is highest on the Outer Barrier with mean values ranging from 15.28% at 2 metres depth to 21.81% at 12 m. Total Non-*Acropora* cover increases with increasing depth on the Outer Barrier reef (Fig. 10a) and on fringing reefs (Fig. 10c). The opposite pattern is shown on the inner side of the barrier (Fig 10b) with a marked decrease in coral cover with increasing depth.

The main Non-*Acropora* lifeforms present were encrusting, massive and submassive forms with the former most prevalent at all three reef types. Foliose corals were recorded most often on the Outer Barrier at low levels (<1.5%) but were absent from the inner barrier reef and only recorded rarely on fringing reefs at 12 and 16 metres depth. Mushroom corals were also recorded at low levels at all reef types but were only seen at one depth band on the inner barrier reef. Branching corals were recorded consistently (2-2.5% cover) at all depth bands on the Outer Barrier reef but were rare on fringing reefs and very rare or absent on the inner barrier reef.

Figure 10 Non-*Acropora* coral cover at four depth bands for three reef types at Kadavu.

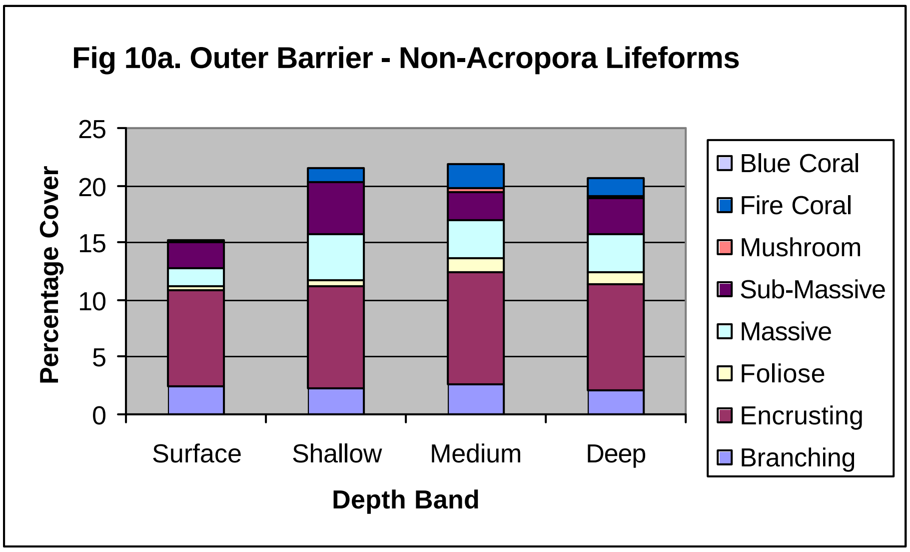
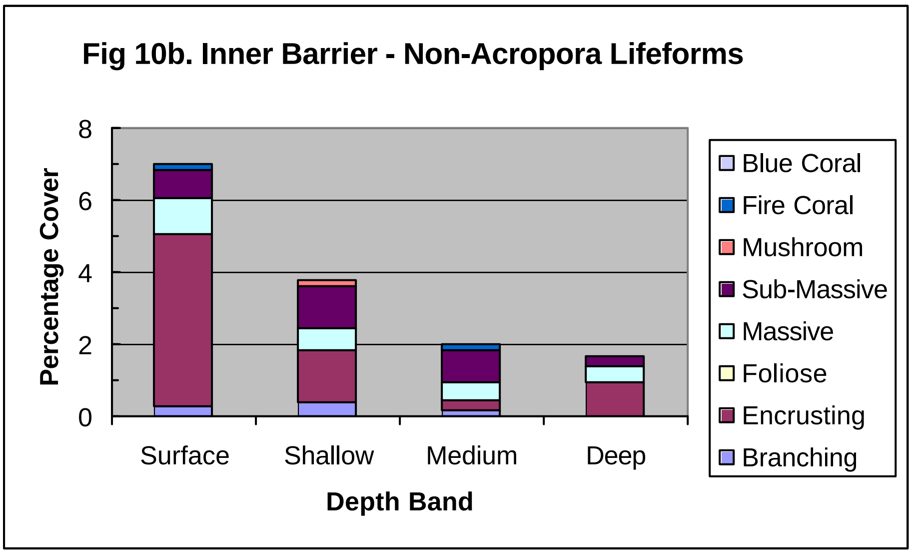
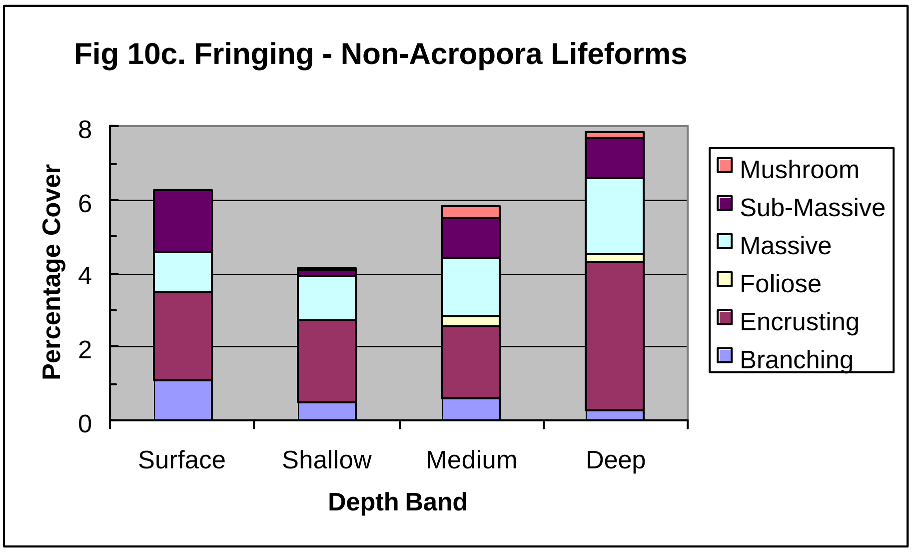


Figure 10 (continued)





4.3.2 Reef Fish Abundance

Reef fish densities are presented in Table 6 for selected families and one species, the bumphead parrotfish (*Bolbometopon muricatum*), at the four depth bands surveyed at each reef type: fringing, inner barrier and outer barrier reefs. Comparison between reef types for overall means (all depths combined) indicates that densities were generally higher on the barrier reef than on fringing reefs (Figure 11). The outer barrier reef contains the highest densities of Surgeonfish (Acanthuridae), Parrotfish (Scaridae), Butterflyfish (Chaetodontidae) and Wrasse (Labridae) while the inner side of the barrier reef had the highest densities of Rabbitfish (Siganidae), Triggerfish (Balistidae) and Emperors (Lethrinidae). The highest density per family was recorded for Surgeonfish on the outer barrier (94.36 per 1000 m^2), which was more than triple the density seen on fringing reefs (29.83 per 1000 m^2). Parrotfish densities were also considerably higher on the Outer Barrier, more than double than that found on the other reef types. Densities of groupers were similar between reef types (3.87 – 4.33 individuals per 1000 m^2) and marginally higher on fringing reefs. Bumphead parrotfish were recorded at low densities on the Outer Barrier reef on a number of occasions.

Figure 11 Reef Fish Densities for Selected Families on three main reef types in the northern Kadavu region (mean value for all depths combined).

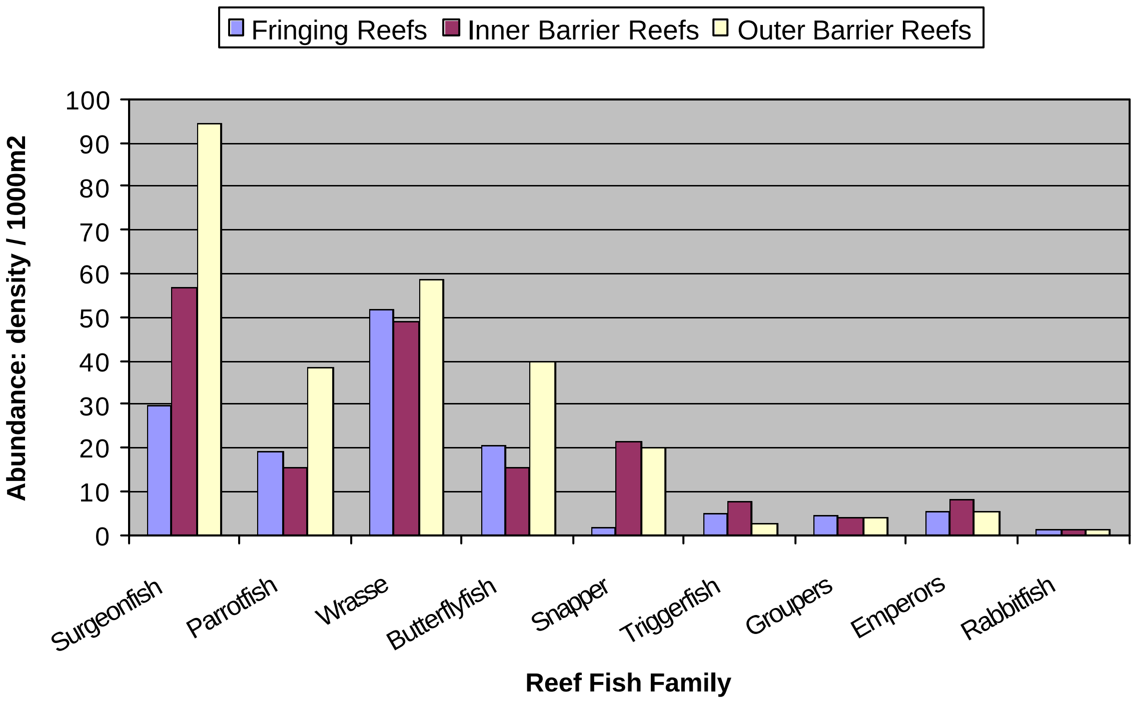


Table 6 **Reef Fish Densities for nine families and one species at four depth bands and three reef types in northern Kadavu.**
(Number of individuals per 1000 m^2)

	Surgeonfish	Parrotfish	Rabbitfish	Butterflyfish	Wrasse	Triggerfish	Groupers	Emperors	Snapper	Bumphead Parrotfish
Fringing Reefs (n = 15)										
Surface	25.67	17.33	2.33	24.00	46.67	9.67	3.33	10.67	5.00	0.00
Shallow	18.00	18.33	0.67	16.67	30.00	3.33	5.33	5.33	0.67	0.00
Medium	43.33	26.00	0.67	21.67	88.67	4.00	4.33	3.33	0.33	0.00
Deep	32.33	14.00	0.33	19.33	42.00	3.00	4.33	1.67	0.33	0.00
Overall Mean	**29.83**	**18.92**	**1.00**	**20.42**	**51.83**	**5.00**	**4.33**	**5.25**	**1.58**	**0.00**
Inner Barrier Reefs (n = 17)										
Surface	76.76	10.88	0.00	14.12	38.82	7.65	4.41	8.82	54.12	0.00
Shallow	56.56	15.63	0.31	12.81	56.56	9.69	3.13	1.56	5.00	0.00
Medium	77.06	25.59	4.71	26.18	66.18	3.24	4.71	19.41	6.76	0.00
Deep	16.76	9.12	0.29	9.41	34.71	10.00	3.24	2.06	19.41	0.00
Overall Mean	**56.79**	**15.30**	**1.33**	**15.63**	**49.07**	**7.64**	**3.87**	**7.96**	**21.32**	**0.00**
Outer Barrier Reefs (n = 45)										
Surface	90.67	29.67	1.78	38.00	80.67	2.44	3.00	1.67	29.00	0.22
Shallow	110.11	49.43	1.93	42.27	53.30	1.93	3.30	5.80	32.39	1.02
Medium	72.89	23.89	1.00	37.44	47.78	2.44	4.44	7.44	6.33	0.11
Deep	103.78	50.22	0.44	40.78	52.67	3.33	5.22	6.00	11.78	0.00
Overall Mean	**94.36**	**38.30**	**1.29**	**39.62**	**58.60**	**2.54**	**3.99**	**5.23**	**19.87**	**0.34**

4.3.3 Target Invertebrate Density

The density of selected invertebrate groups is presented in Table 7 for four depth bands at each reef type and as overall mean densities for all depths combined (Figure 12). Values are presented as the number of individuals in 1000 m^2 of reef area. Highest densities of giant clams, octopus and edible sea cucumbers were recorded on fringing reefs for overall mean values (all depths combined). The highest density of sea cucumbers at a particular depth band was found in very shallow water (2 m.) on fringing and inner barrier reefs. Long-spined sea urchins were rarely recorded on inner barrier reefs and low densities were observed at fringing and outer barrier reefs in comparison to the mainland 'Coral Coast'. Very few Crown of Thorns seastars (*Acanthaster plancii*) or Triton Trumpet shells (*Charonia tritonis*) were recorded on surveys for all reef types. Octopus densities were high on both fringing and outer barrier reefs with greater numbers seen on the medium and deep transects. Sea urchin densities were greater in shallow water (2- 6 m depth) for fringing reefs but the opposite was seen on outer barrier reefs with highest densities recorded at 12 metres.

Figure 12 **Invertebrate Densities on three main reef types in the northern Kadavu Region (mean values for all depths combined).**

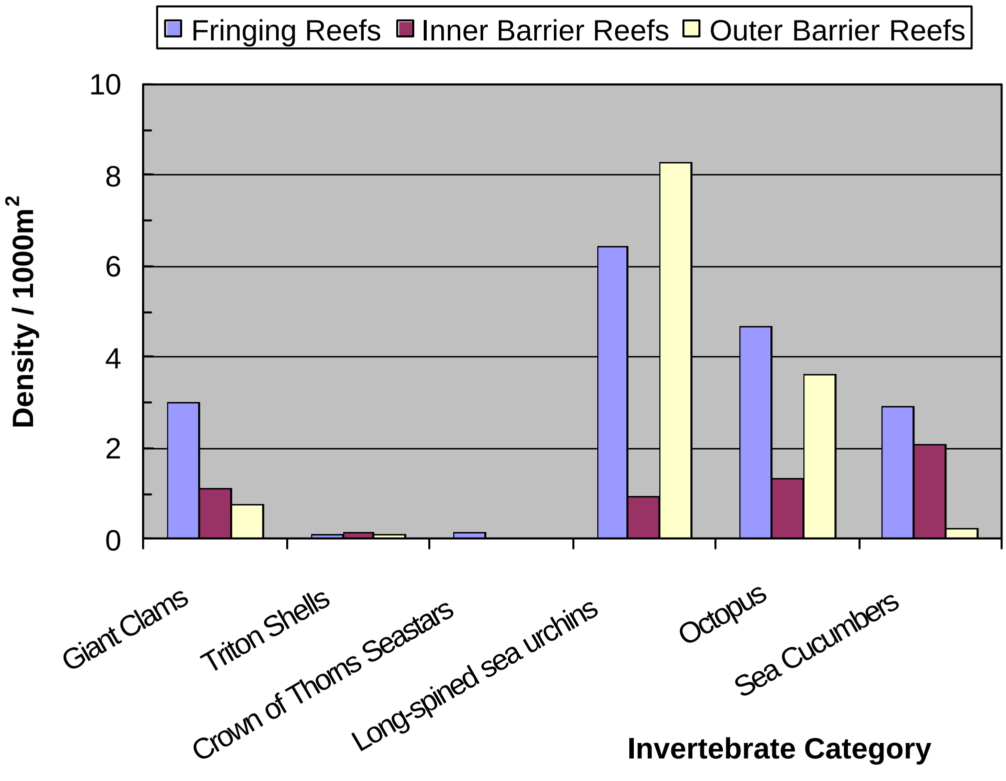


Table 7 Densities of selected invertebrate s at four depth bands for three reef types in northern Kadavu (Number of individuals per 1000 m^2)

Fringing Reefs (n = 15)	Giant Clams (*Tridacna*)	Triton Shells	COTs	Sea Urchins	Octopus	Edible Sea Cucumbers
Surface	5.00	0.00	0.33	5.33	0.67	4.33
Shallow	3.00	0.00	0.00	17.00	1.00	3.00
Medium	1.67	0.33	0.00	2.00	13.00	1.33
Deep	2.33	0.00	0.33	1.33	4.00	3.00
Overall Mean	**3.00**	**0.08**	**0.17**	**6.42**	**4.67**	**2.92**
Inner Barrier Reefs (n = 17)						
Surface	1.76	0.00	0.00	1.18	0.00	3.53
Shallow	1.00	0.00	0.00	0.00	3.00	0.33
Medium	0.88	0.59	0.00	1.47	1.76	2.06
Deep	0.88	0.00	0.00	1.18	0.59	2.35
Overall Mean	**1.13**	**0.15**	**0.00**	**0.96**	**1.34**	**2.07**
Outer Barrier Reefs (n = 45)						
Surface	0.89	0.00	0.11	2.67	0.11	0.22
Shallow	0.45	0.11	0.00	4.77	3.41	0.11
Medium	1.11	0.11	0.00	17.11	6.22	0.22
Deep	0.56	0.11	0.00	8.56	4.78	0.44
Overall Mean	**0.75**	**0.08**	**0.03**	**8.28**	**3.63**	**0.25**

Notes: COT = Crown of Thorns seastar; Edible sea cucumbers includes *Holothuria edulis, H. fuscopunctata, H. nobilis, H. scabra* and *Stichopus chloronatus*

4.4 GIS Contour Mapping

The previous section provides information on average values for selected ecological criteria at particular depth bands and reef types. However, the data in this format does not pinpoint exactly where in the survey area there are high densities of reef fish or invertebrates or the parts of the reef systems with high coral cover or biodiversity.
Presentation of data as a series of contour maps enables spatial comparison of ecological criteria across the study area. In this section we present contour maps for a range of coral reef criteria for one of the four depth bands surveyed ('shallow' depth band of 6±1 m.). This depth was selected as it is the optimal depth for hard coral cover and diversity on most reef systems, which has been positively correlated with the abundance and diversity of motile fauna, particularly reef fish.

4.4.1 Benthic Cover

Percentage cover distributions of selected benthic categories are presented in Figures 11-18 below. Areas of high cover of bedrock were identified on the outer barrier reef to the northwest of Vanuakula Island, due west of Yaukuvelevu Island and due east of the northern tip of Dravuni Island. Bedrock cover reached between 39% and 63% in these locations (Figure 11). High cover of bedrock was also recorded on fringing reefs around the southern end of Vanuakula and on inner barrier reefs in the southeast corner of the area surveyed. Percentage cover of coral rubble was low on the eastern part of the barrier reef (Figure 12). A few small areas with a high cover (32-55%) of rubble were found on the western barrier and were located next to coral reef channels at the ends of sections of the barrier reef. Medium levels of coral rubble (10-16%) were also observed around Vanuakula Island.
Crustose coralline algae (CCA) was patchily distributed (Figure 13) with a number of 'hotspots' of high cover (25-42%) along the seaward side of the main barrier reef on both the east and west sides. Low CCA cover was recorded on fringing reefs around islands (<2%) and on some sections of the barrier reef. Macroalgal cover was generally low on all reef types surveyed (Figure 14) with the exception of the inner side of the barrier reef due east of Dravuni Island where cover reached 30-48%.

Percentage cover of hard corals is shown by Figures 15-17 for *Acropora*, Non-*Acropora* and total hard coral cover respectively. The plots show that hard coral cover is high along the barrier reef, particularly on the outer seaward side in the north and north east. Percentage cover of *Acropora* corals was greatest in this region near the northern tip of the reef, reaching between 31% and 50% cover (Figure 15). *Acropora* cover was low on fringing reefs and lower on the western barrier reef than on the eastern side. Non-*Acropora* coral cover was also higher on the eastern barrier with highest levels recorded along the seaward side of the north-eastern section approximately 5 km in length (Figure 16). Fringing reefs possessed low levels of Non-*Acropora* coral cover while the western barrier reef was characterised by a more patchy distribution with a few small areas of high percentage cover along the western side facing the Kadavu channel. A plot of total live hard coral cover emphasises the high abundance of hard corals in the north and northeast of the survey area with a particularly high percentage cover (48-68 %) just east of the northern tip of the main barrier reef (Figure 17)

Total biotic cover mirrors this north-east skewed distribution pattern but also shows that parts of the western barrier reef to the west of Yaukuvelevu Island have substantial levels of overall biotic cover. Lowest levels were generally recorded on fringing reefs.

Figure 13 Percentage bedrock cover for the area of reefs surveyed in northern Kadavu.

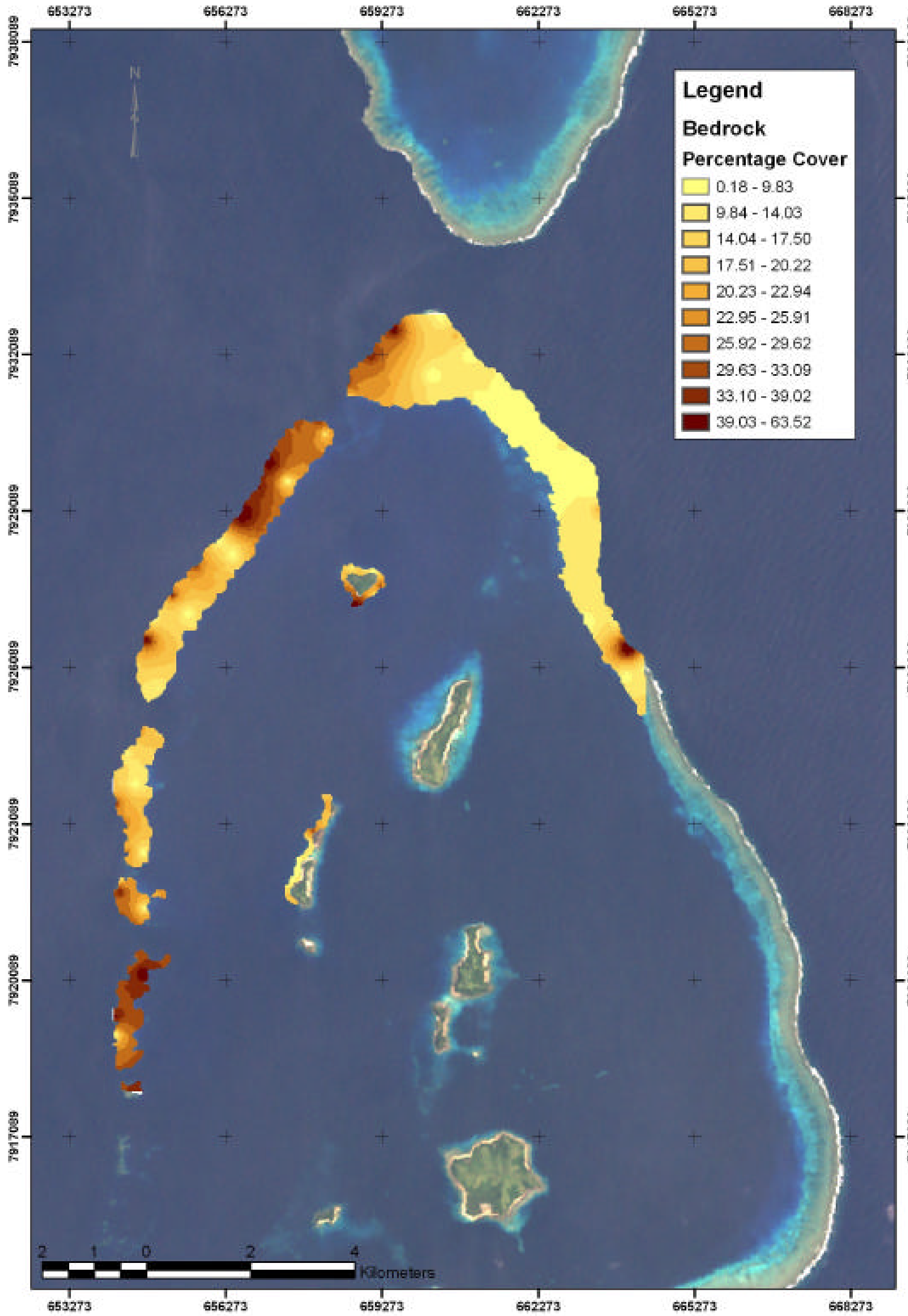


Figure 14 Percentage Rubble cover for the area of reefs surveyed in northern Kadavu.

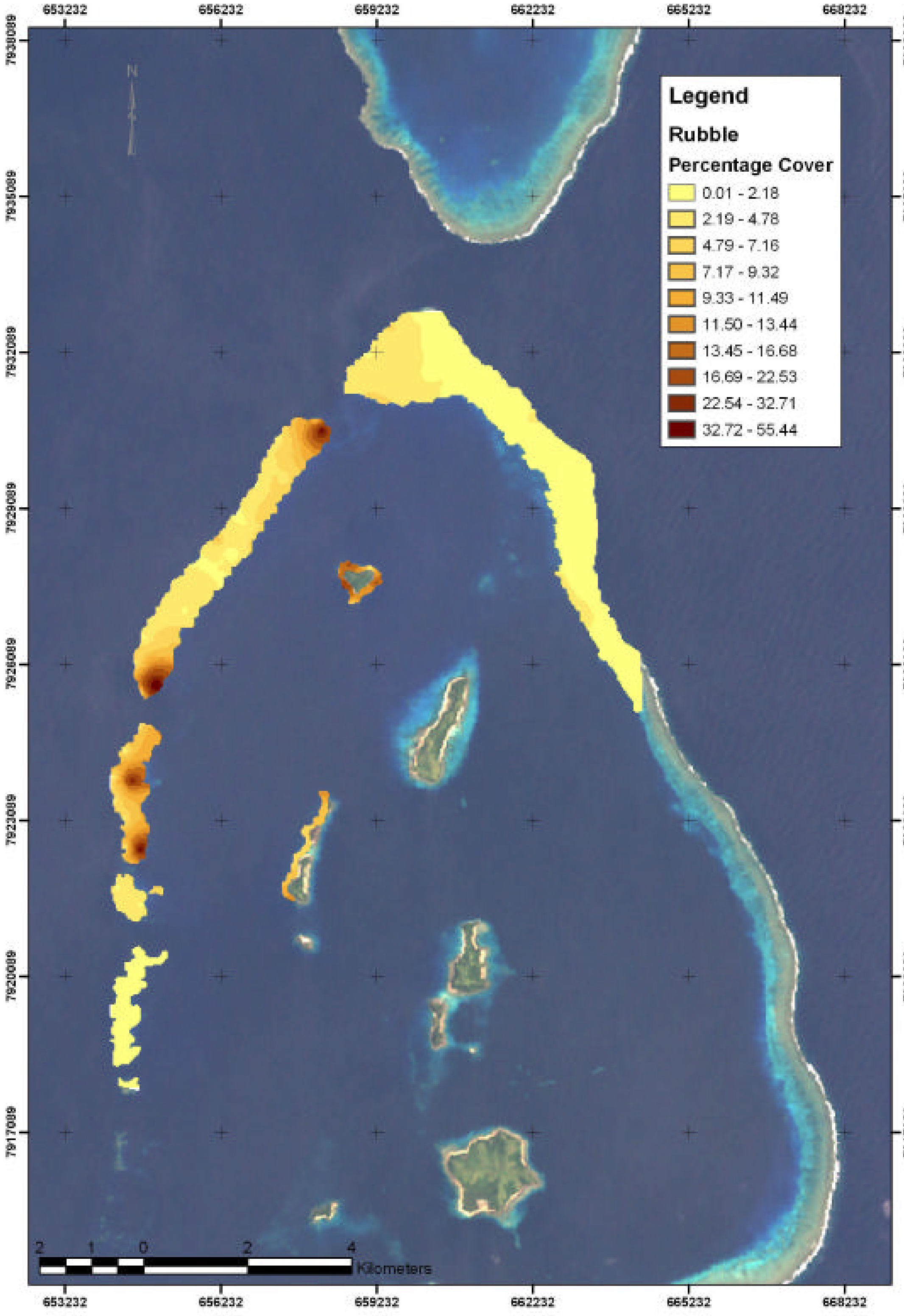


Figure 15 Percentage of Crustose Coralline Red Algae for the area of reefs surveyed in northern Kadavu.

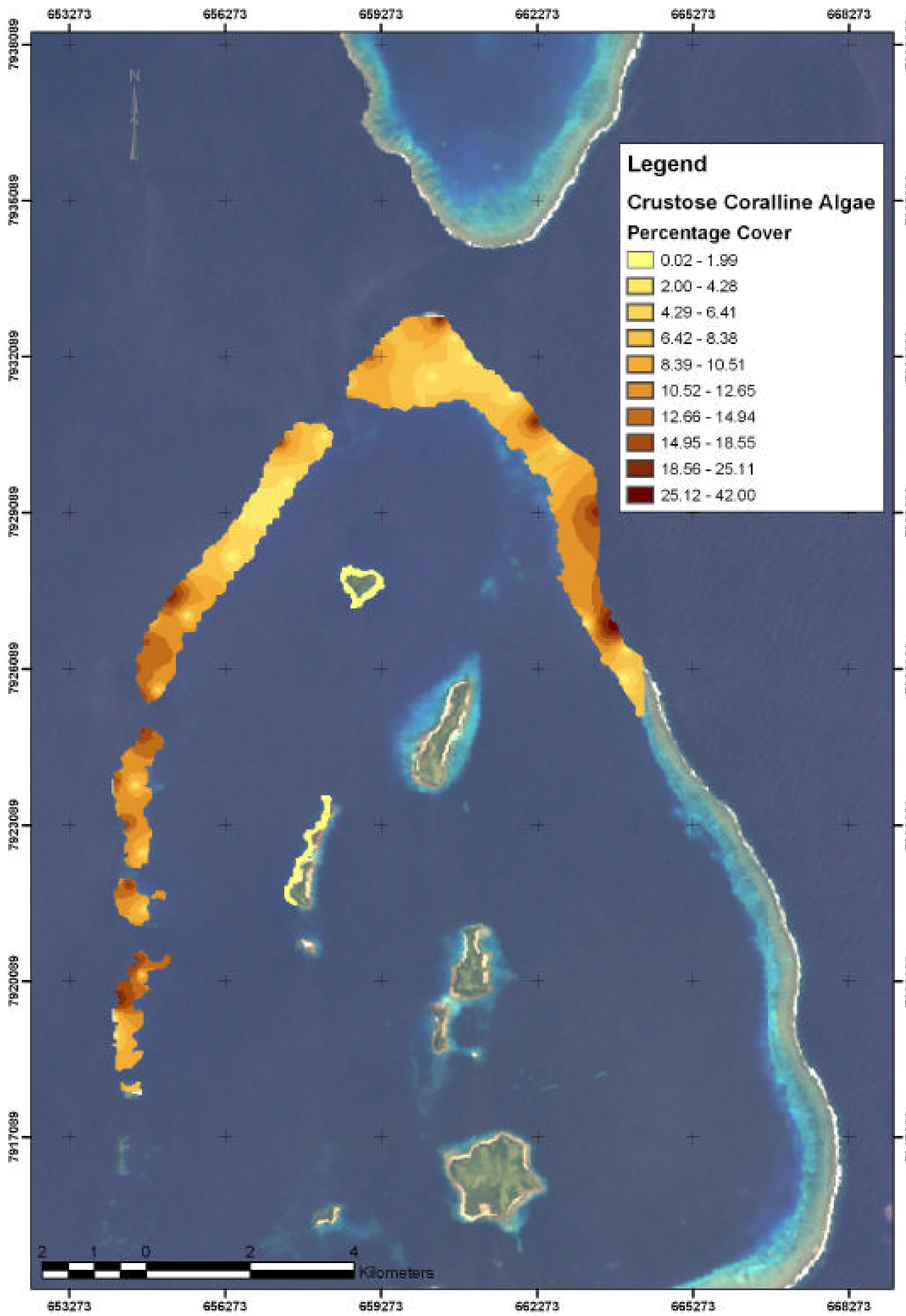


Figure 16 Percentage cover of macroalgae for the area of reefs surveyed in northern Kadavu.

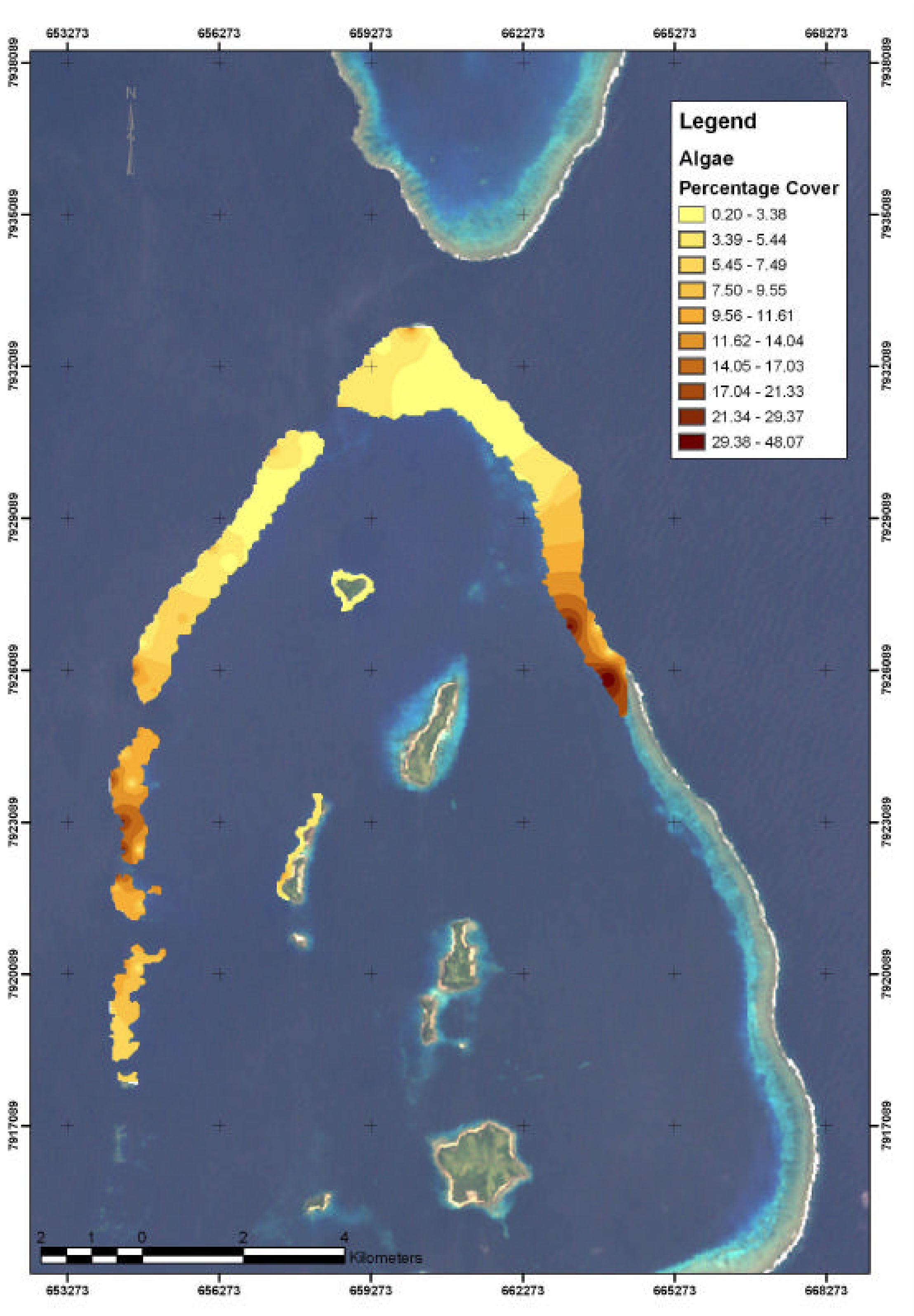


Figure 17 Percentage Cover of *Acropora* corals for the area of reefs surveyed in northern Kadavu.

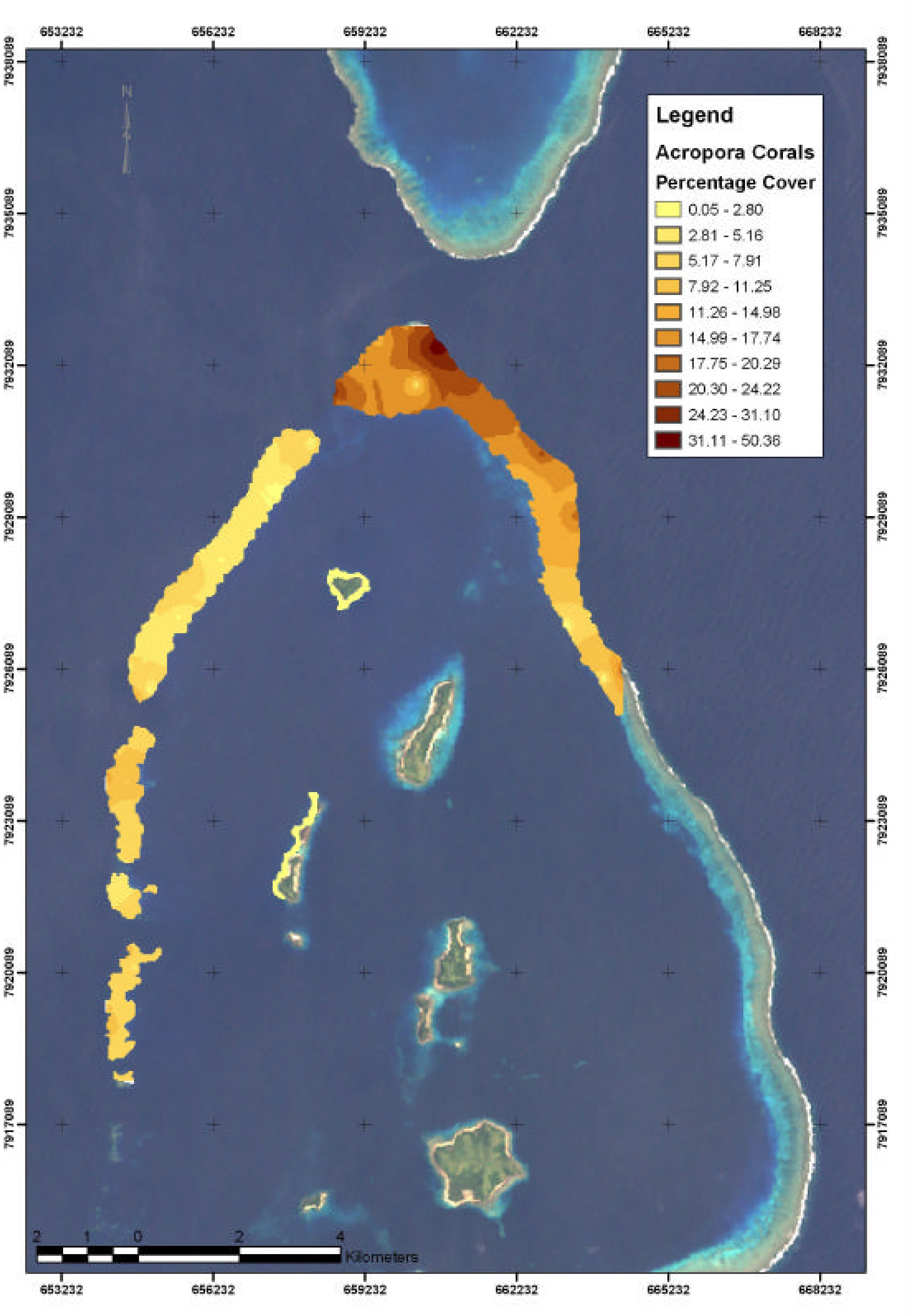


Figure 18 Percentage cover of Non-*Acropora* corals for the area of reefs surveyed in northern Kadavu.

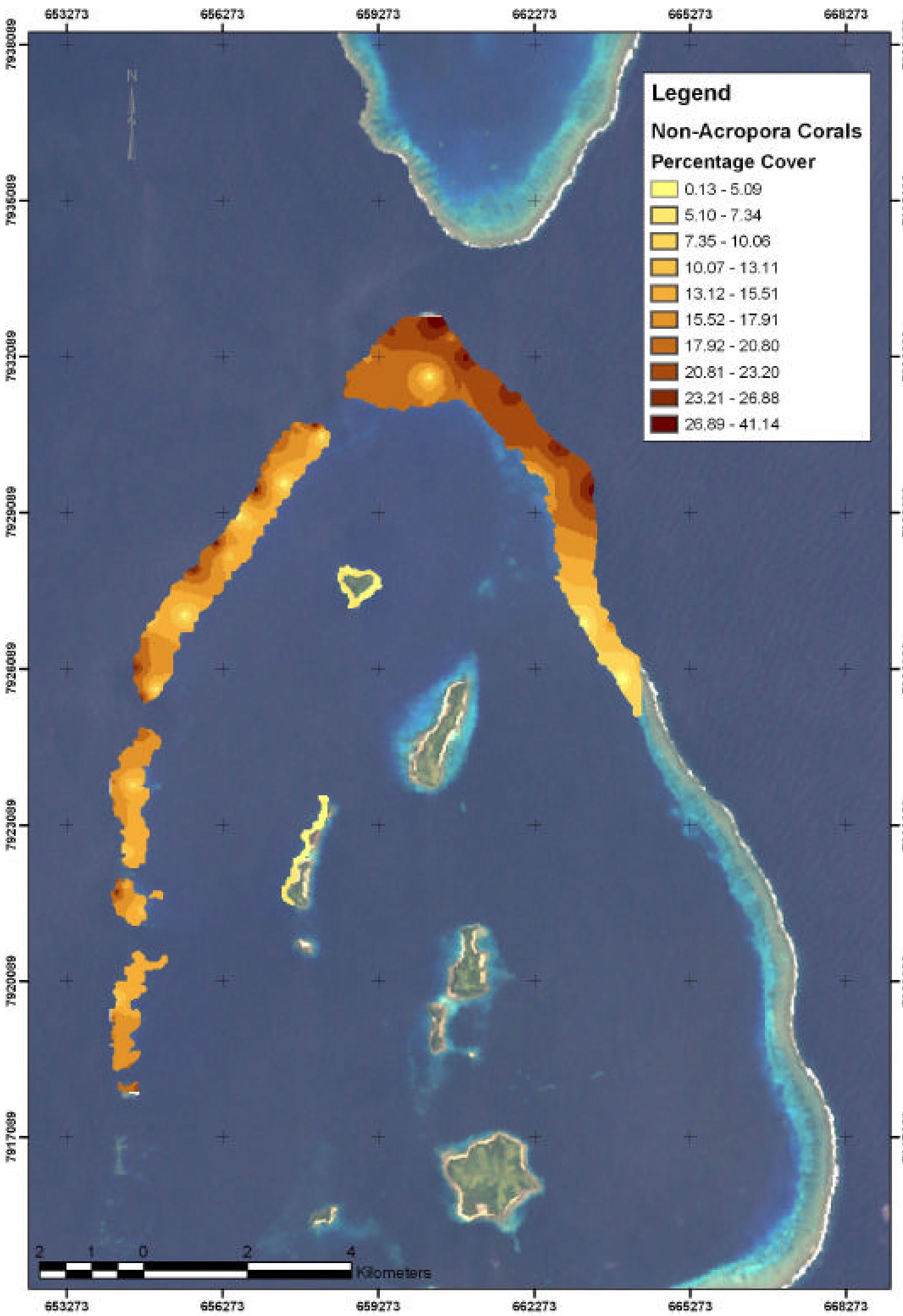


Figure 19 Percentage Live Hard Coral cover for the area of reefs surveyed in northern Kadavu.

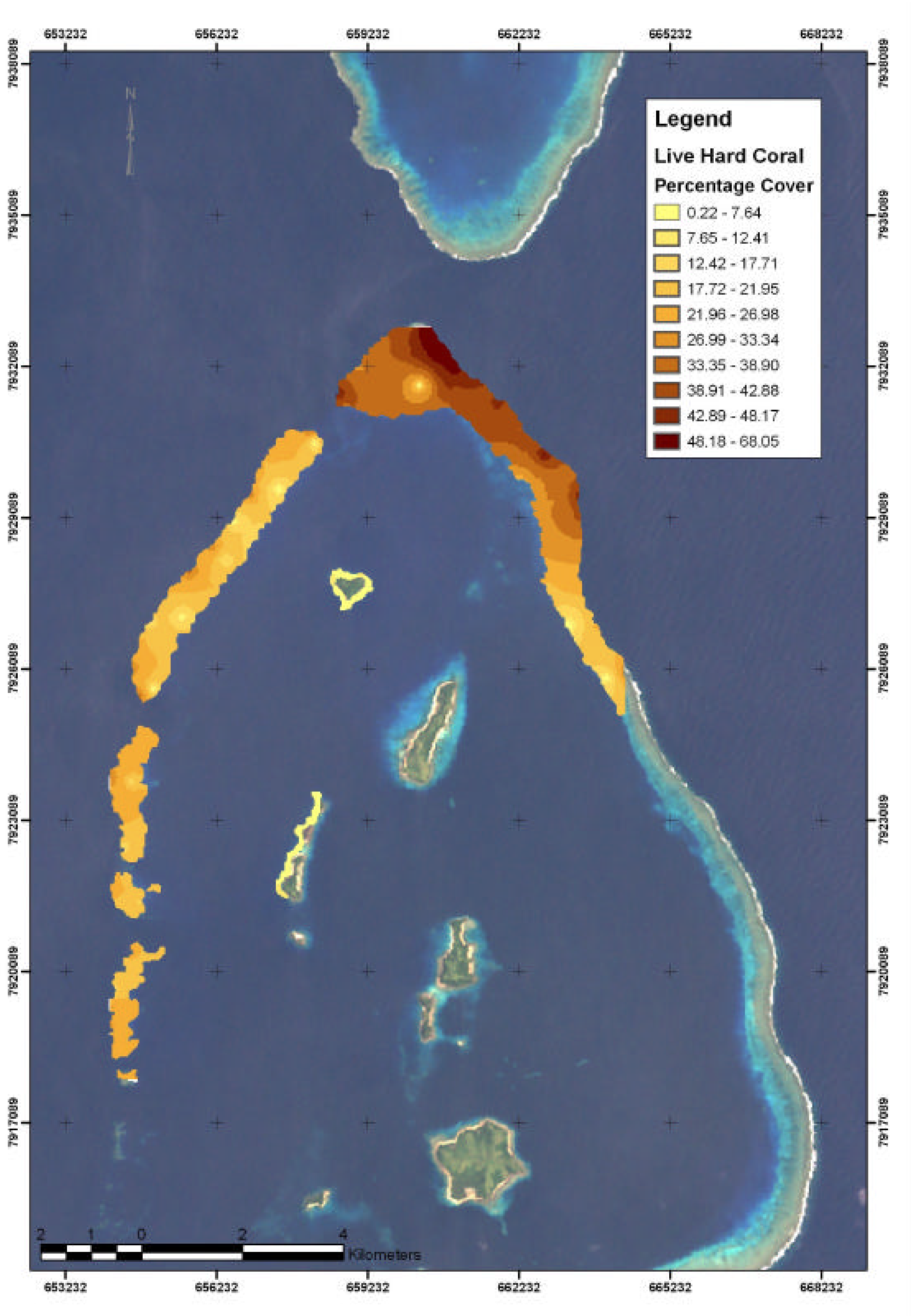
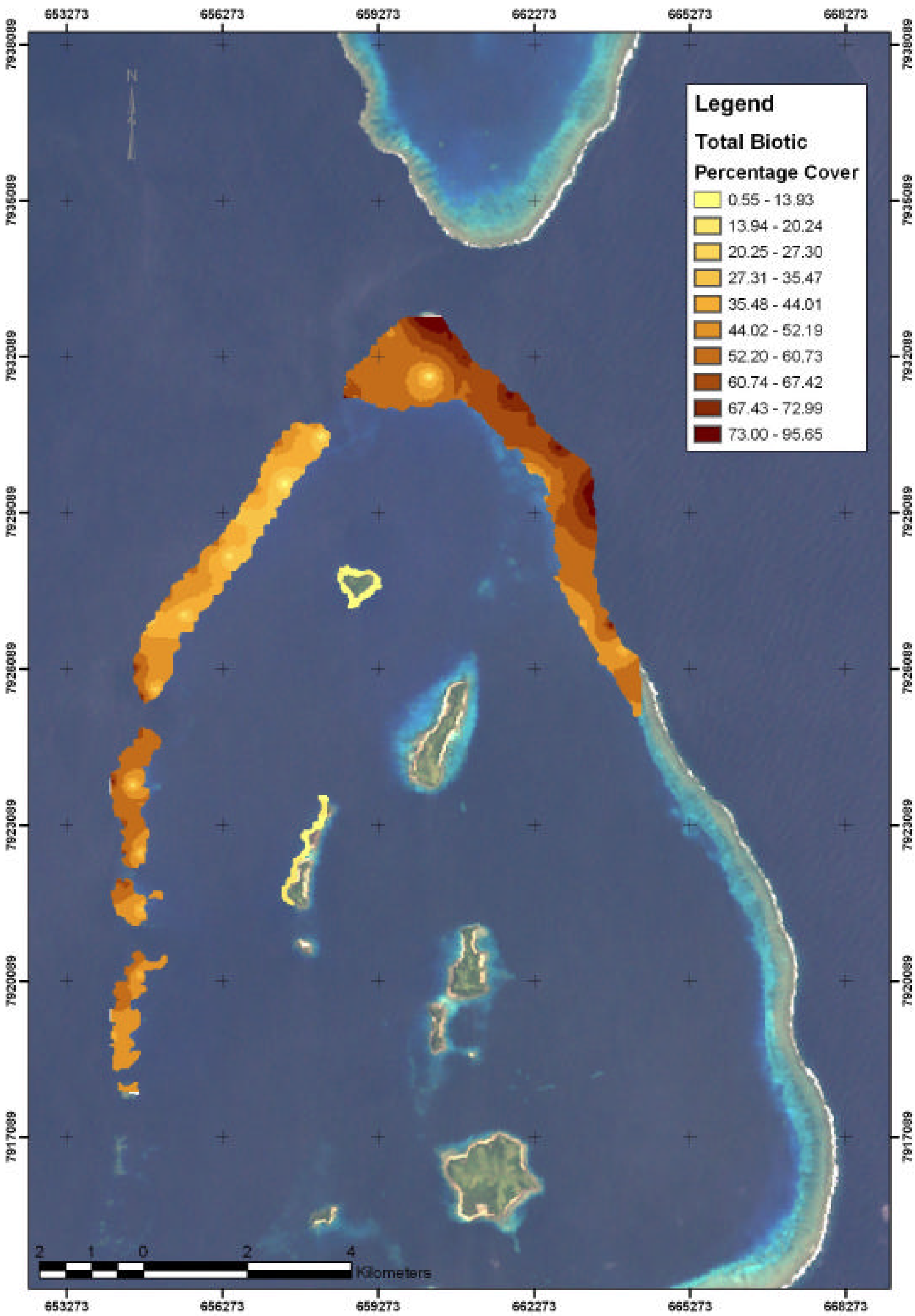


Figure 20 Percentage Total Biotic cover for the area of reefs surveyed in northern Kadavu.



4.4.2 Reef Fish

Densities for nine reef fish families and one species are presented in Figures 19-28. The distribution of three herbivorous fish families, Surgeonfish (Acanthuridae), Parrotfish (Scaridae) and Rabbitfish (Siganidae) are depicted in the first three contour maps (Figures 19-21). Surgeonfish (Figure 19) were most abundant on the outer barrier reef in the north-east reaching between 61 and 92 individuals per transect. A few isolated patches of high density were also recorded on the western barrier reef. Low densities were found on fringing reefs. Densities of Parrotfish were considerably lower than Surgeonfish and showed a more even distribution with highest densities recorded on the barrier reef in the far north of the study area and on the western side due west of Yaukuvelevu Island (Figure 20). Rabbitfish were also recorded at low densities across most of the reefs surveyed but were highest on the western barrier reef due west of Yaukuvelevu Island where 6.7–10 individuals were recorded per transect (Figure 21).

Butterflyfish (Chaetodontidae) were recorded in high densities at three main locations on the barrier reef; on the northern tip, west of Yaukuvelevu and north-west of Vanuakula. Densities reached up to 35 individuals per transect at these locations (Figure 22). Wrasse (Labridae) were generally more abundant (Figure 23) with highest densities of 37-58 individuals per 200 m^2, again on the barrier reef to the north and northwest of Vanuakula and also west of Dravuni.

The remaining four maps show the recorded densities of four carnivorous fish families (Figures 24-27). Triggerfish densities were generally highest on the western barrier reef, mainly on the inner side within the lagoon (Figure 24). Densities reached up to 5.45 individuals per 200 m^2. Densities were also high on the fringing reefs around northern Vanuakula and at one location on the inner side of the eastern barrier, north-east of Dravuni Island. Emperors (Lethrinidae) reached a maximum density of between 12 and 19 individuals per transect at three locations, on the western side of Vanuakula and two sites on the western barrier reef (Figure 25). Densities were low on the eastern barrier reef. Snappers (Lutjanidae) reached considerably higher densities than Emperors with up to 80 individuals per transect seen at a few locations (Figure 26). Highest densities were recorded on the western barrier reef with aggregations observed near to reef channels. Conversely groupers were recorded more often on the eastern barrier reef and on the southern part of Yaukuvelevu Island (Figure 27). Densities reached up to 6 individuals per 200 m^2 on the northern part of the barrier reef on the seaward side.

The last plot (Figure 28) presents recorded densities of the Bumphead Parrotfish (*Bolbometopon muricatum*). This species was seen on both fringing reefs around Yaukuvelevu Island and on the outer barrier reef. Highest densities were observed very close to the northern tip of the barrier reef where up to five individuals were recorded per transect.

Figure 21 Density of Surgeonfish (*Acanthuridae*) per 200m[2] of reef area in northern Kadavu.

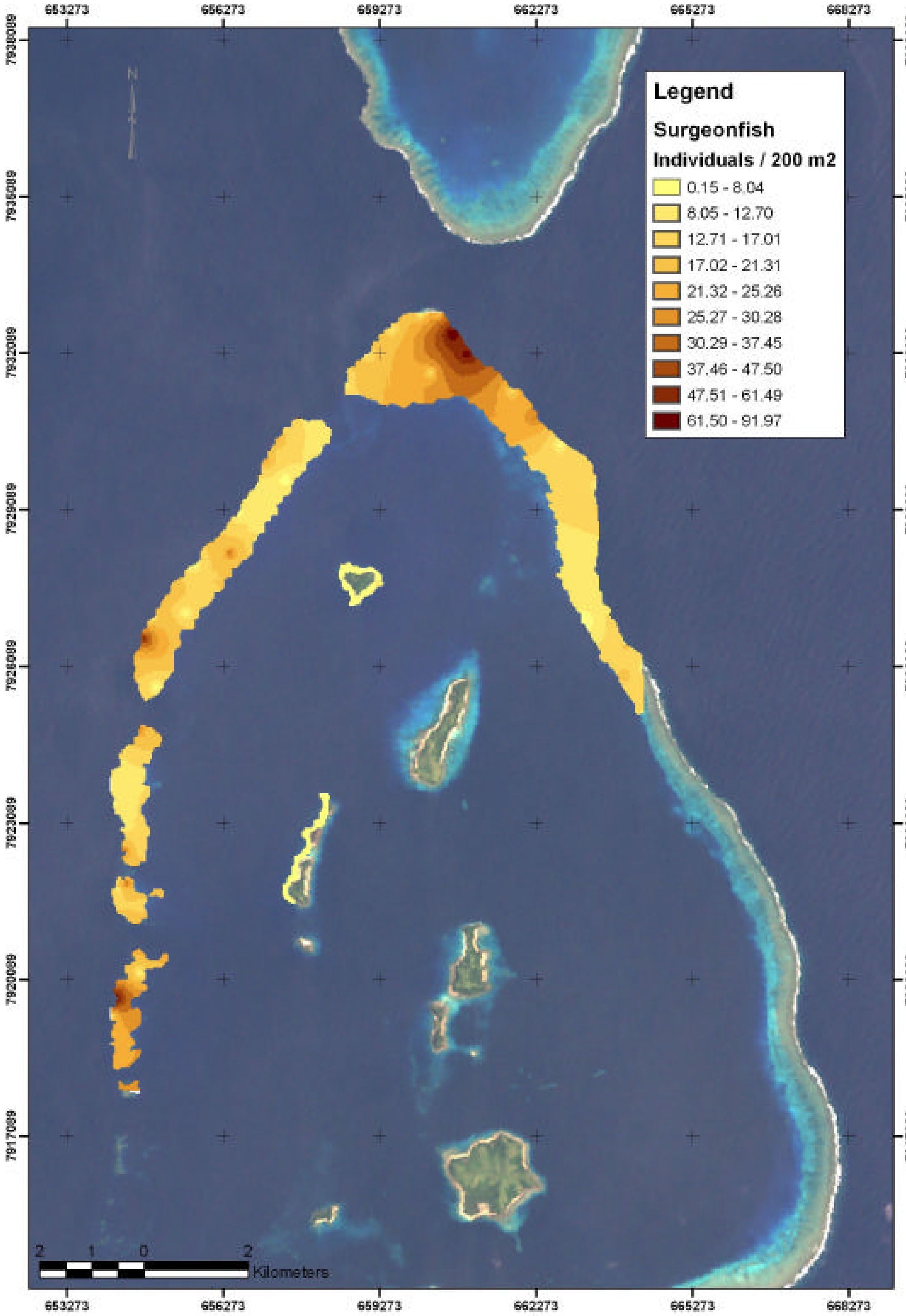


Figure 22 Density of Parrotfish (*Scaridae*) per 200m² of reef area in northern Kadavu

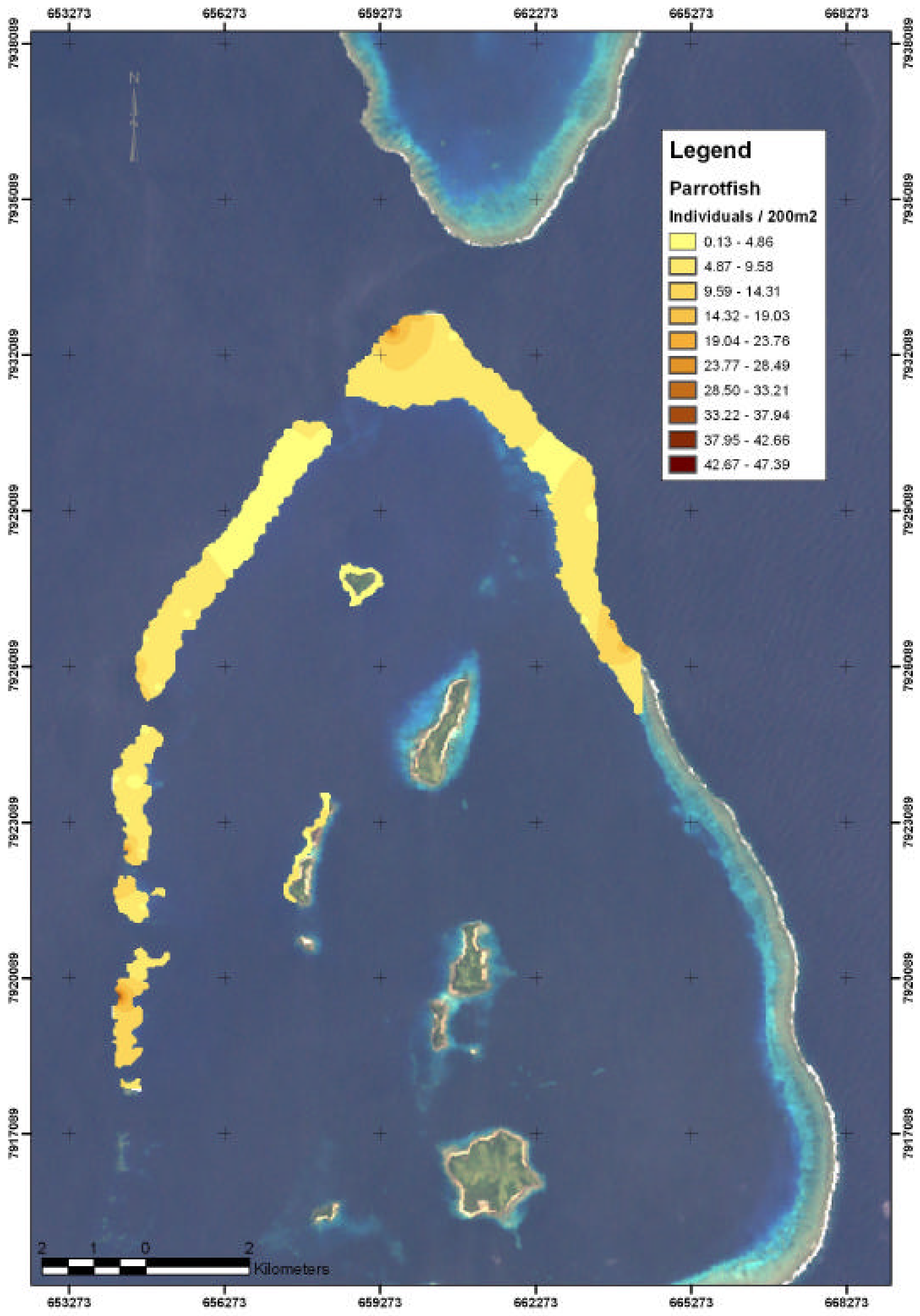


Figure 23 **Density of Rabbitfish (*Siganidae*) per 200m² of reef area in northern Kadavu.**

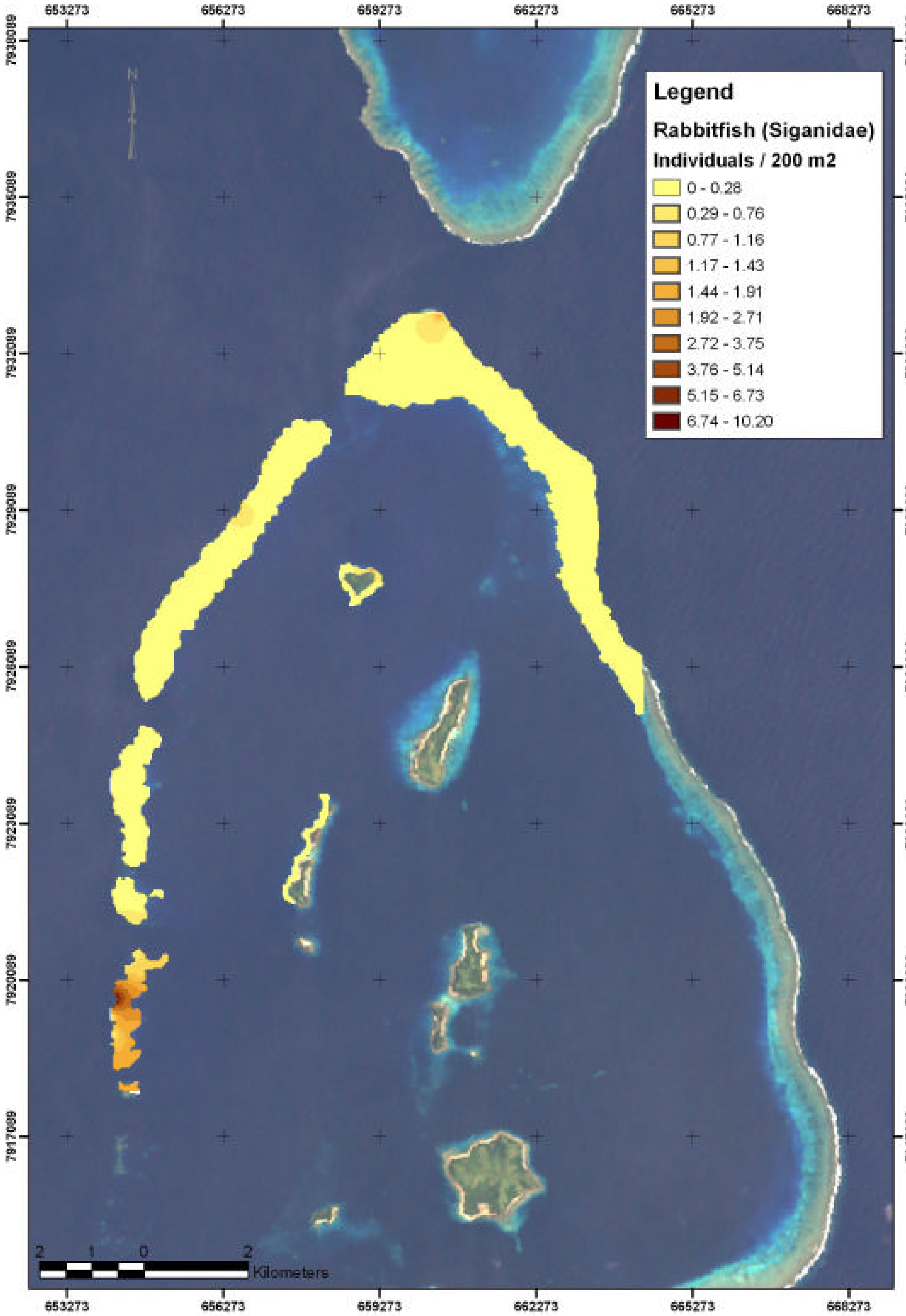


Figure 24 Density of Butterflyfish (*Chaetodontidae*) per 200m^2 of reef area in northern Kadavu.

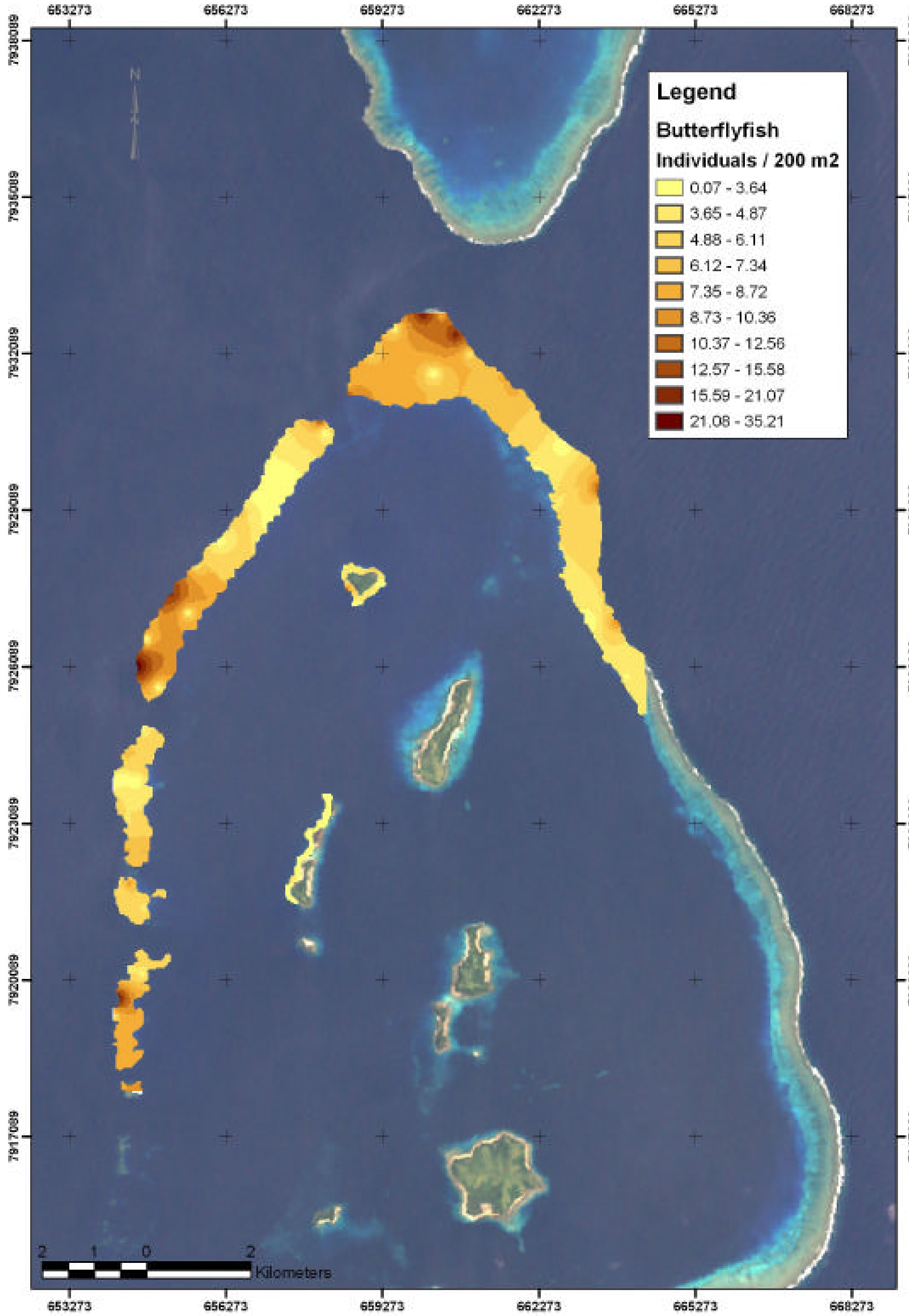


Figure 25 Density of Wrasse (*Labridae*) per 200m^2 of reef area in northern Kadavu.

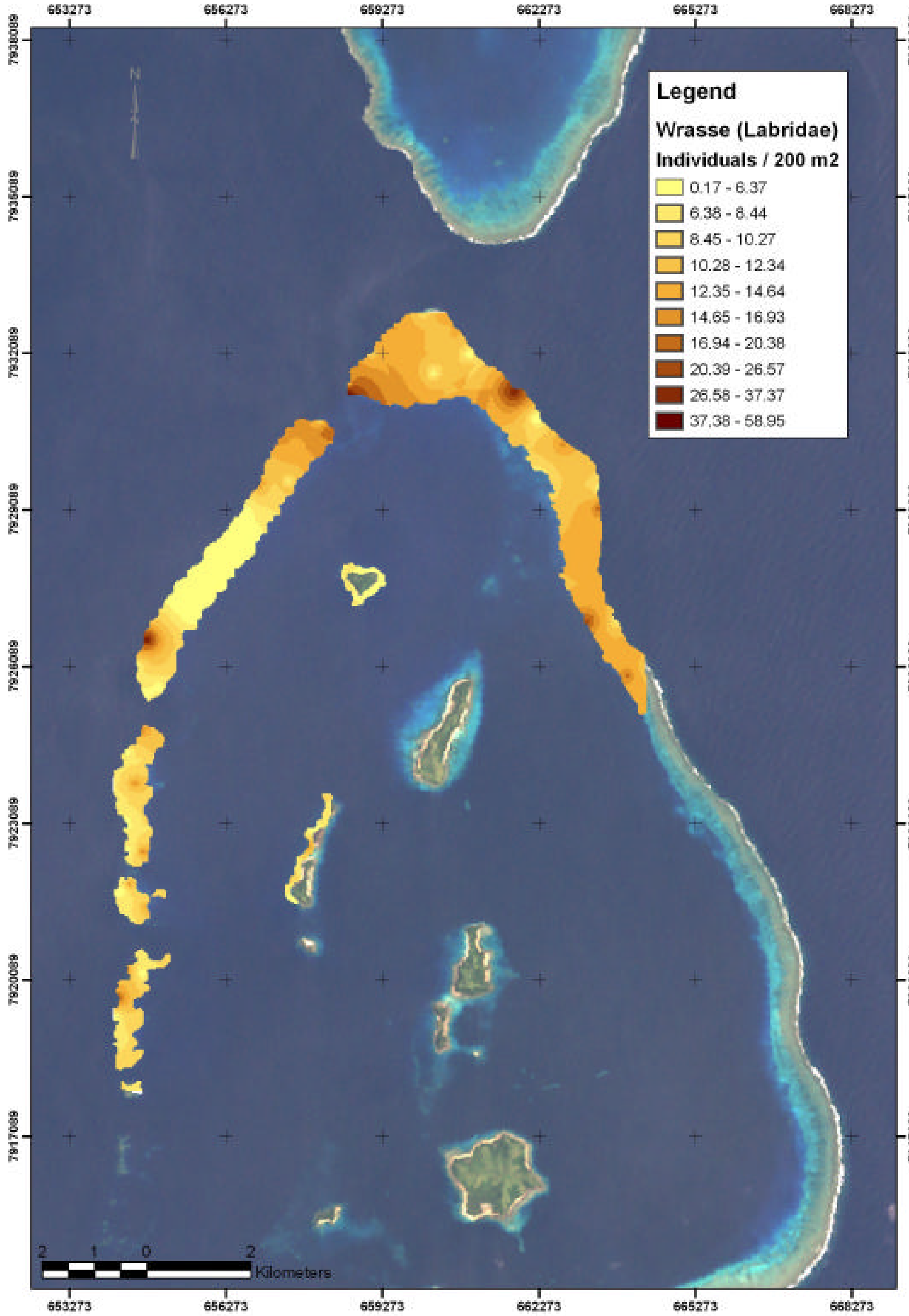


Figure 26 Density of Triggerfish (*Balistidae*) per 200m^2 of reef area in northern Kadavu.

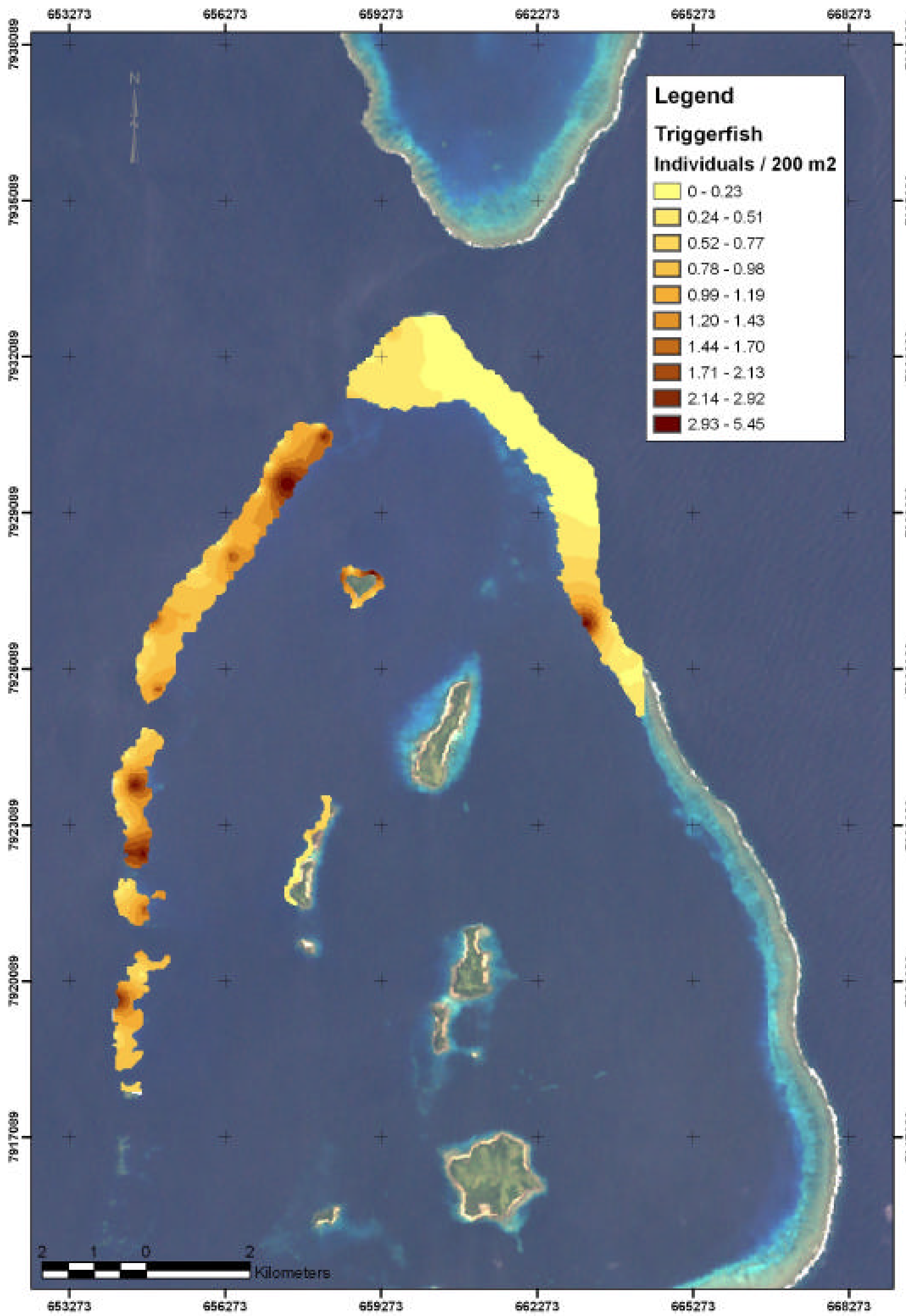


Figure 27 Density of Emperors (*Lethrinidae*) per 200m^2 of reef area in northern Kadavu.

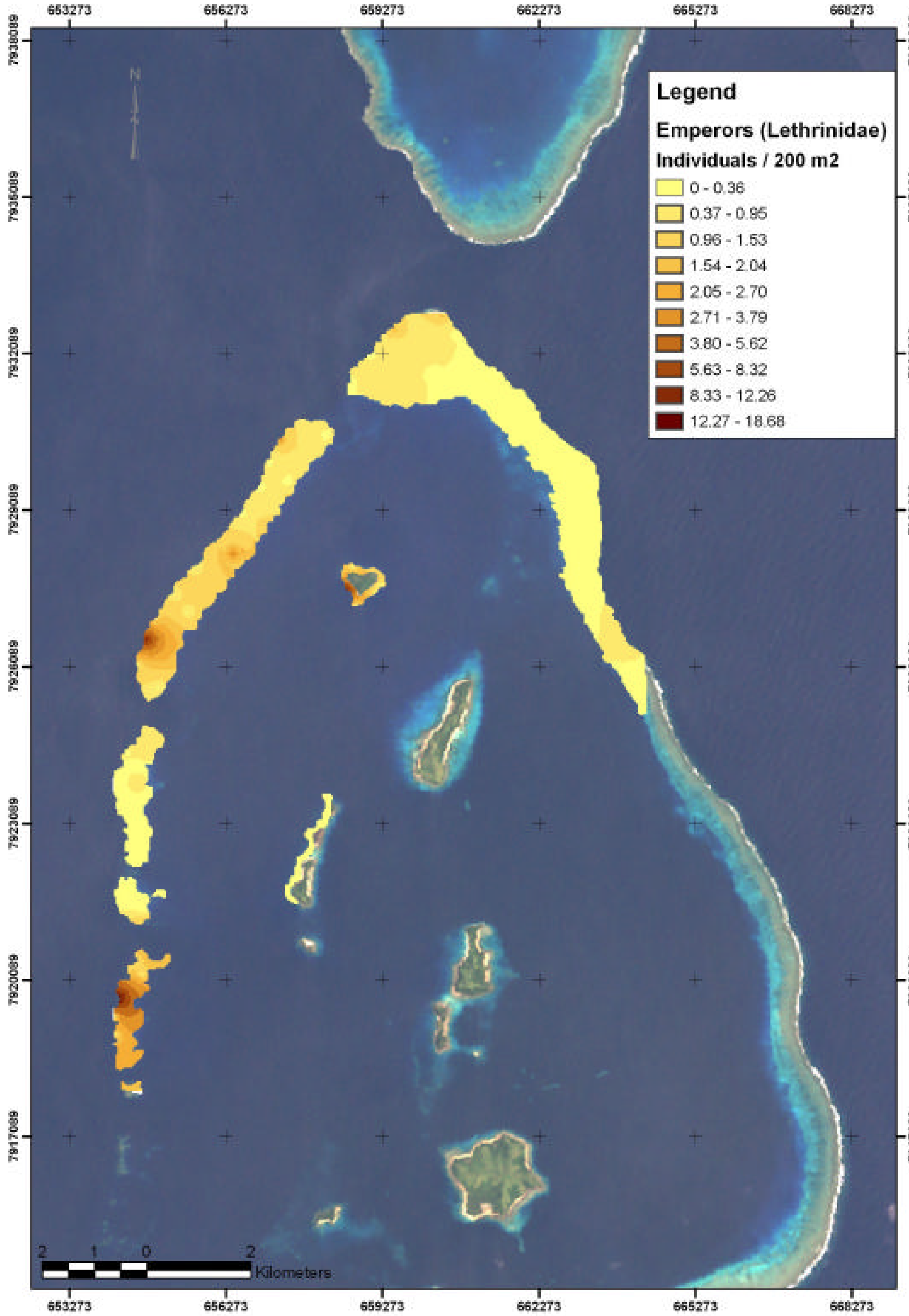


Figure 28 Desnsity of Snappers (Lutjanidae) per 200m² of reef area in northern Kadavu.

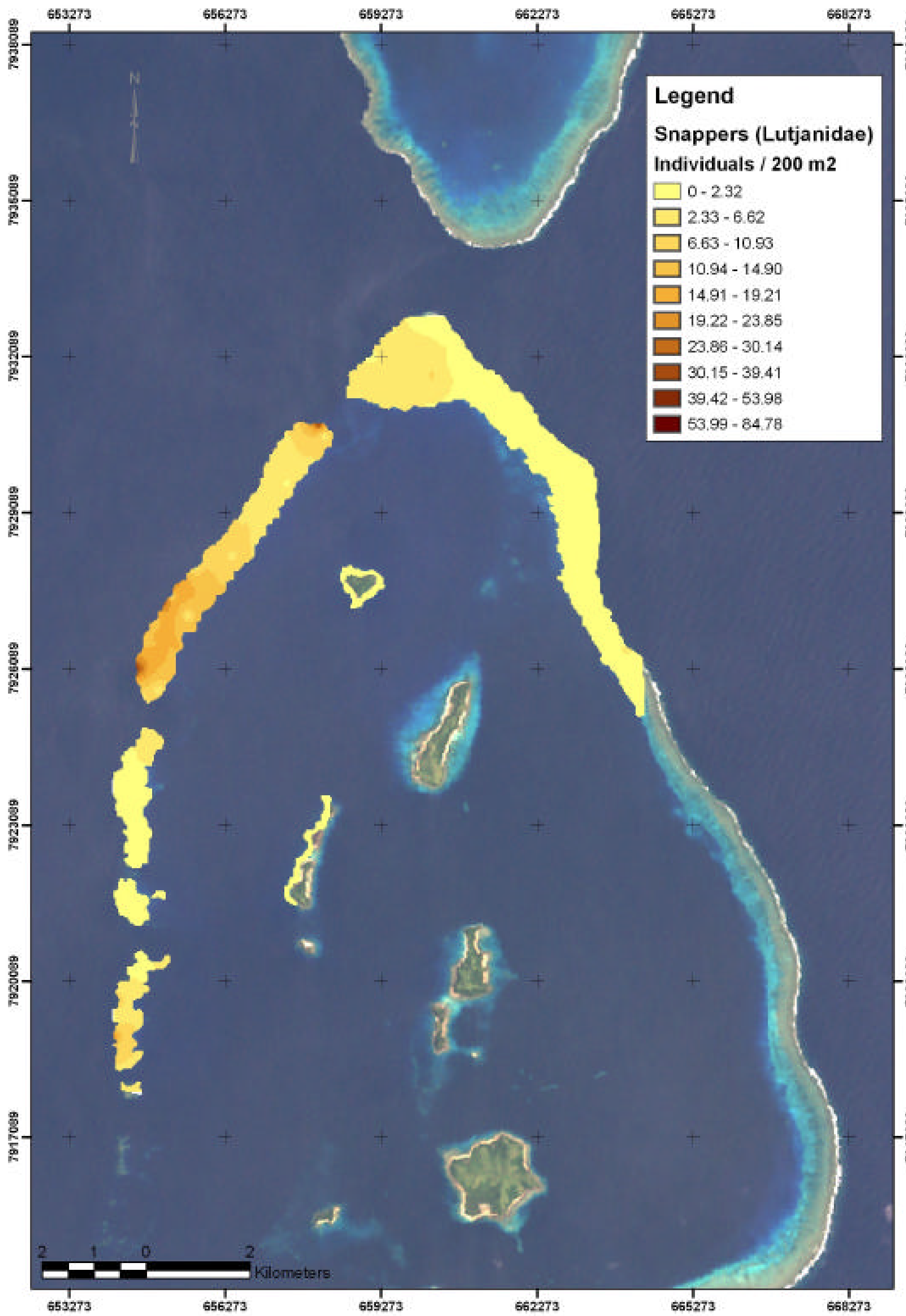


Figure 29 Density of Groupers (Serranidae) per 200m^2 of reef area in northern Kadavu.

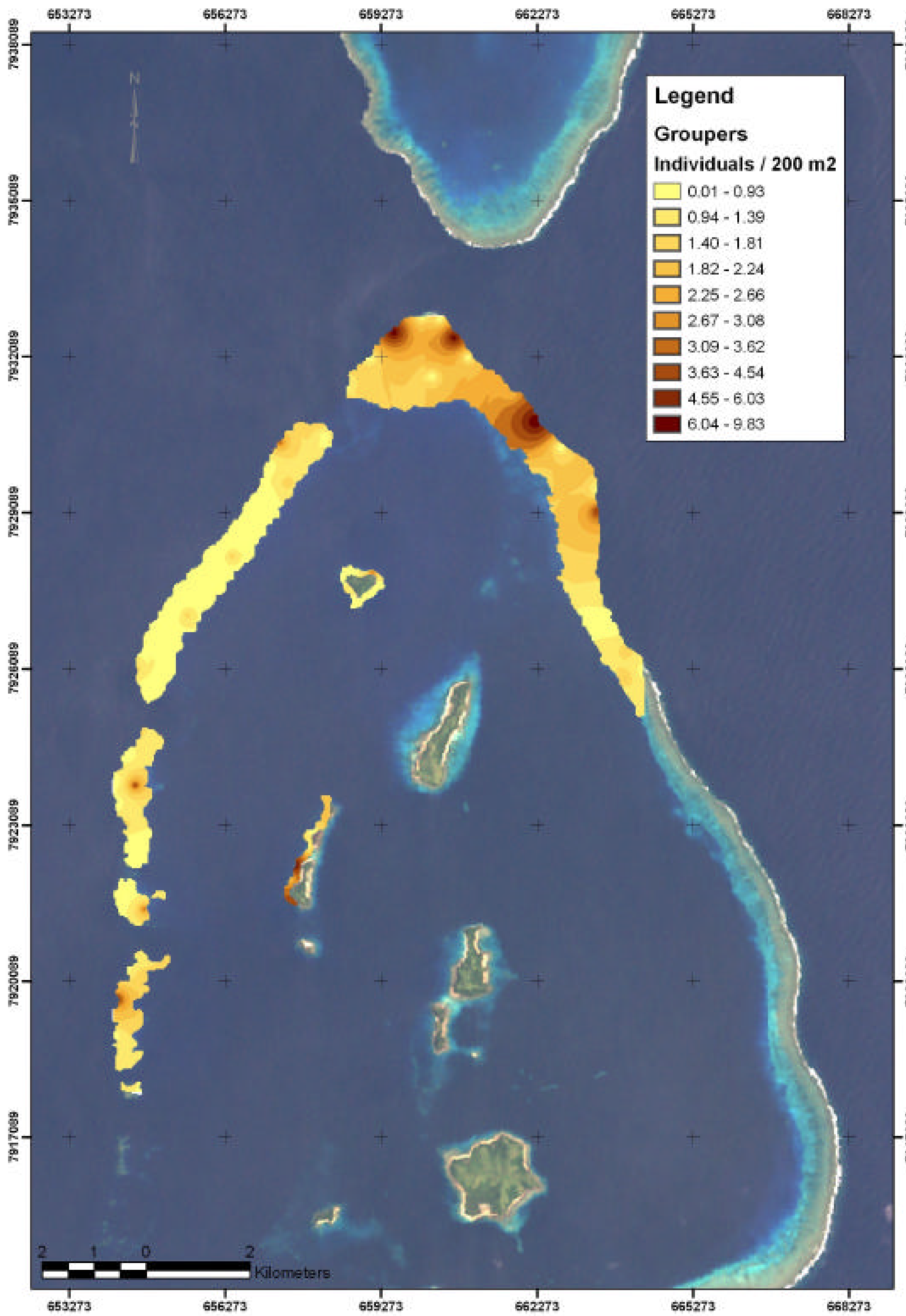
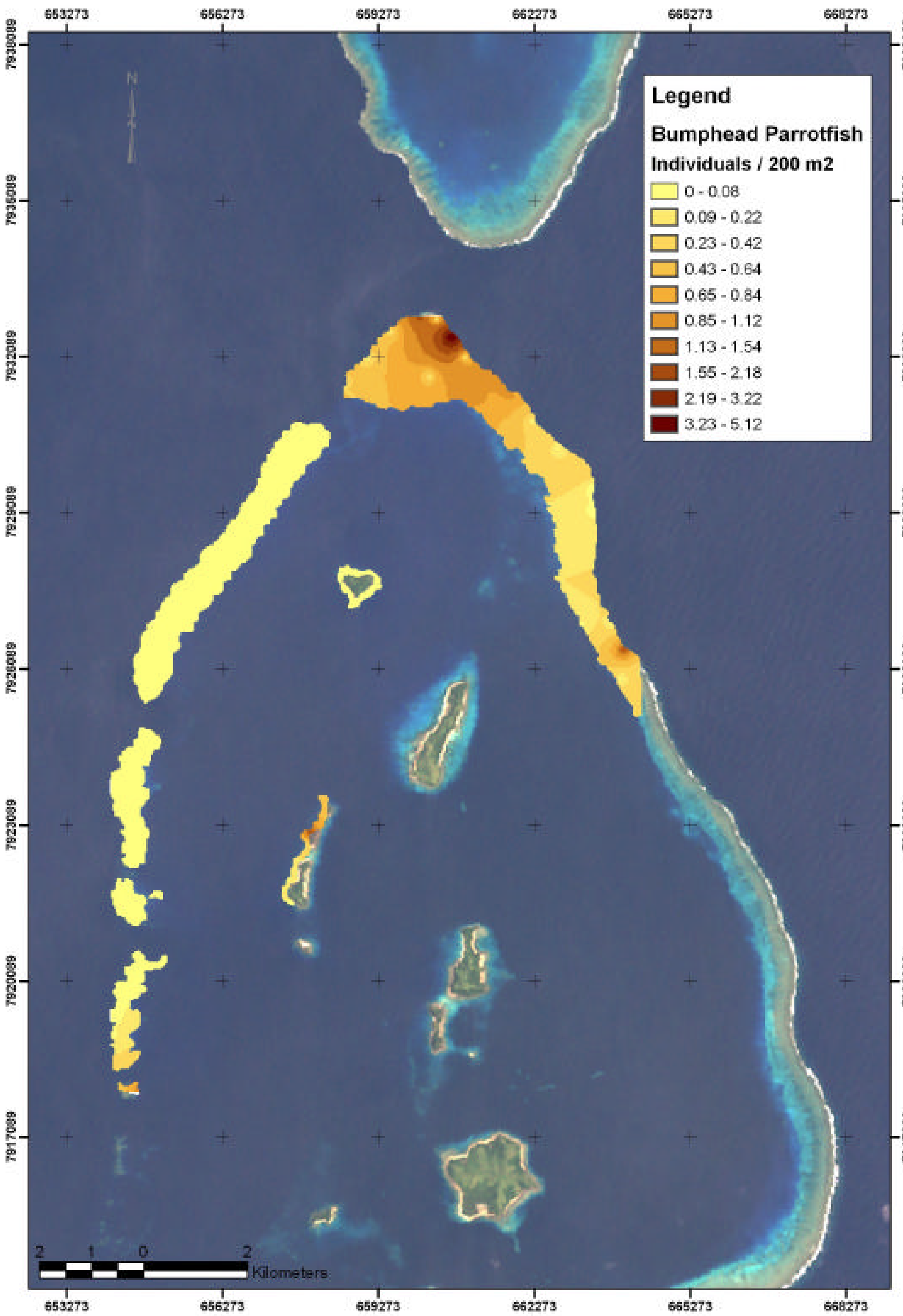


Figure 30 Density of Bumphead Parrotfish (*Bolbometopon muricatum*) per 200m² of reef area in northern Kadavu.



4.4.3 Selected Invertebrates

Densities for three macro-invertebrate categories are presented by Figures 29–31 for sea cucumbers (*Holothuria*), giant clams (*Tridacna* spp.) and Triton Trumpet Shells (*Charonia tritonis*) respectively. Edible sea cucumbers were rarely recorded on the barrier reef but were observed most often on island fringing reefs (Figure 29). Highest densities were observed at Vanuakula Island where up to 2.73 individuals were recorded per 80 m^2. Giant clams (*Tridacna* spp.) were also most abundant at Vanuakula Island (Figure 30) reaching 4.67 individuals per 80 m^2 but were also recorded in moderate densities (~1 per 80 m^2) on the outer barrier reef northeast of Vanuakula Island. The last graph (Figure 31) for this section indicates that Triton Trumpet Shells are present in the region but at low densities with only a few observed over the area surveyed to date. No Crown-of-Thorns seastars (*Acanthaster plancii*) were recorded on transects at the 'shallow depth band used for contour plots. Low densities were found at other depths, mainly in very shallow water (Table 7).

4.4.4 Biodiversity Indices

A total of 290 biotic criteria were used to plot contour maps of overall biodiversity for benthic composition (110 categories), selected reef fish (137 categories) and invertebrates (43 categories). Shannon-Weiner indices of biodiversity were calculated using PRIMER software and then incorporated into GIS to produce the contour maps (Figures 32-34).

Benthic diversity was rather evenly spread out between reef types (outer and inner barrier, fringing) and geographic location in the area surveyed with highest diversity recorded on the barrier reef in the northeast and also on fringing reefs around Vanuakula and Yaukuvelevu Islands (Figure 32). A clear pattern of biodiversity was visible for reef fish (Figure 33) with the western barrier reef and island fringing reefs showing the highest diversity in the area surveyed. Reef fish diversity was generally lower on the eastern barrier reef sections with the exception of the northern tip. Invertebrate diversity was quite patchy with all reef types having areas of high diversity. Barrier reefs in the southwest contained the highest diversity of invertebrates, closely followed by barrier reef locations in the northwest and northeast. Invertebrate diversity was generally lower on fringing reefs than on the barrier reef.

Figure 31 Density of Sea Cucumbers (Holothuridae) per 80 m² of reef area in northern Kadavu.

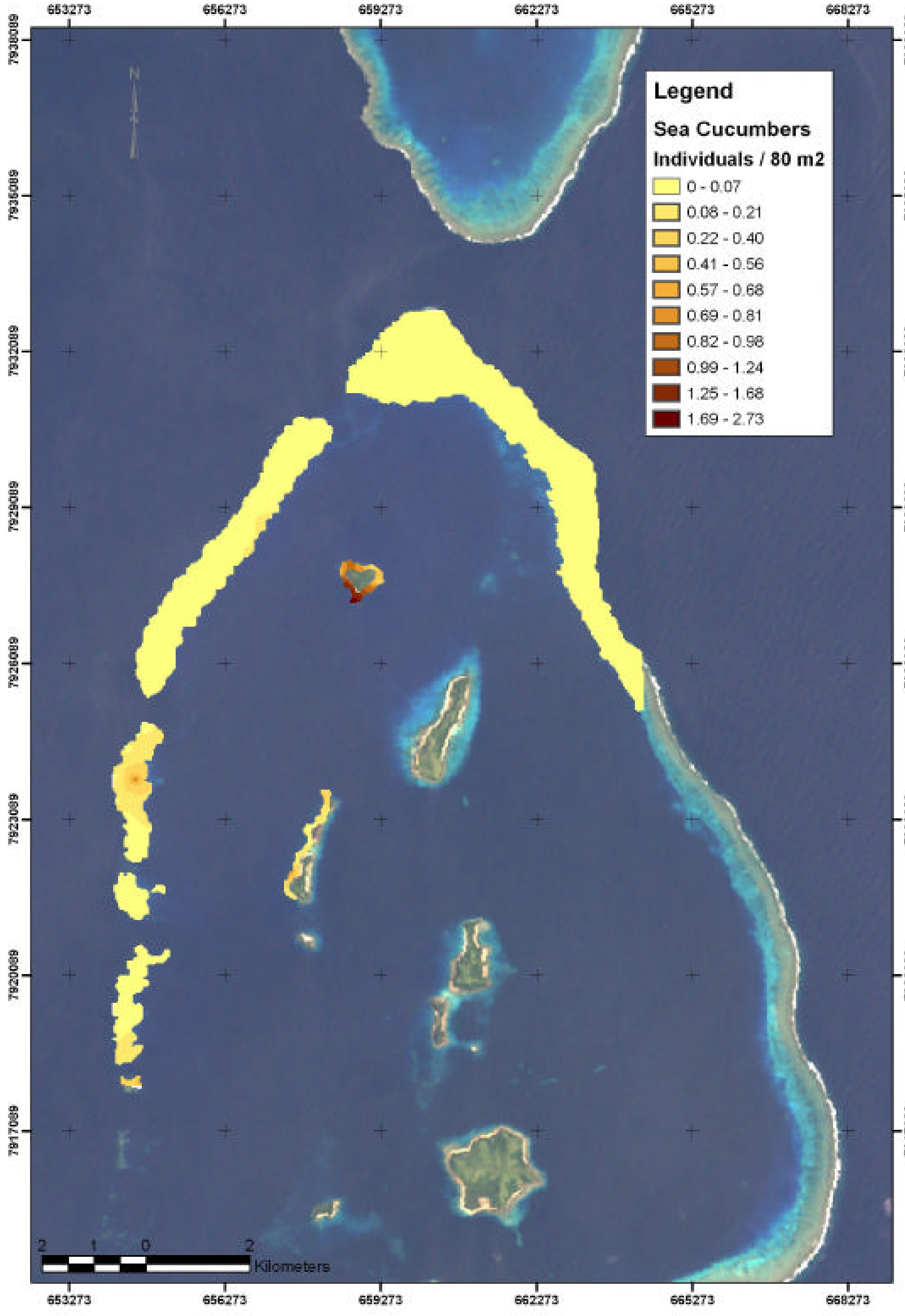


Figure 32 Density of Giant Clams (*Tridacna* spp.) per 80 m² of reef area in northern Kadavu.

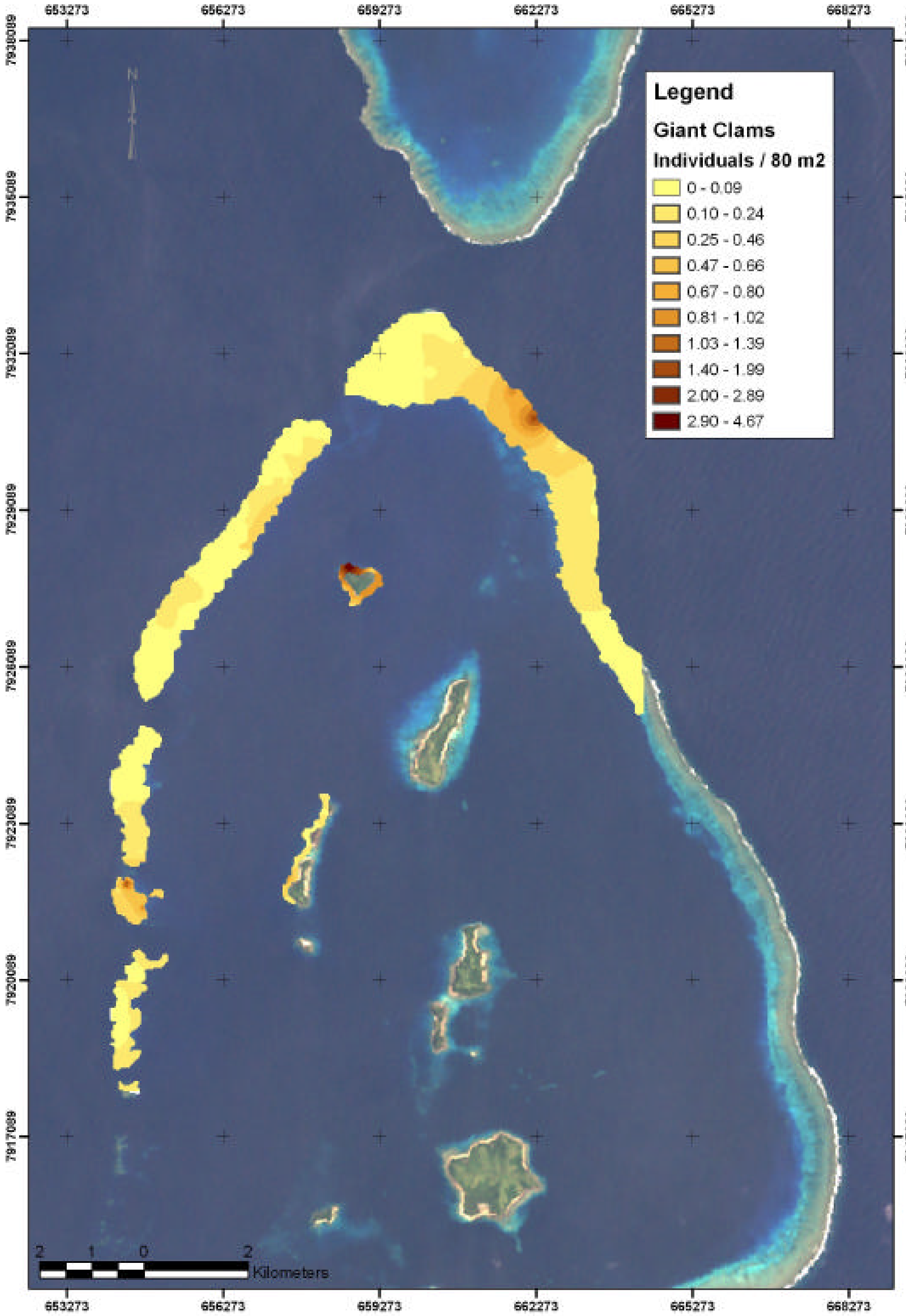


Figure 33 Density of Triton Trumpet shells (*Charonia tritonis*) per 80 m² of reef area in northern Kadavu.

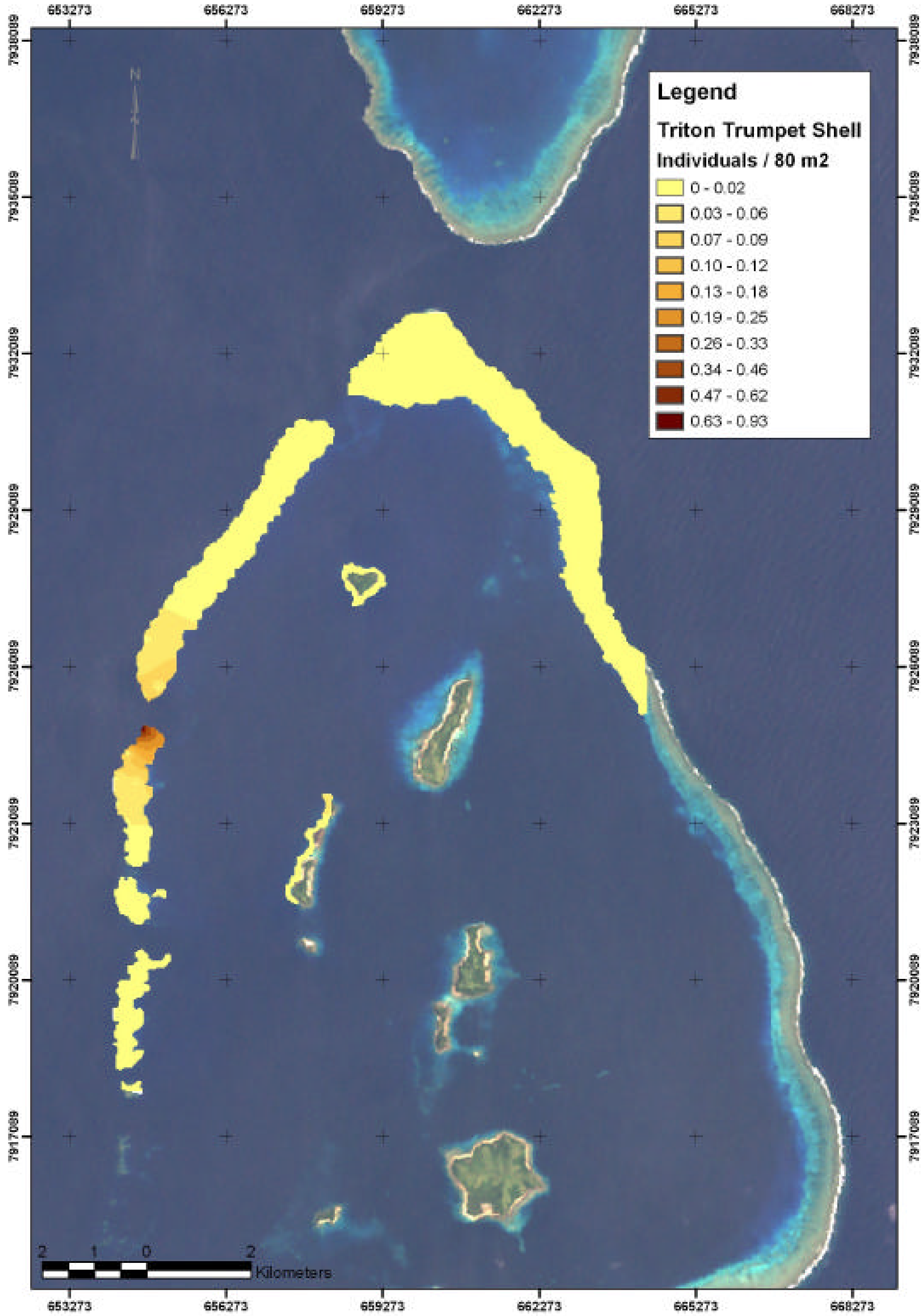


Figure 34 Shannon-Weiner Biodiversity Indices for Benthic Composition in the northern Kadavu Region.

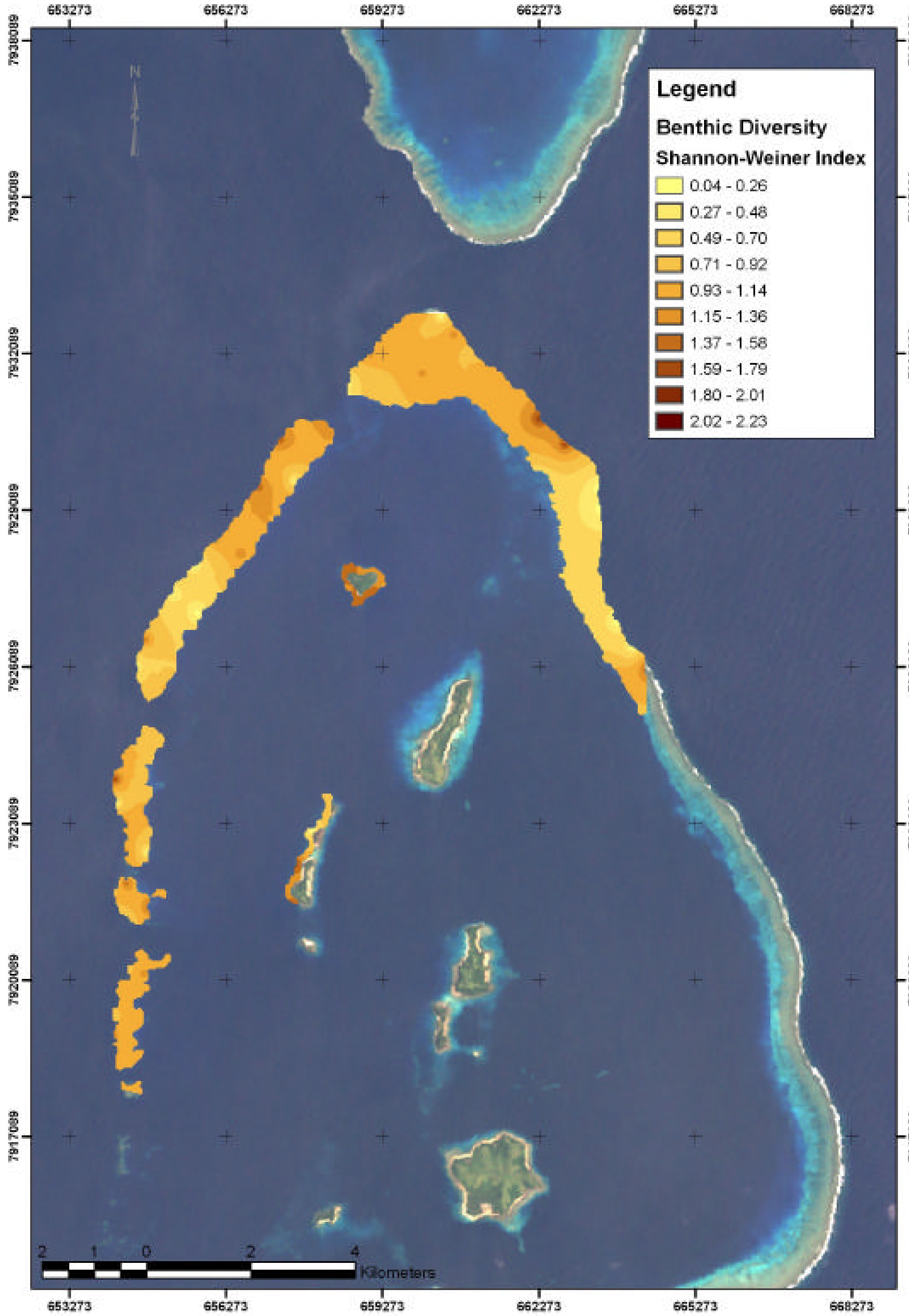


Figure 35 **Shannon-Weiner Biodiversity Index for Selected Reef Fish in the northern Kadavu Region.**

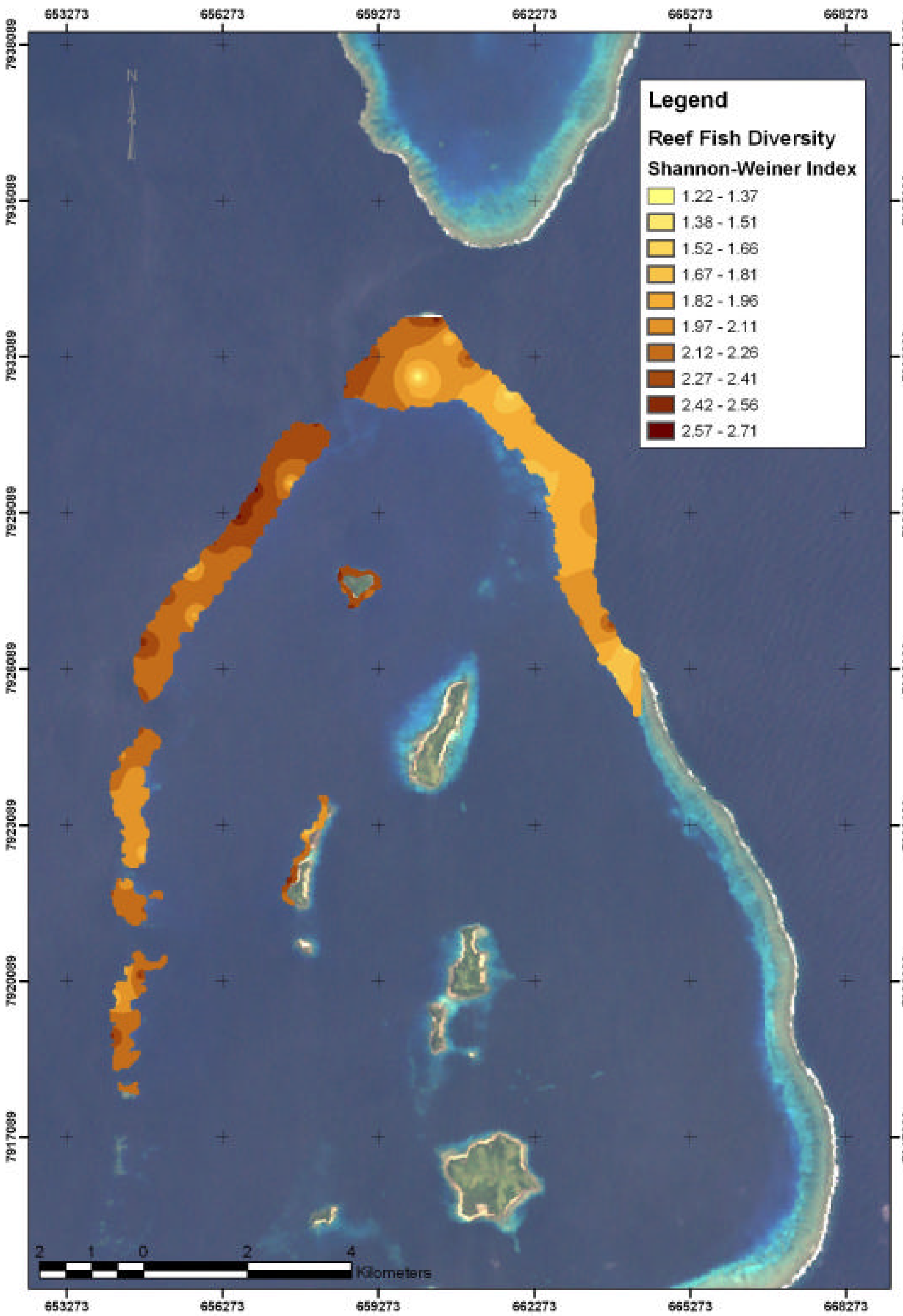
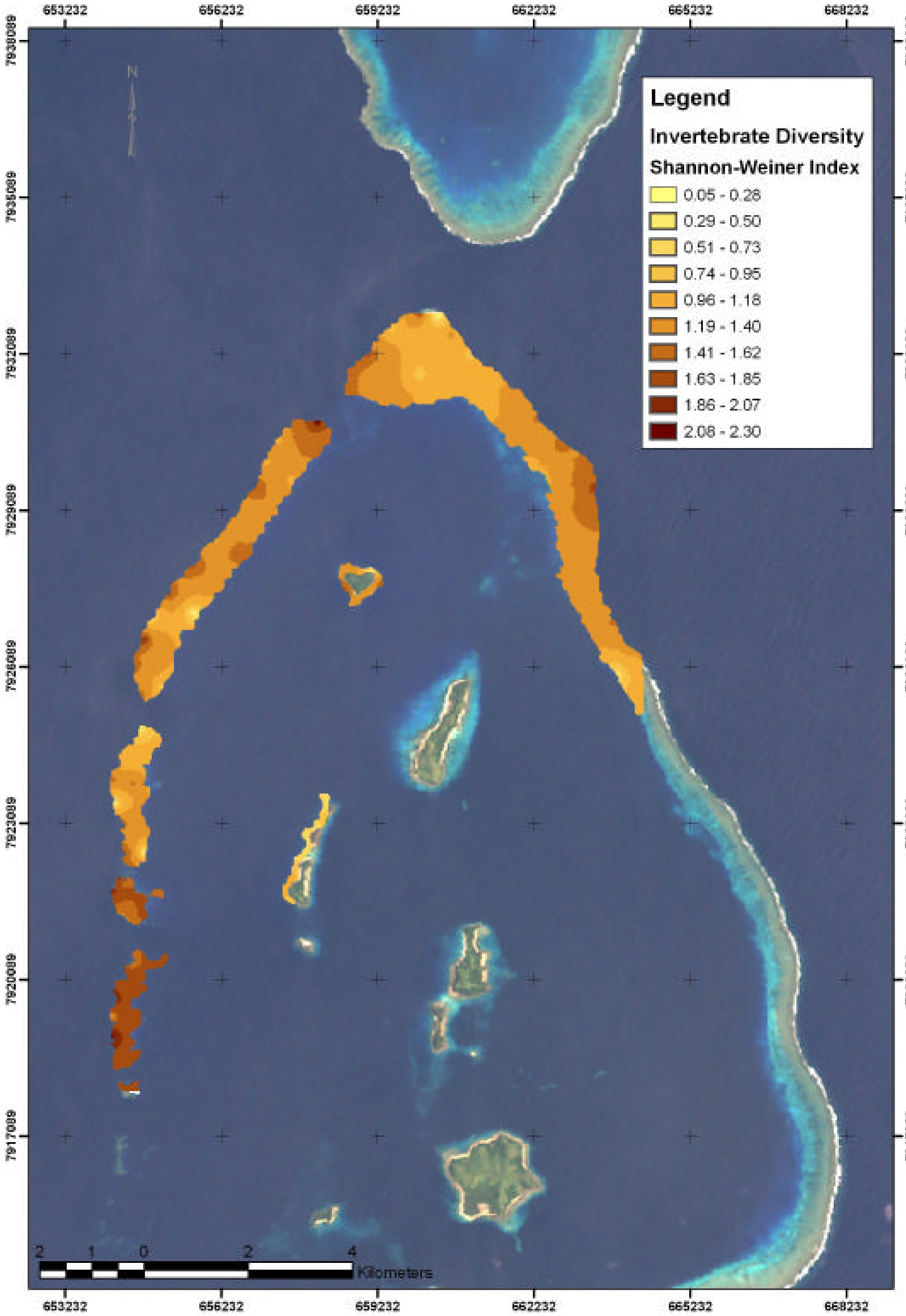


Figure 36 Shannon-Weiner Biodiversity Index for Selected Invertebrates in the northern Kadavu Region



5. DISCUSSION

5.1 Training

The CCC training programme used in Kadavu proved to be appropriate for volunteer survey work in Fiji. For example, the results in the tests and in water validation exercise were, on the whole, excellent and, therefore, the data collected during survey work are likely to be accurate and consistent. The training schedule has been deemed appropriate for novice divers as well as relatively experienced divers. Further details of the training results are available upon request from the CCC-UK head office

5.2 Environmental Awareness and Community Work

Training for Community Fish Wardens

Of the ten Community Fish Wardens trained to date, eight have come through CCC's partnership with an NGO (WWF) with the remaining two having been sought from the local community directly. This is indicative of one of the largest hurdles to the Community Fish Warden training programme where the level of spoken and written English and the motivation for the individuals applying has to be determined. Through the use of a Community Liaison Officer, a system of vetting candidates through interviews and written processes has now been put into place. There are currently six additional Community Fish Warden candidates from within the local communities that are due to undertake training in the forthcoming months.

Training scholarships for USP students

The periods of the year during which USP students can take scholarships is limited primarily to outside of teaching semester times. Accordingly, there has been a limit on the number of scholars that have been able to take part in the scholarship programme to date. There is currently a recruitment process on going at the University with an aim of enrolling as many as possible over the next few months.

Reef Awareness Field Trips

The schools programme and awareness field trips conducted to date have been very successful. With only one small school on Dravuni Island however, the numbers of children involved have by definition been limited. The first six months of the project have given chance to refine the type of activities undertaken with the school and there are currently plans in place to expand the programme to the school on the neighbouring island of Buliea.
In addition, in early 2007, CCC plan on establishing a satellite base on Ono Island closer to mainland Kadavu. This base will allow extension of the areas over which surveys are being conducted and being close to far larger primary schools and the large provincial school in Kavala Bay, it is anticipated that the reef awareness field trips can be expanded considerably.

Resort Support

The only resort within 15 km of Dravuni Island is Yaukuve Island Resort. Yaukuve was originally to be operational in August 2006. However logistical difficulties by the resort construction teams have meant that this time-frame could not be adhered to. Accordingly, the originally proposed resort support activities could not be undertaken in the first six months of the project. With the rescheduled opening of Yaukuve Island Resort now planned for early 2007, there has been considerable interest expressed by the resort management team in the resort support activities offered and it is expected that these activities will be carried out as planned in the coming year.

5.3 Survey Progress

Baseline surveys have progressed well over the first six months of the project. The vast majority of the survey stations on the western barrier reef have been completed. Fringing reef sites around Vanuakula Island and on the western side of Yaukuve Island are also complete. The eastern side of the main barrier reef is the next priority. Once survey stations have been completed on this side then it will be time to open up a satellite base on Ono Island to enable surveying to progress further south.

5.4 Oceanographic, Climate and Anthropogenic Impact Data

The high underwater visibility encountered on most survey dives is not surprising given that the majority of survey stations were located on the barrier reef on the seaward side where clear oceanic waters occur. Visibility was lower within the main lagoon and on fringing around the islands, which is partly a natural phenomenon through bioturbation processes. Lower visibility on fringing reefs may also be partly attributed to slight sedimentation from freshwater runoff and increased turbidity in shallow waters through local small-scale disturbance caused by fishing and gleaning activities. There was one record of sedimentation on fringing reefs as a sub-surface impact at Dravuni.
The frequency of surface impacts was very low with no recordings of two categories (sewage or fishing nets) and rare sightings of litter and macroalgae on both fringing and outer barrier reefs. Sub-surface impacts were more frequent and were predominantly related to hard corals. Coral bleaching was frequently recorded on the ribbon barrier reef and was slightly higher on the inner side where the calmer conditions are more suited to thermal stratification and warming. The coral bleaching observed may be related to a thermal stress event reported by NOAA's Coral Watch Programme (http://coralreefwatch.noaa.gov) in April 2006 which highlighted that sea surface temperatures were high enough for coral bleaching to occur in the region. Coral damage was recorded more often on the outer barrier and fringing reefs than on inner barrier reefs. For the outer barrier this may be a natural phenomenon related to the high-energy environment and effects of highly motile coral fauna on coral structures. However, coral damage on fringing reefs is more likely an anthropogenic effect caused by fishing and boating activities in shallow waters. Similarly the higher occurrence of coral disease on fringing reefs may be related to the higher levels of small-scale disturbance that is damaging living coral and allowing easier access for pathogens into coral tissue.
Overall the data discussed in this section indicates that the parts of the region surveyed are rather pristine, particularly the barrier reef where anthropogenic effects are minimal.

Fringing reefs do show some signs of anthropogenic impacts and are degraded in places, more so in shallow waters.

5.5 Baseline Biophysical Surveys

Although only a portion of the planned surveys have been completed during the first six months of the project, with data for certain reef types somewhat limited, we can indicate the reef areas that are of high or low quality using the data provided and make very preliminary recommendations for management.

5.5.1 Benthic Composition

Benthic cover data has highlighted the generally high status of the Great Astrolabe Reef in northern Kadavu, particularly on the outer, seaward facing side where hard coral cover is very high in places. Contour maps have highlighted a region of exceptional hard coral cover on the northern tip of the outer barrier for both *Acropora* and Non-*Acropora* corals. *Acropora* corals were less common on both fringing and inner barrier reefs, especially branching and tabulate forms while levels of coral rubble were higher especially on the inner barrier. Back reef areas of barrier reefs are often characterised by large stands of branching *Acropora* species. It is likely that one or a series of disturbance events have reduced the cover of *Acropora* corals on the inner side of the barrier reef. The mass coral bleaching event that occurred in Fiji in 2000 indeed caused 80% of hard coral colonies to bleach at survey sites in northern Kadavu (Cumming et al., 2003 – 9th ICRS) with *Acropora* corals particularly affected. Subsequent mortality of bleached corals was between 10 and 40% (Wilkinson, 2004), which could partly explain the low cover of *Acropora* corals in the area surveyed to date for inner barrier and fringing reefs. Furthermore, subsequent recovery has been slower on the western side of the Astrolabe Reef than on the eastern side (Wilkinson, 2004), which supports the findings of this study of lower hard coral cover on the western reefs. Fringing reefs were characterised by a high level of bedrock and low level of hard corals in shallow waters, which may be indicative of long-term anthropogenic effects such as damage to live corals through trampling whilst gleaning.

Cover of macroalgae was low in the survey area on the whole with no major reef areas inundated with macroalgae as can be the case in other parts of Fiji. One section of the inner barrier reef east of Dravuni was highlighted as having high macroalgal cover on the contour plot. This may be part of a seasonal pattern of macroalgae abundance or related to patterns of fishing activity and requires further investigation.

5.5.3 Reef Fish Abundance

Recorded reef fish densities were generally higher on the barrier reef than on fringing reefs. Highest densities were recorded on the outer Barrier reef for Surgeonfish (Acanthuridae), Parrotfish (Scaridae) and Butterflyfish (Chaetodontidae). Snapper densities were also considerably higher on both the inner and outer sides of the barrier reef than on fringing reefs. When fish densities were plotted spatially on contour maps two main areas of the barrier reef were highlighted, the northern point of the barrier reef and the southwest section. High densities of Surgeonfish, Butterflyfish, Groupers (Serranidae) and Wrasse (Labridae) were all recorded on the northern point of the barrier reef or in the section directly southeast of this point. This coincides with the areas of high live coral cover and marks this area as one particularly suitable for conservation. Furthermore, the globally rare and highly threatened Bumphead Parrotfish (*Bolbometopon muricatum*) was recorded along this section of barrier reef with schools of up to 20 individuals also seen off-transect in this location. The other section of barrier reef to the southwest of the survey area revealed high densities of fish families that are preferred for food such as Rabbitfish (Siganidae) and Emperors (Lethrinidae) as well as Surgeonfish and Parrotfish. The two reef areas just mentioned are also the furthest parts of the barrier reef from inhabited islands within the main lagoon. Fishing pressure is likely to be highest on fringing reefs around islands and then decrease with increasing distance so that more distant reefs are the most likely ones to contain higher densities of targeted fish families. Triggerfish (Balistidae) were recorded most often on the inner barrier reef mainly along the western side. The combination of substratum types (hard coral, sand, bedrock and rubble) along the inner side of the barrier reef provides the ideal foraging habitat for triggerfish species.

5.5.4 Invertebrate Abundance

Particular invertebrates often regarded as pests or problems on coral reefs when present at high densities were not an issue in the area surveyed. Crown of thorns sea stars (*Acanthaster plancii*), a well-known predator of hard corals, were recorded at very low densities during the survey period and were only seen in very shallow water on fringing and outer barrier reefs. Herbivorous sea urchins in the genera *Diadema*, *Echinothrix* and *Echinometra* were also recorded at low densities at all reef types. High sea urchin densities are commonly associated with overfishing of urchin predators such as triggerfish and are thought to increase erosion rates of coral reefs through bioerosion by grazing. The low densities of urchins recorded at Kadavu plus the high densities of triggerfish seen at some locations in the region suggest that populations of urchins are currently being kept in check by predation.

Highest densities of giant clams (*Tridacna* spp.) were found on fringing reefs around the north-west of Vanuakula Island. Natural intact populations of giant clams are rare in Fiji as they are a popular food item. The high density recorded at Vanuakula has not been recorded anywhere else to date and marks this location out as a candidate site for protection from potential future over-exploitation.

Edible sea cucumbers were also recorded most often on fringing as well as inner barrier reef sites. Sea cucumbers are often targeted for export for the international market. In shallow water surveys, highest densities were found around Vanuakula Island, thereby providing another reason for protecting fringing reefs at this location.

5.5.5 Biodiversity Indices

Contour plots of Shannon-Weiner biodiversity indices generally support the suggestion that there are particular parts of the reef system surveyed to date that stand out as areas in need of protection and management. Hotspots of benthic biodiversity were located on the north-eastern barrier reef while high invertebrate diversity was shown in the south-west section. Reef fish diversity was high at the northern point of the barrier reef but also along the north-western section. It should be noted that the plots are diversity at one depth band only (shallow). Patterns of biodiversity are likely to change with depth according to reef type. The 'shallow' depth band presented in this report is likely to contain the highest levels of biodiversity across all reef types surveyed to date.

5.6 Preliminary Areas Recommended for Management

As only a part of the coral reef system in Northern Kadavu has been surveyed so far we are not in a position to make final recommendations for management for the whole area. However, the area surveyed to date has highlighted some hotspots of coral cover, reef fish and invertebrate abundance and overall biodiversity ratings that can be used to make initial recommendations for conservation of marine habitats and their resources. In particular the following areas are recommended for protection and management:

- The northern tip and north-western section of the Great Astrolabe Reef – high cover of hard corals, abundant and diverse populations of reef fish and the presence of rare species such as the Bumphead Parrotfish.
- The south-west section of the Great Astrolabe Reef – high invertebrate diversity and high densities of food-fish families.
- Fringing reefs along the north coast of Vanuakula Island – highest recorded densities of rare and often targeted invertebrates (Giant Clams and edible Sea Cucumbers).

One of the next steps is to work with local communities in northern Kadavu in order to present the main findings of this report and begin discussions on management approaches that are feasible. Our recommendation is that KQMST, working closely with CCC on the ground, are the best-suited organisation in Kadavu region to follow this process through. Existing locally marine managed areas, as part of the qoliqoli network should be studied in conjunction with spatial management recommendations from this preliminary report and subsequent, more substantial documents produced by CCC. The idea that existing management strategies can be altered according to new research findings should be introduced and/or reiterated to local communities.

6 RECOMMENDATIONS

The following section of recommendations is divided in two; firstly recommendations and aims for the continuation of CCC's work in the Kadavu Islands and secondly recommendations towards the implementation of Marine Protected Areas in an integrated conservation programme for the northern Kadavu region.

CCC

Recommendation 1- Continue Baseline data collection in the northern Kadavu region

Recommendation 2- Continue community capacity building activities in close collaboration with the KQMST. These activities include school workshops, resort and guest education initiatives and best practice guidelines. Of key importance here is the inclusion of all stakeholder groups in the northern Kadavu region.

Recommendation 3-Continue to develop habitat definitions for the Kadavu region to derive a comprehensive breakdown of all reef types found in the area.

Recommendation 4-Develop more advanced Geographic Information Systems and habitat mapping techniques to aid in the efficient dissemination of data to all stakeholders

Marine Protected Area Implementation

Recommendation 1- CCC recommends that the KQMST take the lead role in the implementation of Marine Protected Areas in conjunction with the existing network of qoliqolis in the Kadavu Islands

Recommendation 2- To act, if invited, in an advisory capacity to support the appointed lead agency in the process of Marine Protected Area implementation. To provide assistance in areas such as the development of a monitoring scheme and educational workshops aimed at the integration of MPAs.

Recommendation 3- To seek support from all levels of administration to forward the development of a legislative framework as a sound platform for MPA implementation

Recommendation 4- Evaluate sources of infrastructure support for MPAs. Infrastructure needs to include patrol bases, offices and community education and environmental interpretation facilities

Recommendation 5- Conduct specific and targeted workshops be to inform all stakeholders of the importance of Marine Protected Areas and conservation

Recommendation 6- Data and recommendations derived from CCC's work are not definitive. Using techniques such as the GIS developed for this and subsequent reports, all stakeholders to be invited to a consultation process to refine MPA location and function. Without consensus from all stakeholders, any Marine Protected Areas will fail to be successfully implemented

Recommendation 7- Undertake studies on the socio-economic and demographic factors that may affect successful MPA implementation. The findings of these studies will assist in defining suitable MPA sites as well as providing a feedback-monitoring programme to detail the success of implemented MPA programmes

Recommendation 8- Establish a monitoring programme to identify changes in the coral reef communities of the northern Kadavu region in collaboration with local stakeholders and communities

Recommendation 9- Promote Adaptive Management -Any MPAs and management planning needs to be dynamic in order to respond to feedback from both socio-economic and biological monitoring programmes

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APPENDIX 1

Recording forms used for data collected during CCC baseline surveys.

BACKGROUND INFORMATION

Station code	______	Fish recorder- contour A	______
Survey Date	______	Point data recorder- contour A	______
Easting- shallow transect	______	Fish recorder- contour B	______
Northing- shallow transect	______	Point data recorder- contour B	______
Easting- deep transect	______	Fish recorder- contour C	______
Northing- deep transect	______	Point data recorder- contour C	______
Start Time	______	Fish recorder- contour D	______
End Time	______	Point data recorder- contour D	______
Marshall name	______		
		No. of dives to complete Station	______
Wind strength	______	Horizontal visibility- contour A	______
Wind direction (from)	______	Horizontal visibility- contour B	______
Current strength	______	Horizontal visibility- contour C	______
Current direction (to)	______	Horizontal visibility- contour D	______

SURFACE IMPACTS

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

UNDERWATER IMPACTS

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

Station Code ____________

Recorders name ____________

TARGET FISH

	Cntr A	Cntr B	Cntr C	Cntr D
Butterflyfish				
(Big) Long-Nosed				
Klein's				
Vagabond				
Pyramid				
Eastern Triangle				
Latticed				
Redfin				
Chevroned				
Saddled				
Threadfin				
Teardrop				
Longfin Bannerfish				
Masked Bannerfish				
Humphead Bannerfish				
Pennant Bannerfish				
Angelfish				
Regal				
Bicolour				
Emperor				
Blue-girdled				
Dusky				
Semicircle				
Lemonpeel				
Surgeonfish				
Convict				
"Ringtail" spp.				
Brushtail tang				
"Bristletooth" sp.				
Sailfin tang				
Mimic				
Unicorn spp.				
Tuna/ Mackerel				
Narrow-banded king mackerel				
Fusilier				
"Blue and yellow" sp.				
Bluestreak				
Damselfish				
Blue-Green Chromis				
Black Bar Chromis				
Other "Chromis" sp.				
Threespot dascyllus				
Humbug dascyllus				
Reticulated dascyllus				
Whitebelly				
Staghorn				
Talbot's demoiselle				
Blue devil				
Lemon				
Golden				
Black				
"Anemone fish" sp.				
"Sergeant" sp.				

	Contour A	Contour B	Contour C	Contour D
Wrasse				
Diana's hogfish				
Mesothorax hogfish				
Humphead				
Red-banded				
Checkerboard				
Twotone				
Crescent				
Sixbar				
Jansen's				
Cigar				
Bird				
Rockmover				
Blackedged thicklip				
Cleaner				
Sling-jaw				
Goatfish				
Half-and-half				
Two-barred				
Dash-and-dot				
Multibarred				
Blackstriped				
Yellowfin				
Triggerfish				
Redtooth				
Orangestriped				
Clown				
Blackbelly Picassofish				
Pinktail				
Scythe				
Halfmoon				
Picasso				
Moustache / Titan				
Groupers				
Flagtail				
Peacock				
Humpback				
"Honeycomb" sp.				
Lyretail				
Saddleback				
Leopard Coral				
Soapfish				
Anthias				
Parrot Fish				
Bumphead				
Bicolour juv.				
Spinecheek				
Twoline				
Snapper				
Two-spot				
Black-and-white				
Bluelined				
Twinspot				
Fivelined				
Paddletail				

Station Code ____________

Recorders name ____________

TARGET FISH (CONT)	Contour A	Contour B	Contour C	Contour D
Rabbitfish				
Foxface				
Pencil-streaked				
Uspi				
Dartfish				
Blackfin				
Cardinalfish				
Pyjama				
Blackstriped				
Puffer				
Blackspotted				
Goby				
Sphynx				
Brownbarred				
Toby				
Spotted				
Blenny				
Yellowtail poison fang				
Bicolour				
OTHER MAJOR FAMILIES				
Jack / Trevally				
Sweetlips				
Barracuda				
Moorish Idol				
Emperor				
Spadefish / Batfish				
Porcupine				
Trunk / Box / Cowfish				
Squirrelfish / Soldierfish				
Filefish				
Lionfish				
Scorpionfish / Stonefish				
Lizardfish				
Hawkfish				
Sandperch				
Sharksucker				
Needlefish				
Pipefish				
Trumpetfish				
Moray Eel				
FURTHER SPECIES				

TARGET INVERTS	c	Contour B	Contour C	Contour D
Annelid Worms				
Segmented Worms				
Feather Duster				
Christmas Tree				
Anthropoda: Crustacea				
Shrimps				
Spiny Lobster				
Crab				
Mollusca:				
Gastropods:				
Abalone				
Murex sp.				
Conch				
Cowrie				
Triton				
Cone Shell				
Drupella sp.				
Limpet				
Topshell				
Nudibranch				
Worm Snail				
Bi-Valves:				
Oyster				
Giant Clam				
Other Clam				
Other				
Chiton				
Cephalopods:				
Cuttlefish				
Squid				
Octopus				
Echinodermata:				
Sea Stars:				
Acanthaster planci (COT)				
Linkia laevigata (Blue)				
Nardoa sp. (Brown)				
Culcita novaeguineae				
Protoreaster nodosus				
Choriaster granulatus				
Other				
Brittle Star				
Feather Star				
Basket Star				
Sea Urchin:				
Sea Cucumber:				
Synaptid				
Other				
H. edulis				
H. scabra				
H. nobilis				
H. fuscogilva				
Bohadschia marmorata				
Actinopyga mauritana				
Stichopus chlorinatus				
Tunicate				
Bryozoan				
Further species				

Sheet 4: Point Intercept Data.

Data Identifier ______________________

Station Code ______________________

Depth contour ______________________

Recorders name ______________________

POINT	LIFEFORM	TARGET SPECIES	POINT	LIFEFORM	TARGET SPECIES	POINT	LIFEFORM	TARGET SPECIES	POINT	LIFEFORM	TARGET SPECIES
1			1			1			1		
2			2			2			2		
3			3			3			3		
4			4			4			4		
5			5			5			5		
6			6			6			6		
7			7			7			7		
8			8			8			8		
9			9			9			9		
10			10			10			10		
11			11			11			11		
12			12			12			12		
13			13			13			13		
14			14			14			14		
15			15			15			15		
16			16			16			16		
17			17			17			17		
18			18			18			18		
19			19			19			19		
20			20			20			20		

Sheet 5: Benthic Categories and Codes:

	LIFEFORM	SPECIES
SUBSTRATES		
Bedrock	1	
Sand	2	
Mud	3	
Dead Coral & Algae	4	
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	
Halodule sp.	11	24
Halophila sp.	11	25
Mangroves	12	

	LIFEFORM	SPECIES
TARGET INVERTEBRATES		
Porifera: Sponges	13	
Tube	13	26
Barrel	13	27
Elephant Ear	13	28
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	
SUB-MASSIVE	26	
MUSHROOM	27	
OTHER:		
FIRE (*Millepora*)	28	
BLUE (*Heliopora*)	29	

		SPECIES
Target species		
Pocilloporidae		
Pocillopora sp.:	Small	49
	Medium	50
	Large	51
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

Benthic Codes and Categories (continued).

SPECIES	
Milleporidae	
Millepora platyphylla	79
Millepora intricata	80
Dendrophylliidae	
Tubastrea micrantha	81
Turbinaria reniformis	82
Merulinidae	
Hydnophora sp.	83
Merulina scabricula	84
Miscellaneous	
Brain: Small	85
Medium	86
Large	87