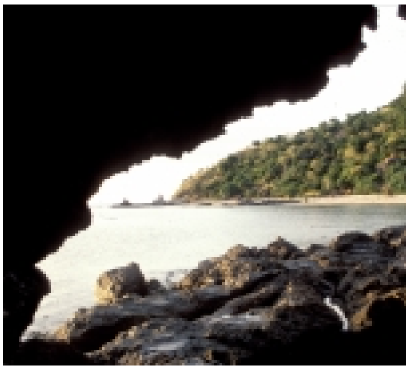
FIJI CORAL REEF CONSERVATION PROJECT

1ST ANNUAL REPORT





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May 2003

Ministry of Tourism, Culture, Heritage and Civil Aviation

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ACKNOWLEDGEMENTS

The continuing success of the *Fiji Coral Reef Conservation Project* would not have been possible without: the vision and leadership provided by the Government of Fiji, and in particular the Ministry of Tourism and the Fiji Visitors Bureau; the generous hospitality of Castaway Island Resort, in particular Geoff Shaw, Garry Snodgrass, Craig and Karen Flannery, Geof and Trudy Loe, Veresa Naiqara, Tevita Layasewa and Joape Waqairawai; and the guidance, encouragement and generous support provided by the following project partners (listed in alphabetical order):

Air New Zealand: Francis Mortimer, Simon Bean and colleagues.
Andhra College Lautoka
Aqua-Trek: Andrew Redfern, Dave Dickenson, Yoshi Kyakuno and colleagues.
Beachcomber Island Resort: Dan Costello and colleagues.
Biological Consultants Fiji: Edward Lovell.
Bounty Island Sanctuary Resort: Bruce Carran
British Airways.
British High Commission, Fiji.
Captain Cook Cruises: William Gock and colleagues
Dive Centre Suva
Dive Pacific Magazine.
Dive Tropex: Alex and Will Wragg.
Fiji Institute of Technology: Winifereti U. Nainoca
Fiji Times
FLMMA Network members
International Secondary School, Suva: Litiana Temol and colleagues.
Live & Learn: Christian Nielsen.
Mana Adventist School
Malolo District School, Solevu: Solwanne Waqanidrola
Malolo Island Resort: Steve & Danielle Ward and colleagues.
Ministry of Fisheries & Forests: Hon. Konesi TabuYabaki, Malakai Tuiloa and colleagues
Ministry of Tourism: Kerisoni Baledrokadroka, Marika Kuilamu, Manoa Malani, and colleagues.
Musket Cove Resort: Dick Smith and colleagues.
Mamanuca Fiji Hoteliers Association: All members.
Navini Island Resort: Arthur Reed and colleagues.
Nacula Tikina Tourism Association: Andrew Fairley and colleagues
Pacific Marine Vuda
PADI: Colin Melrose.
Resource owners: Ratu Jeremaia Matai, Ratu Sevanaia Vatunitu Nabola, Ratu Sakiusa Tuni Toto, Ratu Osea Gavidi and others.
Resort Support: Helen Sykes.
Solevu Village, Malolo Island; friends and associates
SOPAC: Robert Smith and colleagues.
South Seas Cruises: Mark Fifield, Penny Smith and colleagues.
Subsurface Fiji: Tony Cottrell, John Brown and colleagues.
Sun Fiji News Limited
Tokoriki Island Resort: Andrew Turnbull and colleagues.
Turtle Airways Ltd.
UNDP: Jenny Bryant-Tokalau and colleagues.
University of the South Pacific (USP):
USP Department of Biology: Robin South, Robyn Cumming, Johnson Seeto, Shirley Mohammed and colleagues.
USP Institute of Applied Science; Prof. Bill Aalbersberg and colleagues

USP Department of Geography, GIS Unit; Michael Govorov, Fabrice Lartigou and Conway Pene.
Wadigi Island Resort: Ross Allen and colleagues
West Side Water Sports: Lance and Lily Millar, John Purves and colleagues.
WWF: Dermot O'Gorman, Kesaia Tabunakawai, Lisette Wilson, Etika Rupeni and colleagues.

Finally, we would like to thank all the Coral Cay Conservation team members and local staff members at Ravinaki/Castaway Island Resort who have contributed to the production of this report in various ways.

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 Fiji's reef ecosystems.

- Following on from the successful pilot project (MCRCP), stakeholders in the Mamanuca Islands invited Coral Cay Conservation (CCC) to continue working in the region, leading to the implementation of a full CCC project entitled '*Fiji Coral Reef Conservation Project* (FCRCP). This report outlines the progress of the FCRCP over the first year of operations (March 2002 – April 2003).

- Fieldwork during year one of the FCRCP focused on gathering data from a number of allocated survey sectors over a wide range of geographical locations and habitat types using: baseline transects for habitat mapping and Reef Check surveys to assess reef health.

- Results from year one of the FCRCP showed a range of detrimental anthropogenic influences to be present in the Mamanuca Islands. In particular coral bleaching, sedimentation and the combination of nutrient elevation and over exploitation of marine resources are subjects that require attention in the region. Perhaps the most obvious of these impacts was the mass coral bleaching event, which occurred in early 2000, with a second smaller event in 2001. However Reef Check results of hard coral cover indicate that some recovery has taken place (see separate CCC report; Walker *et al*., 2002).

- Of the 31 designated survey sectors, 14 have been completed during the first year of the FCRCP. Preliminary maps showing the habitat composition of survey transects on all surveyed reefs were produced. Analysis of survey data in the form of six analysis areas has revealed a range of habitats in the completed sectors. Habitats with the highest hard coral cover and diversity and most diverse reef fish assemblages have been highlighted.

- An extensive environmental awareness and education programme for local communities and stakeholders has successfully been established in the Mamanucas during first year of the FCRCP. It is vital the environmental education goes hand in hand with the CCC marine survey programme so that awareness of the importance of both sides of the FCRCP is known in the region.

- The support by many stakeholders for mitigating measures in the Mamanuca Islands represents a clear desire to address the threats to reef health and work towards sustainable use. Such a goal could be addressed by both reducing the threats to reef health and establishing a series of marine reserves.

- Marine reserves are important since they: conserve biodiversity; increase fish abundances within the reserve and provide 'spill-over' into surrounding areas; facilitate reef recovery; separate conflicting uses; serve as a centre for public education and attract sustainable tourist revenue.

- Research indicates that 20% of the reefs of an area should be 'no-take' in order to maximise the chances of sustaining the fisheries and g*iven that the reefs delineated on the habitat map cover approximately 70* km^2*, the eventual aim should be to protect 14* km^2 *of shallow (<30 m) benthic habitat within the Mamanuca Islands from fishing.*

- A number of coral reefs are recommended for the designation of MPAs in the areas surveyed during year one of the FCRCP. These have been selected predominantly on the

basis of the analysis of survey data to identify habitats with high hard coral abundance combined with high benthic faunal and reef fish diversity.

- The areas recommended for protection are south-east Mana Island, Yalodrivi Reef, Mothui Island, Malolo Patch Reef and Navini Island. The areas selected comprise 3.75 km^2 of coral reef habitats leaving 10.25 km^2 still awaiting allocation in the remaining time of the FCRCP.

- Coral Cay Conservation enters into Year 2 of the FCRCP with four main aims:
  - To continue baseline surveys in areas that have not been surveyed to allow the production of a full inventory of the marine resources.
  - To continue and expand community education efforts with all stakeholder groups.
  - To continue monitoring to examine the recovery of the marine resources of the Mamanucas following episodes of natural and anthropogenic disturbance.
  - To assist and support any other body or organisation that displays a willingness and interest in the management of the resources of the Mamanuca Islands.

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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 and hence reefs are well developed 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 because of 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 has 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-scientifically trained, self-financing volunteer divers have been shown to be able to provide useful data for coastal zone management at little or no cost to the host country (Hunter and Maragos, 1992; Mumby *et al*., 1995; Wells, 1995; Darwall and Dulvy, 1996; Erdmann *et al*., 1997; Harding *et al.*, 2000; Harborne *et al*., In press). This technique has been pioneered and successfully applied by Coral Cay Conservation (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 Coral Cay Conservation Trust (the only British-based charity dedicated to protecting coral reefs) and the USA-based Coral Cay Conservation Foundation.

The Mamanuca Islands in western Fiji (Figure 1) have been the focus of tourism development in Fiji for many years and the industry is very much aware of the value of conserving the coral reefs and fostering sustainable development. During 2000, CCC was invited to the Mamanuca Islands by local tourism operators, the Ministry of Tourism and Transport and the Fiji Visitors Bureau to determine the current status of the coral reefs and threats to their integrity and suggest possible conservation initiatives. Following two technical preparatory missions (December 2000 and March 2001), CCC and local Fijian counterparts decided to implement a three-month pilot project entitled '*Mamanuca Coral Reef Conservation Project – Fiji 2001*' (MCRCP).

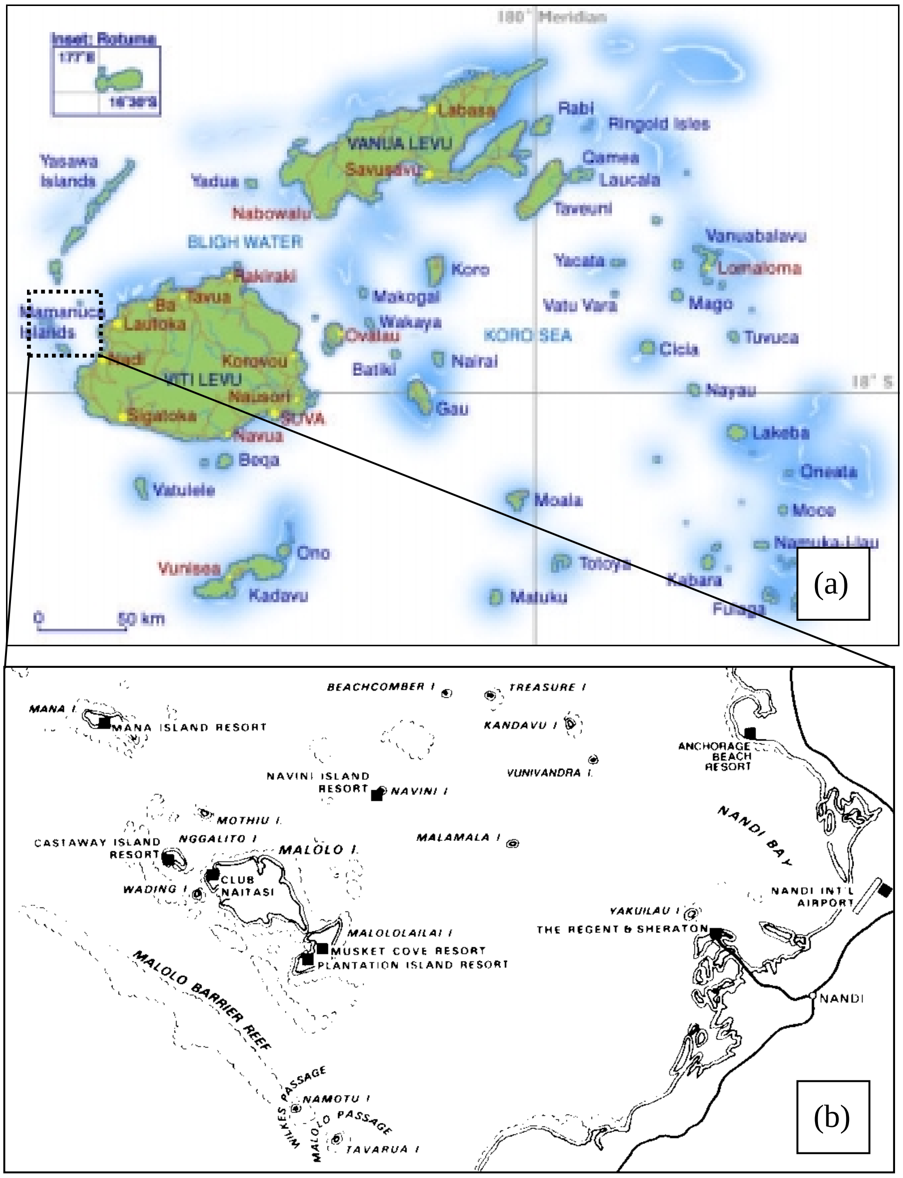

Figure 1. (a) The Fiji islands, showing the project area (dashed line) for the MCRCP. *Source*: Fiji Visitors Bureau. (b) Major islands with the Mamanucas.

This pilot project, which ran from June 8th to August 30th 2001, aimed to demonstrate the longer-term role that CCC could play within the Mamanuca Islands and provide preliminary data on the marine resources of the area and their status. A comprehensive account of the pilot project (Harborne *et al*., 2001) is available from the CCC website and as hard copies on request from the CCC-UK office. The resounding success of the MCRCP led to the commencement of the full CCC project in the Mamanucas region, named the Fiji Coral Reef Conservation Project (FCRCP), in March 2002. A two-year Memorandum of Agreement was signed by CCC and The Ministry for Tourism and Transport of Fiji in order to carry out a more comprehensive and detailed survey programme, whilst also expanding the environmental education and awareness work amongst the local communities of the Mamanucas Islands.

This report documents the results and conclusions of the first year of marine surveying of the FCRCP and offers recommendations for both conservation initiatives and future work in the project area in the coming year. A summary of the environmental community programme is also presented.

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 north-eastern 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 % 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 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 Mamanuca Islands

Along with most other areas of Fiji, the reefs of the Mamanuca Islands suffered from a mass coral bleaching event in March 2000. Local dive operators and resorts reported high mortality of reef building corals, but the extent and scale of the damage has not been quantified. Bleaching was again reported for the Mamanuca Islands in March 2001 and April 2002. The 2001 bleaching event was just prior to Cyclone Sosa passing close to the east coast of Viti Levu and the Mamanucas. The cyclone created substantial waves up to 25 feet high on the Outer Malolo ('Ro Ro') Barrier Reef (Craig Flannery, pers. comm.) and caused physical damage to the reefs at many different sites. Interestingly, there is anecdotal evidence that the water movements caused by Cyclone Sosa may have reduced sea-surface temperatures and allowed some bleached corals to recover. Furthermore, an outbreak of crown-of-thorns starfish was reported in the Mamanucas in 1996 (South and Skelton, 2000). A number of recent CoTs sightings have been reported at Mothui Island in March 2003 although the scale of this event is as yet unknown.
Natural stressors, for example bleaching and cyclones, act synergistically with anthropogenic disturbances such as sedimentation from land development, over-fishing and pollution, which are known to be present in the area. Similarly to other island groups in Fiji, coastal zone management in the Mamanuca Islands has been relatively nascent. However, the oldest private sanctuaries in Fiji, established by "Beachcomber Cruises" in the 1970s, are found around Tai (Beachcomber) and Lovuka (Treasure) Islands. A new MPA is currently being established on Malolo Island through the FLMMA project, which uses a system modelled on the Fijian customary marine tenure system.

2.3 Aims and Objectives

Following the successful pilot survey programme undertaken in 2001 by Coral Cay Conservation (CCC) and local Fijian counterparts a set of ten recommendations were drafted. These involved, but were not necessarily limited to; monitoring, education, setting up a Mamanucas management group, data base acquisition to set up a fully-functional GIS, and to set up multi-user Marine Protected Areas.

The marine science and environmental awareness programmes run during the first year of the FCRCP were designed to enhance and expand on the information collected during the initial pilot phase. A programme of surveys, training and conservation education were undertaken aimed at continuing the assessment of the status of local reefs and improving environmental awareness amongst neighbouring communities.

This section aims to provide a general overview of the scientific programme planned for the first year of the FCRCP. However, because of logistical considerations, it is important to note that the schedule for the full project must remain flexible and hence the survey programme has been and will continue to be dynamic.

2.3.1 Project Activities and Timetable

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

Data Acquisition and Management (Table 1)

1. Systematic surveys of all reefs within the project area from Tokoriki Island in the north west to Tavarua Island in the south east 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*.
2. Assess the environmental impacts and physical oceanography of the coastal areas on the local coral reefs from The Mamanucas and mainland coastline adjacent to Nadi. Again, this will be carried out using divers that have been trained during the *CCC Skills Development Programme* Table 4)
3. Repeat a series of Reef Check surveys initially carried out in 2001 to assess the status and potential recovery of the regions reefs in terms of reef health, particularly live hard coral cover.

Environmental Monitoring (Table 1)

1. Begin the establishment of a biological monitoring programme for the Mamanucas Islands. Arrange meetings and workshops with local dive schools in order to co-ordinate training and monitoring of their own dive sites. Monitoring will involve undertaking Reef Check surveys at a number of different locations to continue and expand upon the effort from the project.

Counterpart Training and Conservation Awareness Programmes (Table 2)

1. Provide scientific and SCUBA training for project counterparts and regional representatives. This will allow the local dive community to carry out their own surveys in the area and empower both local and regional communities to undertake their own reef monitoring and educational tours for fishermen and local children.
2. Establish a schools curriculum for conservation education by participating and joining schools in the Mamanucas areas with presentations, classes and interactive practicals on the local marine environment. Production of educational posters will provide an initial resource to help promote reef conservation at an early stage.
3. 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 Mamanucas.

Training of local project counterparts and stakeholders ran 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 Mamanucas. CCC field science staff gave lectures and practical demonstrations of the importance of mangroves and coral reefs. A beach clean-up was also organised each time a school was visited. Competitions with school children were incorporated into educational visits in order to encourage villagers to keep their beaches clean.

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.

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Table 1. Planned activities for the *Fiji Conservation Project April 2002- March 2003*. - Marine Surveys.

ACTIVITY - Marine	**MONTH**												**ASSUMPTION**
Data Acquisition and Management	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	
1. Development of a comprehensive classification scheme for all Mamanucas 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)	•	•	•	•	•	•	•	•	•	•	•	•	
Environmental Monitoring													Repeat survey sites are located accurately.
Reef Check – Advanced surveys (CCC style) - repeat monitoring of last years sites				•	•	•							
Reef Check – Advanced surveys (CCC style) – new locations							•	•	•	•	•	•	New sites located during April to September – based on finding healthy reefs.
2. Recommendations													
Initial application of protected area boundaries and zoning schemes associated with these areas.											•		CCC field and UK staff liase with the ministry and local stakeholders as to locations and particulars of recommended reserve areas.
3. Reporting													
Updates on web	•	•	•	•	•	•	•	•	•	•	•	•	Data are made available to CCCUK staff.
Summary reports						•						•	Data are made available to CCCUK staff for report production.

Table 2 Planned activities for the *Fiji Conservation Project April 2002- March 2003*. - Outreach activities.

ACTIVITY													**ASSUMPTION**
Counterpart Training	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	
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.
Reef Check surveys					•			•			•		As above.
Report Production						•						•	
Conservation Awareness													
Educational Poster production			•										Poster production goes ahead on time.
Schools visits			•			•			•			•	Acceptance of local schools to facilitate visits by CCC staff.
Production of a national schools teaching programme on coral reefs										•			Input from local schools and ministry of education.
Report Production						•						•	All materials are made available from to CCCUK staff.

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2.3.2 Habitat mapping

One of the major planned outputs of the first year of the FCRCP was a more detailed marine habitat map than the preliminary one produced during the MCRCP in 2001. 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.

3. METHODS

3.1 Survey strategy

Since the area encompassed by the FCRCP is extensive the survey strategy focused on gathering detailed data from a wide range of geographical locations in order to build on the information collected during the MCRCP in 2001. 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 more solid recommendations for MPA designation in the Mamanucas.

The Concept Of 'Survey Sites'

During the first year of the FCRCP, CCC volunteers collected data from a series of 'survey sites', which correspond to a particular island's reef or part of a reef depending on reefal area. 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. Sites were chosen to represent: (1) popular diving areas; (2) the 'best' reefs of the project area; (3) the 'worst' reefs of the project area; (4) a range of reef (and hence habitat) types. Site selection was based on a combination of existing data, local information (e.g. dive resorts), local biologists and initial assessments (e.g. snorkelling). A total of 31 sites were designated for potential surveying during the first year of the project (Fig. X). Reaching the further sites (e.g. 7-13 or 31) requires the establishment of satellite camps away from the main field station on Castaway Island. [Data from the full project will be added to the data collected during the pilot phase] in order to increase the resolution of information and produce a more accurate assessment of both the type, and location of particular subtidal habitats around the Mamanucas.

Two survey techniques were used during the first year of the FCRCP: CCC baseline transects for habitat mapping; and Reef Check surveys to assess reef health.
Firstly, standard *CCC Baseline Survey Technique* transects were surveyed to provide general data on each habitat type present. The exact number of transects at each site varied, depending on the topography of the reef (e.g. fewer transects at those sites with a wide or deep reef profile), but usually numbered between 3 and 20, depending on the scale and size of each survey site (refer to Fig. 2).
Secondly, modified 'Reef Check' surveys were used to collect quantitative data on the health of survey sites. Reef Check[1] is an established method for rapidly assessing reef health and was designed specifically for non-specialist researchers. CCC have adapted the standard Reef Check technique to record a further level of detail in terms of benthic habitats, hard coral and reef fish targets. In addition to these key techniques, further data such as compiling species lists and assessing water quality will be undertaken concurrently.

Baseline transects were completed throughout all months of the first year. Reef Check surveys were undertaken at the same sites visited in 2001 for the MCRCP. These sites were close to the paths of the baseline transects so that the data sets would be complimentary and could be analysed in conjunction.

[1] http://www.ReefCheck.org/

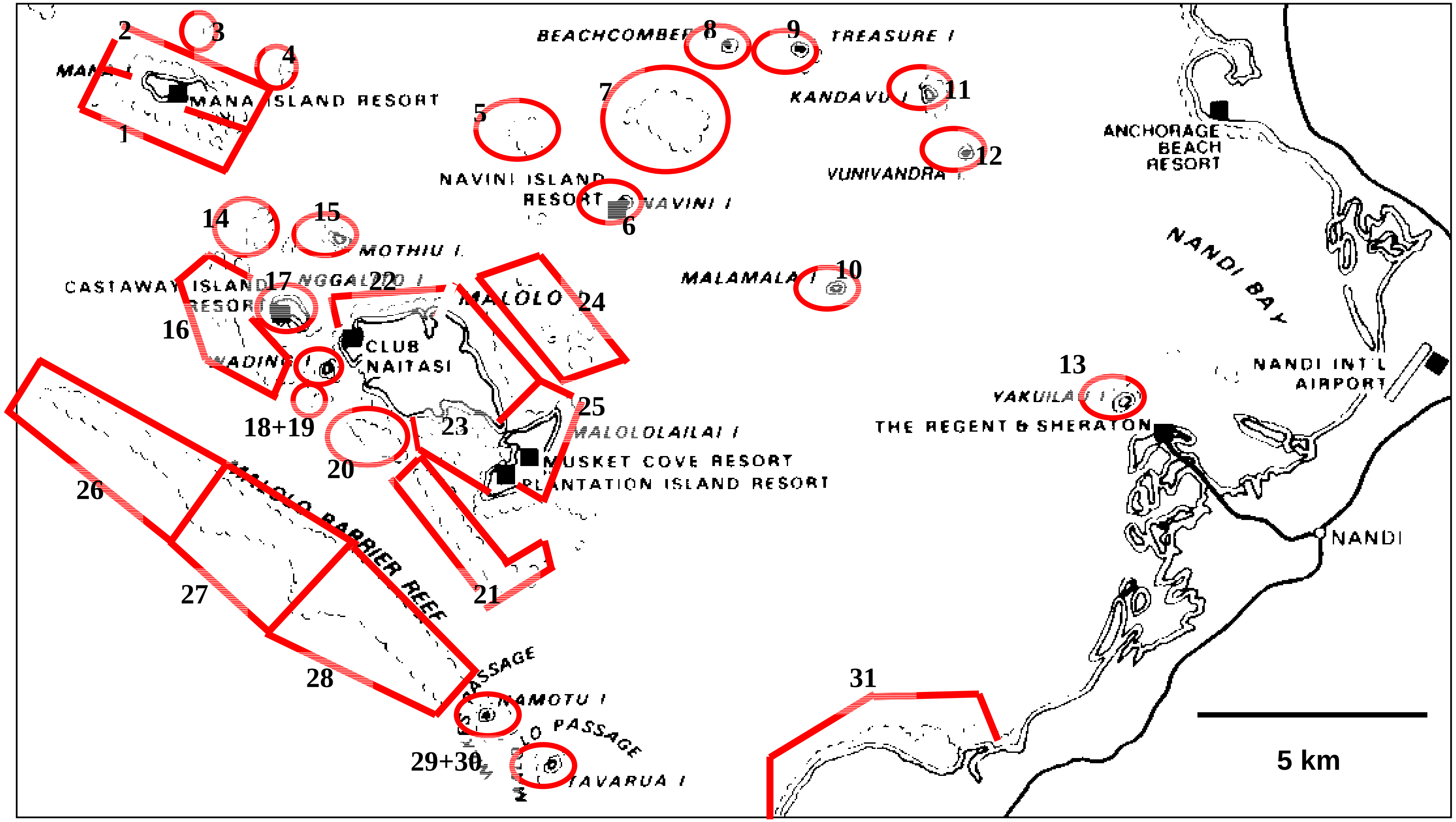


Figure 2. Location of the different 'Survey sites' within the Mamanucas. Thirty one sites are highlighted in red.

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 FCRCP, 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 and local counter-parts during the *Fiji Coral Reef Conservation Project*.

	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 CCC Reef Survey forms, habitat classifications and 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

Year 1 of the FCRCP utilised 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. 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.

Since most transects require two or more dives to complete, transect surveys were usually divided up into sections (or 'sub-transects') with surveys of each sub-transect carried out by a team of four trained divers divided into two buddy pairs (A and B) as shown in Figure 3. At the start point of each sub-transect, Buddy Pair B remained stationary with Diver 3 holding one end of a 10 m length of rope, whilst Buddy Pair A swam away from them, navigating up or along the reef slope in a pre-determined direction until the 10 m line connecting Diver 1 and 3 became taught. Buddy Pair A then remained stationary whilst Buddy Pair B swam towards them. This process was repeated until the end of the planned dive profile, when a surface marker buoy (SMB) carried by Diver 2 was deployed to mark the end of that sub-transect. The SMB acted as the start point for the next survey team and this process was repeated until the entire transect was completed. The positions of the SMB at the start and end of each dive were fixed using a Global Positioning System (GPS).

Diver 1 was responsible for leading the dive, taking a depth reading at the end of each 10m interval, and documenting signs of anthropogenic impact such as broken coral or fishing nets. Diver 1 also described the substratum along the sub-transect by recording the presence of six substrate categories (dead coral, recently killed coral, bedrock, rubble, sand and mud). Divers 2, 3 and 4 surveyed fish, hard corals and algae, soft corals, sponges and invertebrates respectively. Diver 3 surveyed an area of approximately 1 metre to each side of the transect line whilst Divers 1, 2 and 4 survey an area of approximately 2.5 metres to either side of the line.

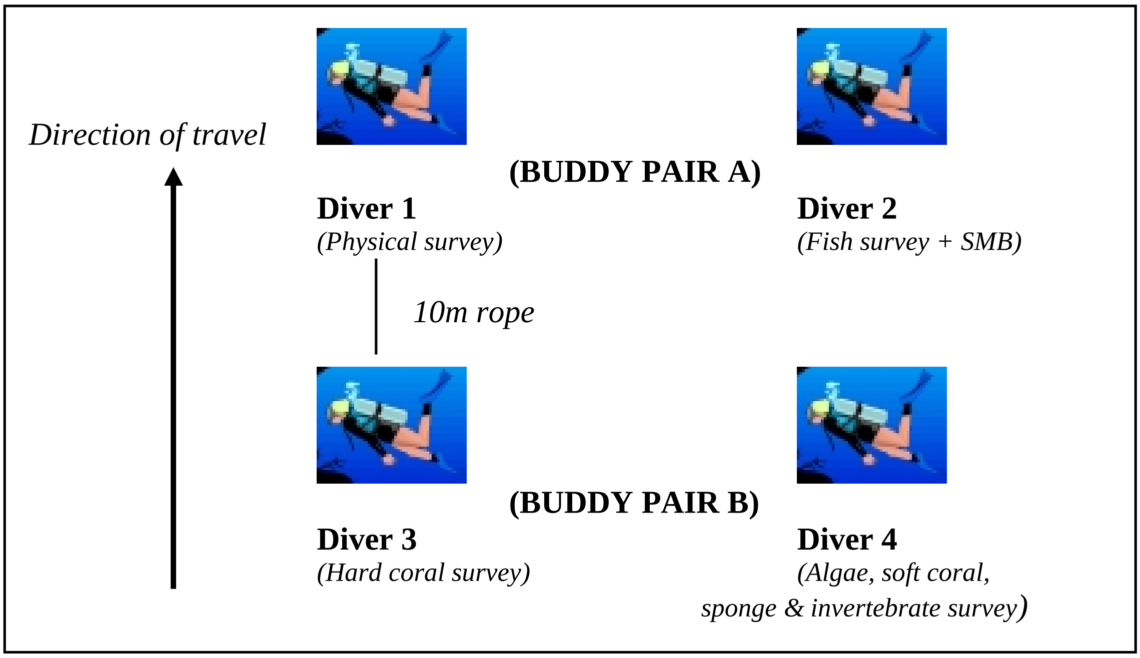


Figure 3. Schematic diagram of a baseline survey dive team showing the positions and data gathering responsibilities of all four divers. Details of the role of each diver are given in the text.

During the course of each sub-transect survey, divers may have traversed two or more apparently discrete habitat types, based upon obvious gross geomorphological (e.g. forereef, escarpment or lagoon) or biological differences (e.g. dense coral reef, sand or rubble; Figure 4). Data gathered from each habitat type were recorded separately for subsequent analysis.

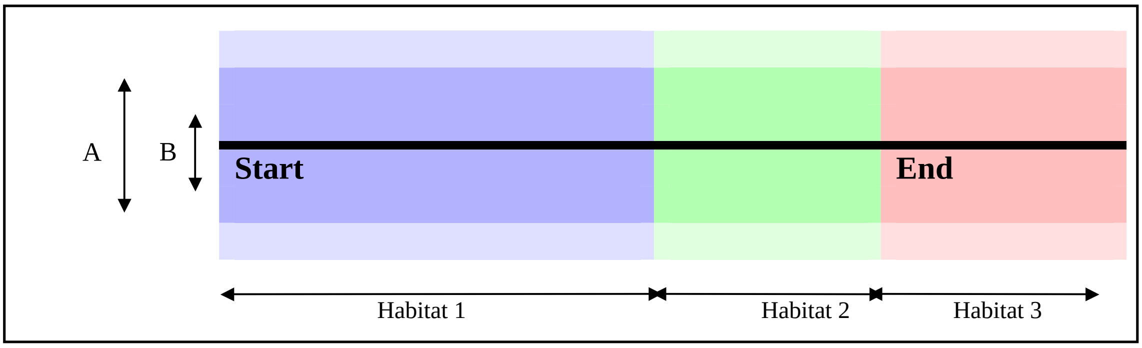


Figure 4. Schematic diagram (aerial aspect) of an example of a reef area mapped by divers during a sub-transect survey. Solid line represents imaginary sub-transect line. Dashed lines and shaded areas represent areas surveyed (A = 5m wide swathe surveyed by Divers 1, 2 and 4; B = 2 m wide swathe surveyed by Diver 3). Benthic data from habitats 1, 2 and 3 (e.g. reef, sand and rubble) are recorded separately.

Each species, life form or substratum category within each habitat type encountered was assigned an abundance rating from the ordinal scale shown in Table 4.

Table 4. Ordinal scale assigned to life forms and target species during baseline surveys.

Abundance rating	Coral and algae	Fish and invertebrates (number of individuals)
0	None	0
1	Rare	1-5
2	Occasional	6-20
3	Frequent	21-50
4	Abundant	51-250
5	Dominant	250+

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 temperature readings (±0.5°C) were taken from the survey boat using a bulb thermometer at the sea surface. The survey team also took the temperature at the maximum survey depth (i.e. at the start of the survey). Similarly, the salinity was recorded using a hydrometer and a water sample taken from both the surface and the maximum survey depth. Water visibility, a surrogate of turbidity (sediment load), was measured both vertically and horizontally. A secchi disc was used on the survey boat to measure vertical visibility through the water column (Figure 5). Secchi disc readings were not taken where the water was too shallow to obtain a true reading. Horizontal visibility through the water column was measured by divers' estimates while underwater. Survey divers 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, volunteers 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.

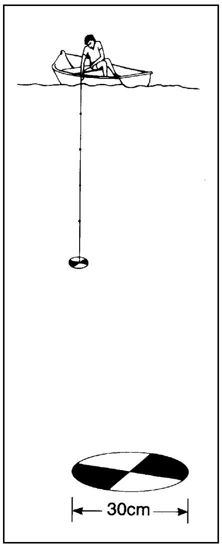


Figure 5. The use of a secchi disc to assesses vertical water clarity. The secchi disc is lowered into the water until the black and white quarters are no longer distinguishable. The length of rope from the surveyor to the disc is then recorded. *Source*: English *et al*. (1997).

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’. Finally the divers recorded a general impression of the site during each survey. These ratings were completed for biological (e.g. benthic and fish community diversity and abundance) and aesthetic (e.g. topography) parameters. Both parameters were ranked from a scale of 5 (excellent), 4 (very good), 3 (good), 2 (average) or 1 (poor).

3.5 Reef Check

Reef Check was designed to be used by non-professional divers to assess reef health and hence generates relatively simple, but quantitative, information. During the FCRCP the standard Reef Check protocol was modified to collect more detailed data (e.g. via greater taxonomic resolution) and hence provide a better assessment of reef health. Such modifications were possible because all CCC volunteers received more intensive training than regular sport divers. Each Reef Check site was located close to a baseline transect in order that the data sets could be spatially linked together and hence analysed in conjunction.

The standard Reef Check survey protocol utilises two transects at depths of approximately 3 and 10 m but, during the FCRCP, deeper transects (e.g. 17 and 24 m) were conducted if the reef topography was appropriate. Similarly, since reef development in the Mamanuca Islands is generally in shallow water, the 10 m transect was not completed if there was minimal coral cover at this depth. Along each depth contour a 100 m transect was deployed and along it four 20 m long replicate transects were surveyed. The replicate transects followed the designated depth contour in sequence but the start and end points are separated by a 5 m space (Figure 6) i.e. the distance between the start of the first transect and end of the last transect was 20 + 5 + 20 + 5 + 20 + 5 + 20 = 95 m. By collecting data from each of the four 20 m sections, four replicates were collected per survey allowing the calculation of a mean per replicate and hence more powerful statistical analysis.

Five types of data were recorded via three surveys along each transect line at each depth. Firstly, a site description sheet was completed which included anecdotal, observational, historical, locational and other data. Secondly, four 5 m wide by 20 m long transects (centred on the transect line) were sampled for commercially important fish, for example those typically targeted by fisherfolk and aquarium collectors. Fish were only counted if they were less than 5 m above the transect line, giving a survey area for each transect replicate of 20 x 5 x 5 m = 500 m^3. CCC volunteers in Fiji recorded data on more fish species than specified by the standard Reef Check protocol. The divers assigned to count fish swam slowly along the transect and then stopped to count target fish every 5 m and then waited three minutes for target fish to come out of hiding before proceeding to the next stop point. Thirdly, four 5 m wide by 20 m long transects (centred on the transect line) were sampled for invertebrate taxa typically targeted as food species or collected as curios.

Quantitative counts were made of each species. In addition, the invertebrate surveyors noted the presence of coral bleaching or unusual conditions (e.g. diseases) along the transects.

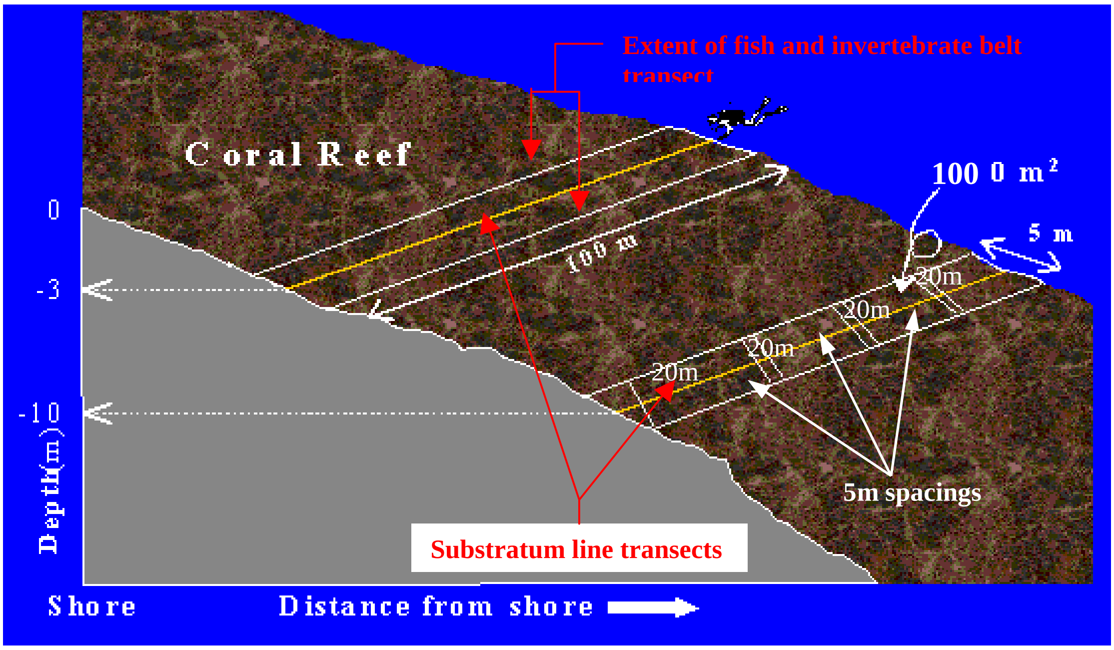


Figure 6. Schematic diagram showing the position of the transect lines during a Reef Check survey. 100 m transect is divided into four 20 m replicates so area of each belt transect is 20 x 5 m = 100 m^2. In addition to the standard 3 and / or 10 m transects, CCC used one or more deeper transects when appropriate. *Source*: modified from figures on http://www.reefcheck.org.

Finally, four 20 m long transects were point sampled at 0.5 m intervals to determine the substratum types and benthic community of the reef. The diver looked at each point and noted down what lay under each of those points. The standard Reef Check protocol specifies that the categories recorded under each 50 cm point are: hard coral, soft coral, recently killed coral, dead coral, fleshy seaweed, sponge, rock, rubble, sand, silt / clay and 'other'. However, CCC volunteers recorded hard corals to life form level (along with target species), soft corals to life form level and five categories of algal cover (mixed assemblage, coralline, *Halimeda*, 'macro' and 'turf'). Finally, the substratum surveyors recorded coral damage from anchors, dynamite, or 'other' factors and trash from fishing nets or 'other'. Divers rated the damage caused by each factor using a 0-3 scale (0 = none, 1 = low, 2 = medium, 3 = high). All data were transferred to specially designed recording forms (Appendix 2).

Reef Check data collected during the year one of the FCRCP is presented in a separate report (Walker et al., 2002) and so is not replicated here. Reef Check surveys will be made available to the global and national databases, hence increasing the impact of the project.

3.6 Data analysis

Note on statistical conventions: during this report the results of statistical tests are given by showing the 'p' (probability) value of the test. Under statistical conventions, a p value of less than 0.05 is regarded as 'significant'(the error of the test is less than 1 in 20) and a p value of less than 0.01 is regarded as 'very significant'.

3.6.1 Baseline data

Oceanographic, climate and anthropogenic impact data

Data on water temperature, salinity, visibility, the strength and direction of currents and wind, natural and anthropogenic impacts, the presence of boats and the biological and aesthetic ratings were summarised graphically and via univariate statistics, along with more detailed examination of the data using Analysis of Variance (ANOVA) and subsequent least significant difference multiple range tests. Data were either summarised for the whole project area or for each of the five reef complexes as appropriate.

Benthic data

In order to describe the reefal habitats within the project area, benthic and substratum data were analysed using multivariate techniques within PRIMER (Plymouth Routines in Multivariate Ecological Research) software. Data from each Biological Form (which represents a 'snap-shot' of the benthic community from either part or all of a habitat type distinguished by the survey team) are referred to as a Site Record. Multivariate analysis can be used to cluster the Site Records into several groups, which represent distinct benthic classes. Firstly, the similarity between benthic assemblages at each Site Record was measured quantitatively using the Bray-Curtis Similarity coefficient without data transformation (Equation 1; Bray and Curtis, 1957). This coefficient has been shown to be a particularly robust measure of ecological distance (Faith *et al.*, 1987).

Agglomerative hierarchical cluster analysis with group-average sorting was then used to classify field data. Cluster analysis produces a dendrogram grouping Site Records together based on biological and substratum similarities. Site Records that group together are assumed to constitute a distinct benthic class. Characteristic species or substrata of each class were determined using Similarity Percentage (SIMPER) analysis (Clarke 1993).

To identify characteristic features, SIMPER calculates the average Bray-Curtis similarity between all pairs of intra-group samples (e.g. between all Site Records of the first cluster). Since the Bray-Curtis similarity is the algebraic sum of contributions from each species, the average similarity between Site Records of the first cluster can be expressed in terms of the average contribution from each species. The standard deviation provides a measure of how consistently a given species contributes to the similarity between Site Records. A good characteristic species contributes heavily to intra-habitat similarity and has a small standard deviation. The univariate summary statistics of median abundance of each species, life form and substratum category were also used to aid labelling and description of each benthic class.

Finally, the benthic class of each Site Record was combined with the geomorphological class assigned during the survey to complete the habitat label. The combination of a geomorphological class and benthic class to produce a habitat label follows the format described by Mumby and Harborne (1999).

Fish and invertebrate data

Fish and invertebrate data were summarised graphically and via univariate statistics, along with more detailed examination of the data using Kruskal-Wallis (KS) and ANalysis Of SIMilarity (ANOSIM, a routine within PRIMER). ANOSIM tests for differences between groups of community samples, defined *a priori*, using randomisation methods on a similarity matrix produced by cluster analysis. Data were either summarised for the whole project area and for each of the survey sectors. Note that the ordinal scores for fish and invertebrates cannot be standardised for transect length.

Assessment of site Conservation Values

Assigning conservation values to areas of the FCRCP project area is important in order to select priority areas for marine protected areas. 'Conservation value' is a complex term that can be related to biodiversity, fisheries potential, aesthetic value, naturalness, representativeness, uniqueness and tourist potential. One method that has been proposed as a summary of conservation value is the use of 'ternary diagrams' of coral morphology (Edinger and Risk, 2000). Using techniques originating in botany, Edinger and Risk (2000) assign conservation values to sites based on the proportion of disturbance-adapted (ruderal) *Acropora* corals, competitively dominant branching and foliose non-*Acropora* corals and stress-tolerant massive and submassive non-*Acropora* corals that are present.

By plotting the proportion of each coral type present on the ternary diagram, each site can be assigned a conservation value as shown in Figure 7. Note that reefs dominated (>60%) by stress-tolerators have a low (1) conservation value, reefs dominated (>50%) by competitively dominated or disturbance-adapted corals are assigned medium (2 and 3 respectively) conservation value and reefs with a mixed community have a high (4) conservation value. Edinger and Risk (2000) assigned these conservation values because they showed them to be correlated with coral species richness, number of rare coral species and habitat complexity (which is likely to be linked to fish diversity and abundance).

The use of ternary diagrams was applied to the semi-quantitative abundance data on coral morphologies generated by CCC baseline surveys in order to investigate their applicability for highlighting areas of high conservation value.

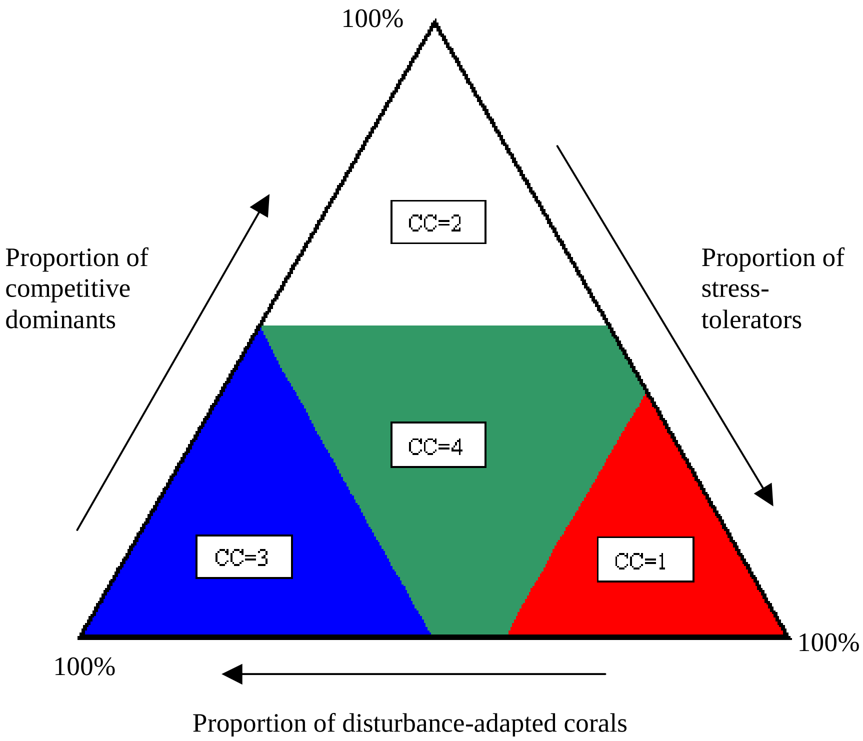


Figure 7. Schematic representation of a ternary diagram of coral morphology and the assignment of conservation values. CC = conservation value from 1 (low) to 4 (high). CC=1 represents poor reefs dominated by massive and submassive corals; CC=2 represents reefs dominated by stands of foliose and branching non-*Acropora* corals; CC=3 represents reefs dominated by branching and tabular Acropora; CC=4 represents mixed coral morphology reefs.

3.7 Observations of Megafauna

Throughout the surveys undertaken during first year of the FCRCP qualitative observations of megafauna were recorded. The abundance of megafauna is important because, for example, they are attractive to tourists and are often the first species to be reduced or extirpated by over-fishing.

3.8 Environmental Awareness and Community work

3.8.1 Marine Ecology Workshop for the Professional Diver

As part of the FCRCP, marine ecology workshops designed for diving professionals working in the Mamanuca Islands were conducted. The workshops consisted of four half-day sessions. Table 5 outlines the content of sessions. The objectives of the Marine Ecology Workshop for the Professional Diver were to:

- Provide participants with a general background in the ecology of coral reefs;
- Emphasize conservation issues and ethics in a fun and practical manner;
- Give participants information in a format that can be easily passed on to their students and clients;
- Provide a forum for the exchange of information between CCC and the Fijian dive community.

Table 5. Schedule and summary of topics covered during the 'Marine Ecology Workshop for the Professional Diver': Days 1 and 2.

Time	*Day 1*	*Day 2*
13:00	Introduction to CCC and aims of Workshop Multiple Choice questionnaire on Corals ***L1*** Introduction to Reef Formation and Ecology ***L2*** Introduction to Coral Biology • Polyp structure, coral colonies • Reproduction, feeding, symbiosis	Review of Coral Life forms from slides Multiple Choice questionnaire on Fish ***L5*** Introduction to Fish Biology • Body structure, patterns, biology • Diurnal, Nocturnal, Habitats ***L6*** Fish Families • ID of fish families
14:00	***L3*** Coral Life Forms • Acropora: Digitate, Tabulate, Branching, Encrusting, Submassive. • Non-Acropora: Branching, Encrusting, Submassive, Foliose, Massive.	***L7*** Commercially important Fish • ID of species that are commercially important and that need to be recorded by Reef Check
14:30	***Spot Dive:*** with CCC Scientists to observe life forms from lecture Underwater validation • ID of Acropora life forms • ID of Non-Acropora life forms	***Spot Dive:*** with CCC Scientists to observe fish families from lecture. • ID of Fish families of Butterflyfish, Angelfish, Snappers, Groupers etc.
16:00	**Review:** Coral life forms with slides	**Review:** Fish families with slides
16:30	Multiple-choice questionnaire to assess knowledge before and after Day 1.	Multiple-choice questionnaire to assess knowledge before and after Day 2.
17:00	***L4*** Interaction of Coastal Ecosystems • Mangroves, Lagoons and Seagrass beds, Coral reefs and Land. Importance and necessity to conserve all environments, not just coral reefs.	***L8*** Fish Ecology • Behaviour, why do they have the colours, patterns and habits they do? • Life cycles of fish, fishing, and ways of preventing over-fishing.

Table 5 (continued). Schedule and summary of topics covered during the 'Marine Ecology Workshop for the Professional Diver': Days 3 and 4.

Time	*Day 3*	*Day 4*
13:00pm	Review of important fish species from slides Multiple Choice questionnaire on Invertebrates and Algae. ***L9*** Introduction to Invertebrates • ID of Tunicates, Echinoderms, Seastars etc. • Biology of these little creatures • Importance to the reef health	Review of Coral, Fish, Invertebrates and Algae Multiple Choice questionnaire on Reef Check ***L12*** Introduction to Reef Check • Why was Reef Check invented? • Explanation of each role of surveyors on Reef Check. • Reef Check Survey Technique
14:00pm	***L10*** Introduction to Algae • Identification of Macroalgae families. • ID of a few species • Contribution of algae to reefs	***L13*** Dry run on land with equipment • Use of Tape Measure & how to lay it. • Diving techniques to use while surveying
14:30pm	***Spot Dive:*** with CCC Scientists to observe invert and algae life forms from lectures. • ID of Invertebrates • ID of Algae and collection of samples	***Practice Survey:*** with CCC Scientists on Reef Check survey techniques. • Practice use of slates, recording species, and Tape Measure laying.
16:00pm	**Review:** Invertebrates from slides Algae from samples collected	**Review:** Debrief on Practice Survey Dive How to fill out Reef Check forms
16:30pm	Multiple-choice questionnaire to assess knowledge before and after Day 3.	Multiple-choice questionnaire to assess knowledge before and after Day 4.
17:00pm	***L11*** Coral versus algal dominated reefs • Importance of fish and Invertebrates to keep down algal species	***L14*** Reef Check • The uses of the data collected with Reef Check. • Partnership of Divers with CCC to collect data

The purpose of teaching the Reef Check technique on the final day of the workshop is two fold; firstly, to provide an insight into the daily work of CCC volunteers. Secondly for capacity building purposes, to give divers the ability to monitor the health of their local reefs and assist with the global reef health monitoring effort.

Marine Ecology workshops were conducted with a number of dive operators in the Mamanucas over the first year of the FCRCP. Many of the participants (Table 6) had been working as professional divers for years and already had a vast observational knowledge of coral reefs. The workshops focused on extending and formalising this information, along with looking at conservation issues and strategies associated with tourism, sustainable development and how to communicate this information to customers. The participants' position as role models for good conservation ethics in diving was stressed.

Table 6. Participants of the CCC Marine Ecology Workshop for Divemasters.

Participants	Organisation
Valu Tamamivalu Charlie Semo Aisake Nisilore Edwin Gardner Temohis Dairo Mesulanbe Vakacegu Emosi Baravilala	Subsurface Beachcomber
Manu Eric Seva Sakai Jinta Kabakaba Junior Naivalurua	Subsurface Musket Cove
Kalevali Vunivalu Will Wragg Alex Garland Nauka	Tokoriki
Geof Loe Trudy Loe Simeli Loganimoce Iliapi Isei Eric Enderson Veresa Naiqara	Castaway Divers
Albert Simon Isoa Maravou Aselai Ratulevu Setareki Qase	Plantation Divers

Following the workshop, participants were asked to fill out a feedback form with several questions on the importance of the workshop, new information learned and who else may benefit from such information. All participants strongly concurred that the information was applicable to their work and that such workshops were invaluable.

3.8.2 Environmental Awareness Workshops at Local Schools

In the early stages of the project an environmental education programme was implemented at Malolo District School. Six sessions were conducted for class 8 students to highlight the importance and threats to reefs, coastal zone management issues and strategies.

Following the success of the initial programme CCC were invited to conduct a similar programme at the start of the new school year. Workshops were incorporated into the curriculum thus allowing for development of teaching materials and content of the workshops sessions for more effective, progressive learning. A ten-week programme was developed to coincide with the term time and was again directed at class 8 students.
The course followed a similar vein but focused on introducing reef ecology and biology concepts to highlight the fragile nature of the reef systems and the need for management. Concepts were promoted through worksheet exercises, word games, drama, art, group debates, and physical exercises such as litter surveys. The aims and objectives of the scheme were to:

- Increase the environmental awareness of the local school children
- Incorporate general science subjects from the National Curriculum into the environmental sessions
- Provide a range of teaching methods and opportunities for the children to express themselves in different media
- Monitor the increase in the children's knowledge levels to evaluate the success of the education scheme
- Facilitate the relationships between the villagers of Solevu and CCC volunteers by providing opportunities for interaction with the community

Table 7 below summarises the programme content. A brief summary of the activities follows.

Rubbish Survey

The impact of rubbish pollution on the marine environment was discussed and the children conducted a survey of litter on the beach along with CCC volunteers. The rubbish was collected and then sorted. Bar graphs and tally charts were made to analyse the results and the implications of the findings discussed.

Sulu Painting

To give the children a lasting memory of the workshops, sulus (traditional Fijian unisex skirts) were created on material kindly donated by Motiram & Co. Each child designed their own sulu and painted pictures, which followed a marine conservation theme.

Presentations

At the end of the workshop programme the children performed a series of plays to other school years and parents at the end of term concert. These performances were designed to draw on lessons learned and highlight the importance and threats to reef systems in Fiji. The children acted out the scenarios whilst they were explained in both English and Fijian. Contributions to the ideas for this workshop series were drawn from a number of sources including Doras *et al.* (2002) and Finlay (2001).

The workshop scheme was very successful and the children's grasp of general marine science and English language improved notably over the duration. The children reacted well to the varied teaching methods and enjoyed the subject matter. CCC were asked by the headmaster of Malolo District School, Solwane Waqanidrola, to prepare exam questions on the subjects covered for incorporation into the end of year Social Science Paper. Questions on the importance, biology and threats to mangrove and coral reef habitats, the impacts of fishing and the mitigation of impacts and management of marine resources were submitted.

Table 7. CCC Environmental Workshop Schedule conducted at Malolo District School

WEEK	ACTIVITY SCHEDULE
1	General introductions – staff & volunteers Ice breaking games – The name game Knowledge Survey – what is CCC? What are we doing in the Mamanucas? Introduction to CCC - aims of our work - surveys completed - day in the life of a volunteer - survey techniques Scuba Equipment Practical Introduction to workshop programme, outline of each week Handout workbooks
2	Introduction to hard corals Links between land and marine systems. Importance of mangrove forests and seagrass beds Reefs as the rainforests of the sea – Introduction to the concept of biodiversity Coral Biology with skeletal examples Reef Formation Homework: Coral questionnaire
3	Review of coral questionnaire Introduction to reef fish Ecology – feeding classification/strategies Fish Biology – diversity Make stencils of favourite fish shapes to be used in sulu making
4	Importance of coral reefs Reef questionnaire Impacts of fishing/harvesting Impact questionnaire Stencils of corals for sulus
5	Threats to coral reefs - Natural - Man-made Homework: Threats word search

WEEK	ACTIVITY SCHEDULE
6	Recap of word search homework The rubbish game – (This is a………!) banana and plastic bag needed Effects of rubbish on the environment Introduction to PADI Aware Litter collection around Solevu beach and village Sorting rubbish – frequency & type Draw bar charts of findings Discuss implications of rubbish found Waste management card game Methods of improvement Homework: Threats to coral reef questionnaire
7	Recap of threats questionnaire A healthy reef system – diversity of organisms – reduction of manmade impacts to allow system to recover from natural impacts Users of the reef Current situation in Fiji - Considerations for management in the Mamanucas Role Play: Aim is to resolve a construction & development problem, which will result in minimal impact to the environment. Allocation of roles – conflict between user requirements Inverts/Sponges stencils for sulus
8	Future of the reefs Introduction to Marine Protected Areas Proposed plans for the Mamanucas Presentation of CCC recommendations Painting of sulus
9	Finishing off sulus Introduction to performances from CCC volunteers Statues – basic story telling in frames. A series of pictures move to show a sequence of events. Follow the consequences of certain actions on the environment. E.g. - Clearance of mangrove forests - Cutting down trees, soil erosion
10	Rehearsal of narrated performances identifying the importance and threats to the reefs in Fiji. These plays are to be shown to the rest of the schoolchildren and the parents in an end of term presentation in order to pass on the lessons learned

On the following three pages are a selection of images taken at school workshops on Malolo and Mana Islands (Figures 8 – 14).

Figure 8. CCC Science Officer Brian Quinn working with two students at Malolo District School.

Figure 9. CCC Project Scientist Nicola Barnard teaching class 8, Malolo District School

Figure 10. Kara and Silipa painting sulus at Malolo District School.

Figure 11. Nabou painting his sulu at Malolo District School

Figure 12. End of term performances, Malolo District School.

Figure 13. Group photo of class 5 and 6, Mana Adventist School.

Figure 14. Group photo of class 8 during litter survey Solevu Village, Malolo Island

3.8.3 Earth Day Events – 2002-2003

PADI Project Aware Cleanup Event

CCC staff and volunteers have conducted a number of beach clean up operations in local villages. Rubbish and seaweed was collected from beaches and occasionally within villages. Local children participated, following talks highlighting the importance of managing coastal areas sustainably. Following the event participants were assigned a Project Aware form to complete. Details of the last event are provided below.

International Beach and underwater Cleanup, September 21st 2002.

Firstly, CCC volunteers gave the children from the Malolo District School a lecture on the effects of rubbish on the environment and the break down times of various materials such as plastic bottles and bags, batteries, fishing gear, cigarette butts, tins and paper. The school children completed an answer sheet after the lecture and then collected rubbish along the length of the beach. On return to the classroom they analysed the rubbish and created bar charts on the different sorts of waste materials collected. They concluded from the event that there was too much rubbish in Solevu and came up with ideas on what should be done to reduce the problem.

Dive Into Earth Day, 21st April 2003

Earth Day is an international scheme organised annually by the Coral Reef Alliance (CORAL) in conjunction with the Earth Day Network and PADI Aware Foundation, which aims to encourage people to participate in marine conservation activities in an attempt to raise public awareness of conservation issues.

Rubbish pollution poses a substantial threat to the reef systems of Fiji. To highlight this problem and also undertake a useful and beneficial activity in support of Earth Day, a large scale clean up of the beach, tidal zone and shallow reef area outside the front of Solevu village, Malolo Island was organised. Over 200 people participated in the event, which commenced with a presentation on the impact of rubbish on the environment.

Participants were from Solevu village, Namotu and Tavarua Island Resorts, FCRCP volunteers. Subsurface Beachcomber and Musket Cove offered free diving to interested guests and assisted with the underwater clean up removing 20 bags of metal and glass waste from the reef. Over 1 tonne of rubbish was collected over the course of the day and was sorted on the beach. The rubbish was taken on a barge for proper disposal at processing facilities on the mainland. As a result of the day's efforts, it was decided that smaller scale events would be conducted on a monthly basis in an attempt to improve the marine environment.

Figure 15. Group photo of participants involved in the Earth Day clean up.

Figure 16. Solevu villagers participating in rubbish collection around the village.


Figure 17. Sorting rubbish collected along Solevu beach

Figure 18. Subsurface divers bringing up debris from the shallow reef environment at Solevu

3.9 Meetings during the course of the first year of the FCRCP.

For activities and meetings conducted between March and November 2002 see the summary report completed in December 2002 (Fiji Coral Reef Conservation Project Summary Report March – November 2002).

DECEMBER 2002

Activities

Environmental workshops were conducted with the staff from Malolo Island Resort, Whales Tails Cruises, and South Sea Island.

JANUARY 2003

Activities

Environmental workshops were conducted with Tropex See Cruises who run day trips out to the Mamanuca Island Group and the boatshed and water sports staff from both Malamala Island and Castaway Island to discuss sustainable use of resources, the creation of simple guidelines and environmental briefings. Environmental guidelines were created for inclusion in the Subsurface operations manual in conjunction with John Brown.

Meetings

CCC met with Ratu Sakiusa Tuni Toto from Solevu village to discuss a tabu protected area recently established in front of the village and workshops being conducted by FSP. CCC was invited to attend the workshops.

CCC met Malakai TuiLowa, Director of Fisheries to discuss the training of departmental staff at CCC base camp. Two candidates were identified to join the CCC skills development programme.

CCC attended FLMMA meeting and were welcomed as new members.

FEBRUARY 2003

Activities

CCC started the ten-week environmental education programme at Malolo District School. Environmental workshops were held at Musket Cove Resort, Castaway Island Resort and Mana Island Resort. The Environmental leaflets produced in conjunction with MFHA were distributed to resorts.

Meetings

CCC invited to present to villagers from Solevu, Malolo Island about the importance of MPAs, associated benefits, importance of location and integrated management strategies for the Mamanuca area.

CCC was invited to attend a series of workshops on sustainable use of marine resources being conducted by PCDF at Solevu village, Malolo Island.

CCC was invited to the Malolo Tikina Council meeting chaired by Ratu Jeremaia Matai. A presentation was made to introduce the concept of MPAs, the importance of MPA location, implementation and management options.

CCC were invited to meet the headmaster from Mana Adventist School to discuss the possibility of conducting a workshop programme with the children in class 5 & 6 after hearing about the scheme at a teachers AGM on the mainland.

MARCH 2003

Activities

Environmental workshops were conducted with the staff from Plantation Island Resort, Bounty Island Sanctuary Resort and Tokoriki Island.

A four-day 'Marine Ecology for the Professional Diver' course was conducted with divers from Plantation Dive shop.

School workshop sessions commenced at Mana Adventist School. Litter surveys were conducted by the children on both Mana Island and Malolo Island.

Anecdotal lists of observed impacts to reef systems were compiled from CCC survey data for WWF.

Meetings

CCC attended the MFHA AGM on Navini Island. The aims and objectives of the Mamanuca Environment Society were presented.

CCC met with Ratu Emosi Dau from Lautoka Andhara College. The work of CCC in the Mamanuca Island Group was discussed along with the importance of MPAs as management tools.

APRIL 2003

Activities

Quadrats deployed to monitor hard corals for bleaching. Reports of observed bleaching compiled from CCC data for FLMMA members.

Dive into Earth Day clean up at Solevu Village to highlight the impact of rubbish on the marine environment and to raise awareness to the need for proper waste disposal.

Meetings

CCC met with Ratu Sakiusa Tuni Toto to discuss the training of members of the village.

CCC attended the monthly MFHA meeting at Malolo Island. The development of a new PAFCO factory in Lautoka and potential impacts were discussed.

CCC attended the Nacula Tikina Tourism Association meeting on Safelanding Resort, Yasawa Islands. A presentation was made on CCC's work in the Mamanucas, MPAs and associated benefits for local communities and value as management tools.

CCC attended the monthly FLMMA meeting at USP in Suva. Lessons learned and progress of each NGO was presented.

CCC met with John Kamea, features editor from the Fiji Sun newspaper to discuss Earth Day event and provide photos. Article appeared in the 26.04.03 issue.

CCC met with Wana Savoi from PCDF to discuss current work in the Malolo Tikina. Marking of the tabu area and biological monitoring were discussed.

CCC met with Bill Aalbersberg, Director of IAS to visit a number of areas along the Coral Coast currently involved in community based marine management programmes. CCC conducting biological monitoring of tabu areas and assisting with the development of survey protocols was discussed.

4. RESULTS

4.1 Baseline Surveys

4.1.1 Survey Progress

Of the thirty survey sites previously outlined, fourteen have been completely surveyed during the first year of the FCRCP (Table 8). All of the data derived from these survey sectors are analysed and subsequently reported in this document. A chronological breakdown of the survey effort is included in Table 9 overleaf. The sector numbers in the table refer to those outlined in Figure 2, Section 3.2.
Thus far a total of 636 survey dives have been conducted, 392 survey team hours, and with one baseline survey team consisting of four divers; 1568 man-survey-hours. With baseline surveys collecting species abundances of approximately 300 target species and substrates, volunteers taking part in the first year of the FCRCP have made 335,000 *in situ* recordings.

For the purposes of benthic cover analysis in this report, the completed survey sectors were grouped into geographically and ecologically bound analysis units. These units are subsequently referred to throughout this report and are summarised in Table 8 and Figure 19.

Analysis Unit	Incorporated Completed Survey Sectors (and number)
Castaway reef complex	Castaway (17), Mothui (15), Castaway Inner Barrier (16), Yalodrivi (14), K's Patch (K)
Malolo	Malolo North (22), Malolo South (23), Malolo Patch Reef (24)
Malolo Lailai	Malolo Lailai (25)
Mana	Mana (02)
Navini	Navini (06)
Wadigi reef complex	Wadigi Island (18), Wadigi Patch Reef (19), Lana Patch Reef (20)

Table 8 Assignment of completed survey sectors into six analysis units delineated during year one of the FCRCP.

Table 9. Chronological CCC Baseline Survey progress during Year One of the Fiji Coral Reef Conservation Project.

Month	Sector Number	Sector Name	Transects Completed	Transect Codes
March	17	Castaway Island	6	1701-1706
			Total = 6	
April	17	Castaway Island	9	1707-1715
	22	Malolo North	15	2201-2215
	15	Mothui	1	1501
	16	Castaway Barrier	3	1601-1603
			Total = 28	
May	22	Malolo North	5	2216-2220
	15	Mothui	4	1502-1505
	16	Castaway Barrier	1	1607
			Total = 10	
June	16	Castaway Barrier	3	1608-1610
	15	Mothui	2	1506-1507
			Total = 5	
July	16	Castaway Barrier	8	1605, 1606, 1611-1613, 1615, 1616, 1618
	15	Mothui	2	1508-1509
			Total = 10	
August	16	Castaway Barrier	2	1614, 1617
	18	Wadigi Island	9	1801-1809
			Total = 11	
September	6	Navini	5	0601-0605
			Total = 5	
October	23	Malolo South	13	2301-2303, 2305-2306, 2308-2311, 2314
	15	Mothui	3	1503, 1506, 1609
			Total = 16	
November	19	Wadigi Patch	7	1901-1907
	23	Malolo South	1	2320
	25	Malolo Lailai	1	2501
	'K'	K's Patch	4	K01-K04
			Total = 13	
December	25	Malolo Lailai	13	2502-2303, 2506,
	23	Malolo South	7	2307, 2312-2313, 2315-2319
			Total = 20	
January	25	Malolo Lailai	3	2504, 2505, 2507
	14	Yalodrivi	8	1401-1408
			Total = 11	
February	20	Lana	12	2001-2012
	24A	Malolo Patch (A)	5	2401-2405
	24B	Malolo Patch (B)	6	24B01-24B06
			Total = 23	
March	24B	Malolo Patch (B)	2	24B07-24B08
	32J	Jaluk	2	32J01-32J02
	32A	Motuse	1	32A01
			Total = 5	
April	30	Tavarua	1	3001
			Total = 1	

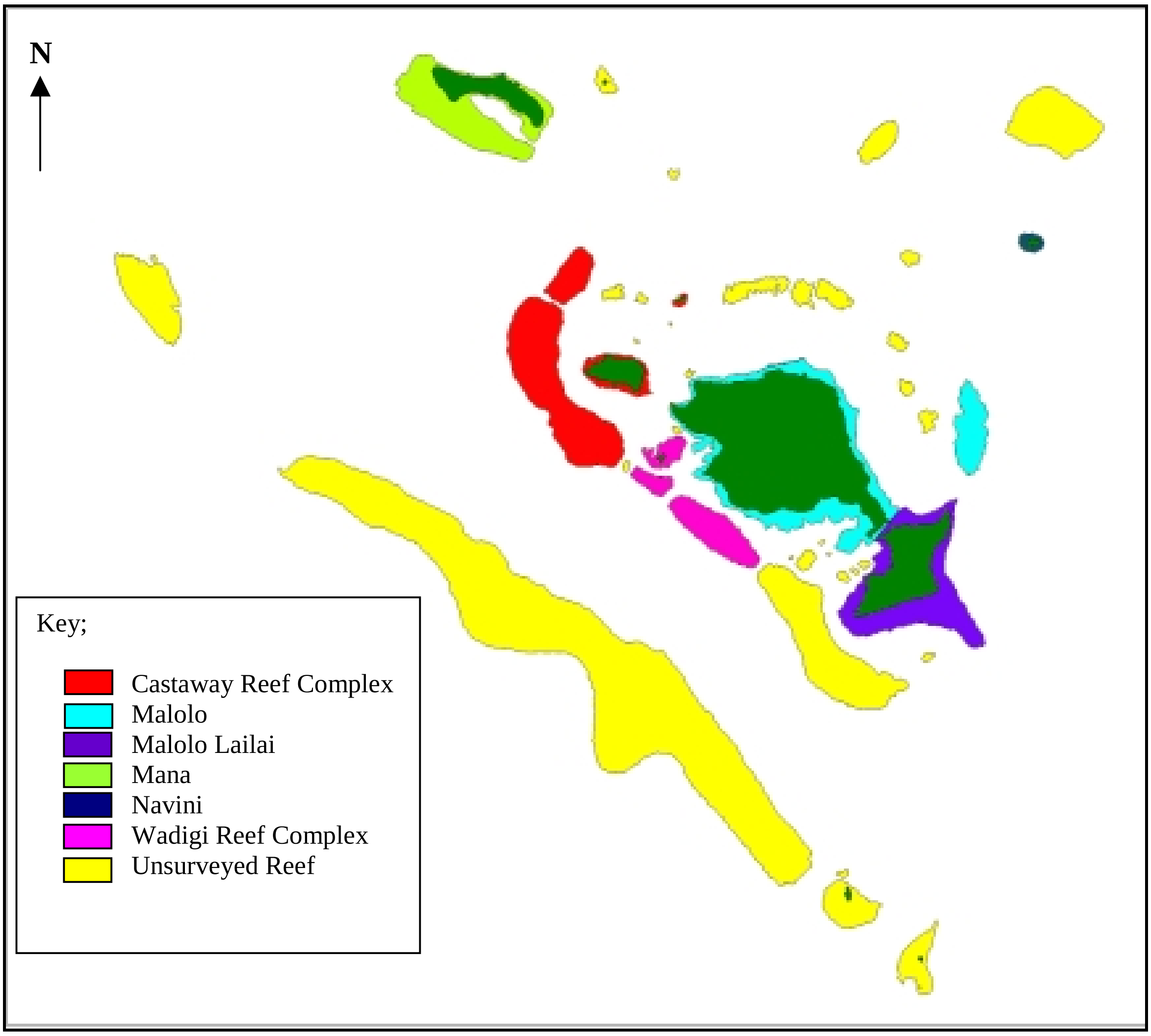


Figure 19. The six analysis units of reefs and reef complexes presented in this report.

4.1.2 Oceanographic, climate and anthropogenic impact data.

Temperature

Mean surface water temperature during the first year of the FCRCP was 28.59 °C (standard deviation 0.79 °C; n = 72). Water temperatures collected by the survey teams at the maximum survey depths were summarised in 5 m classes (0.1-5 m; 5.1-10 m; 10.1-15 m; 15.1-20 m; 20.1-25 m and 25.1-30 m) and the results are shown in Figure 20. There was some evidence of temperature variation throughout the water column, with a general decrease in temperature with increasing depth. The decrease in mean temperature between the first 5 metres and the deepest band (25.1-30 m) was over 1.5 °C. The decrease in temperature was not statistically significant between the aforementioned two depth bands (ANOVA, $p>0.05$).

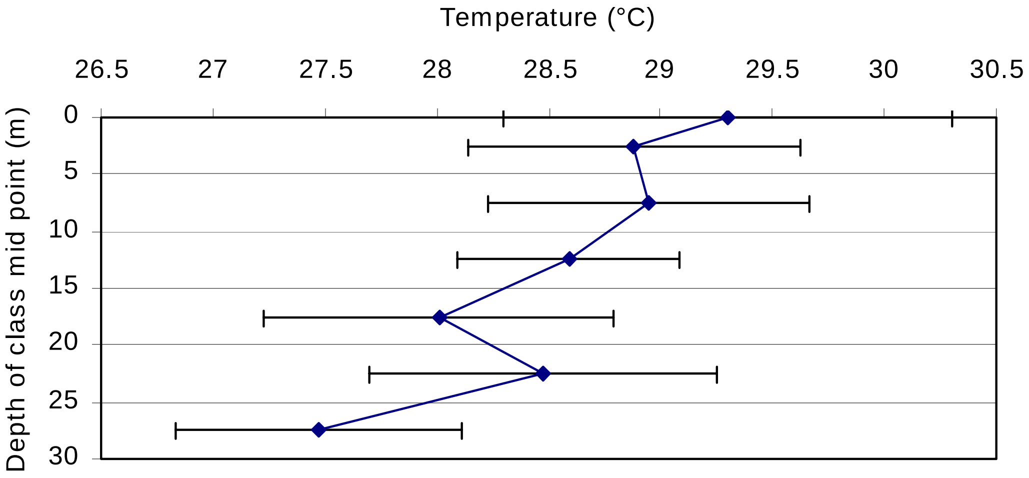


Figure 20. Mean water temperatures for all surveys in the project area in 5 m depth classes throughout the water column. Bars represent standard deviation. Sample sizes: 0.1-5 m = 5; 5.1-10 m = 11; 10.1-15 m = 27; 15.1-20 m = 16; 20.1-25 m = 5; 25.1-30 m = 4

Salinity

Mean surface water salinity during the first year of the FCRCP was 33.19‰ (standard deviation 1.62‰; n = 72). There was little variation between the six main survey areas.
Salinity measurements collected by the survey teams at the maximum survey depths were summarised in 5 m classes (0.1-5 m; 5.1-10 m; 10.1-15 m; 15.1-20 m; 20.1-25 m and 25.1-30 m) and the results are shown in Figure 21. Salinity readings showed little variation with depth, remaining between 32.5‰ and 33.5‰ throughout all the depth bands surveyed. The greatest variation was recorded between 5 and 15 metres where the highest mean value was recorded in the 10.1-15 m band.

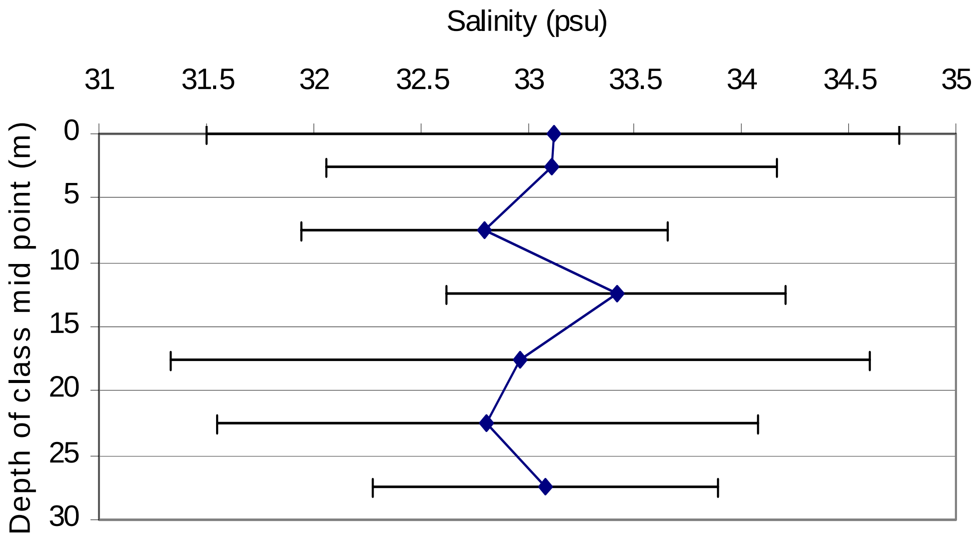


Figure 21. Mean water salinity for all surveys in the project area in 5 m depth classes throughout the water column. Bars represent standard deviation. Sample sizes: 0.1-5 m = 5; 5.1-10 m = 11; 10.1-15 m = 27; 15.1-20 m = 16; 20.1-25 m = 5; 25.1-30 m = 4.

Water visibility and river discharge

A comparison of inverse secchi disc readings of vertical underwater visibility and river discharge (L/min) between late March and early May 2003 is shown by Figure 22. High flow rates are followed by a decrease in vertical visibility over a three to five day period after the peak rate of discharge. This is particularly apparent for the two highest spikes of flow over the period recorded.

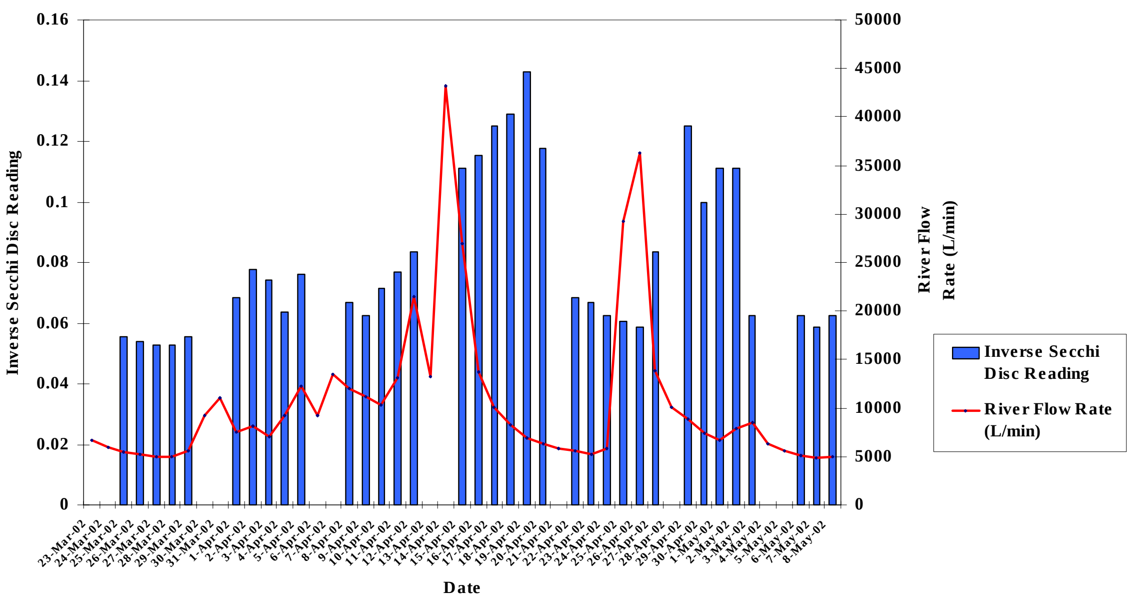


Figure 22. Relationship between river discharge at a sampling station on the mouth of the Nadi River and inverse secchi disc readings in the Mamanuca Islands 23rd March - 8th May 2002. Data on river flow obtained from Fiji Meteorology Service, Nadi.

Wind Strength and Direction

The direction and strength of prevailing winds during the first year of the FCRCP are presented in Figure 23. Estimates of wind were recorded on 68.4% of surveys with the remaining 31.6% experiencing calm weather (no wind). South or south-easterly winds were most prevalent with more than 50 recordings from each direction. For all other directions measured, only northerly winds were recorded on more than 30 occasions for a particular wind strength. Strength was generally light, between 1 and 3 on the Beaufort scale, with only a few observations above wind strength 4.

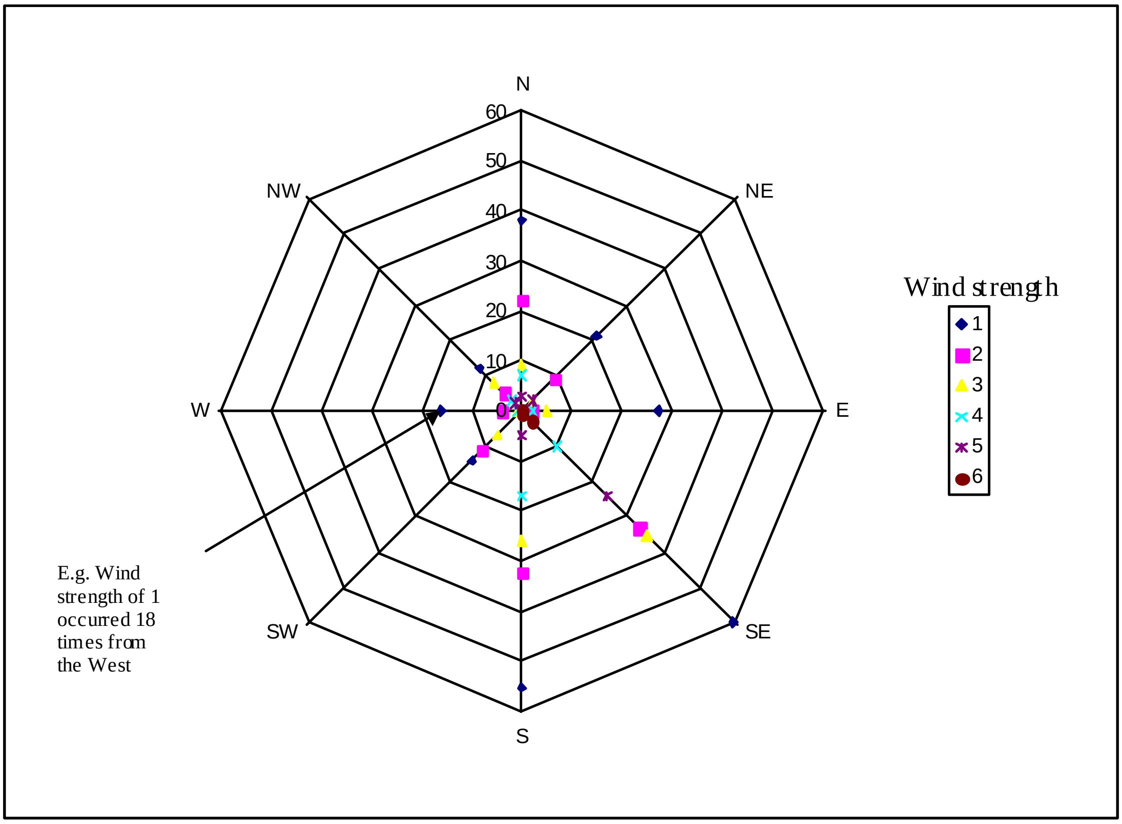
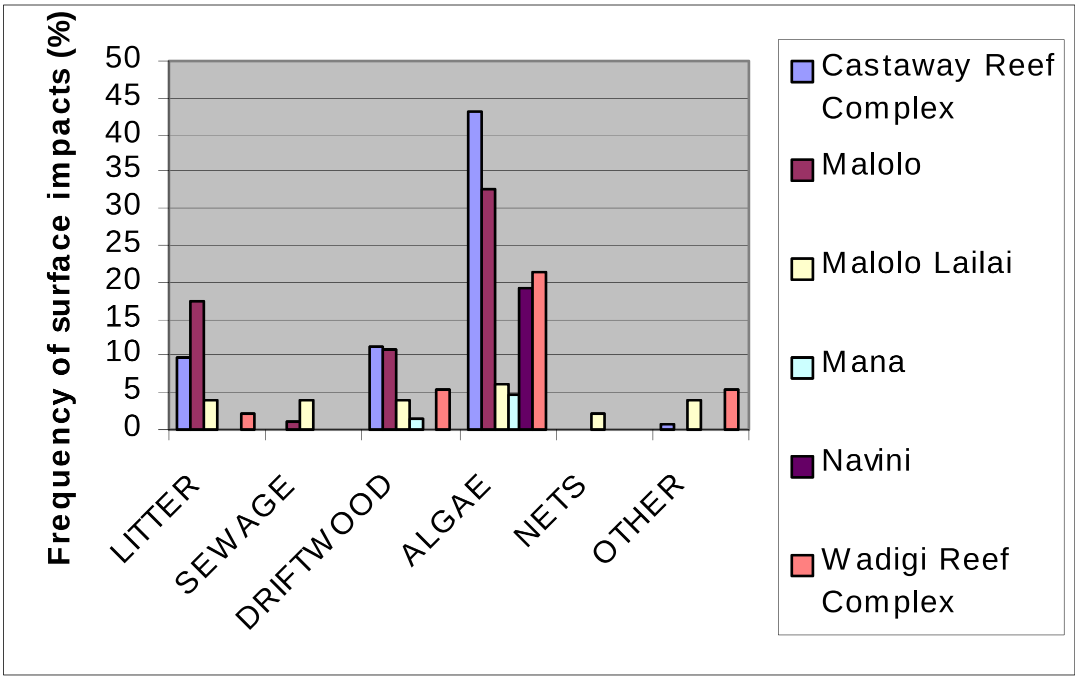


Figure 23. Radar diagram showing the prevailing winds recorded during year 1 of the FCRCP. Points represent the frequency of occurrence of combinations of wind direction and strength. Symbols represent wind strength (Beaufort scale).

Surface Impacts

Surface impacts for the whole survey area recorded over the first twelve months of the FCRCP are presented in Figure 24. The most commonly recorded impact was the presence of drifting clumps of macroalgae, particularly at Qalito (Castaway) and Malolo Islands and to a lesser extent at Navini and Wadigi. Litter and driftwood were also observed occasionally at Qalito and Malolo but rarely at the other reef areas. A discarded fishing net was recorded on one occasion at Mana Island but no nets were seen elsewhere. Evidence of sewage was rarely seen, a few sightings were recorded around Malolo Island but none at the other survey areas.

Figure 24. Frequency of observation of surface impacts recorded during Year 1 of the FCRCP.



Sub-surface Impacts

The frequency of occurrence of sub-surface impacts for the six reef areas is shown by Figure 25. The most frequently observed impacts were litter, coral damage, sedimentation and coral bleaching. All of these four main impacts were predominantly recorded at Castaway Reef Complex, Malolo and Wadigi Reef Complex. Highest frequencies were all found at Malolo for litter, coral damage and particularly sedimentation. The occurrence of sewage, lines and nets, fish traps, coral disease and other sub-surface impacts was low (<5%) for all reef complexes. Both dynamite and cyanide fishing impacts were recorded at Malolo Lailai at low levels. However this is likely to be an erroneous result as both fishing types are not practised in the region and were not found on the pilot study in 2001.

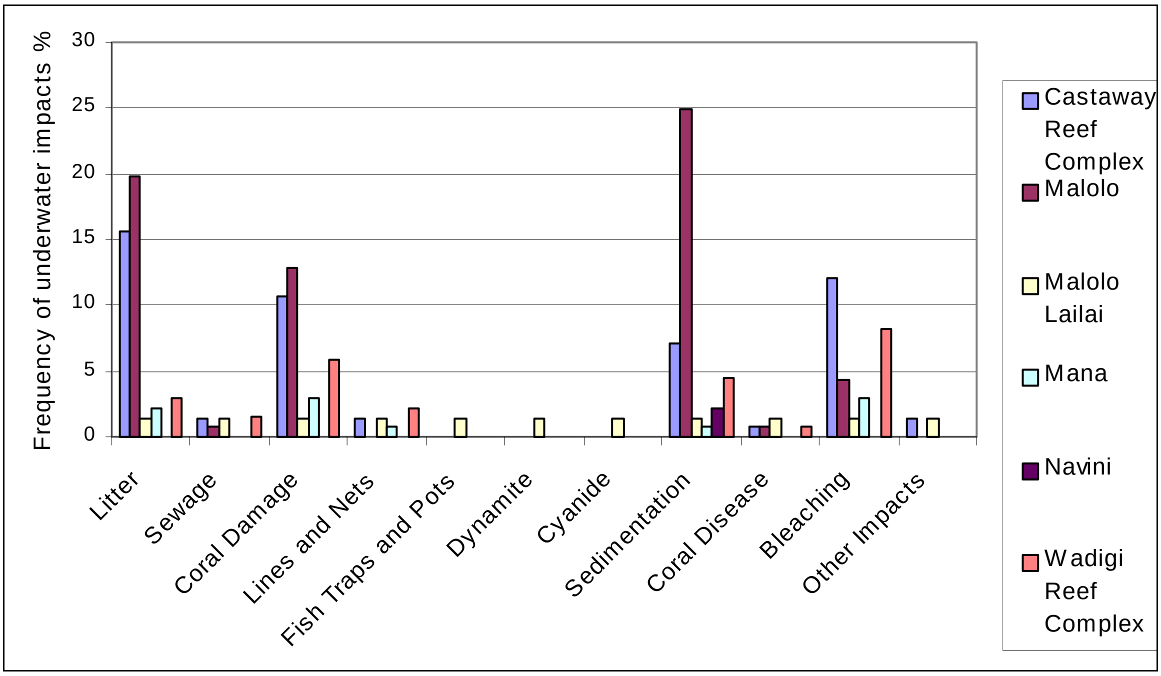


Figure 25. Frequency of observation of sub-surface impacts recorded during Year One of the FCRCP.

Boat Frequency and Activity

A total of 260 boats were observed during 789 surveys over the first year of the FCRCP. Mean boat activity (Figure 26) was greatest around Malolo Island and Malolo Lailai. Fewest boats were observed at Navini, although the small sample size here could be partly responsible for this result. Little activity was also recorded at Mana Island. The vast majority of boats observed around both Mana and Navini were related to the tourism industry, either diving or pleasure boats (Figure 27). Fishing was recorded most often at the Malolo Lailai and Wadigi Reef Complex areas. Commercial boat traffic comprised almost half of all boat sightings around Malolo Island.

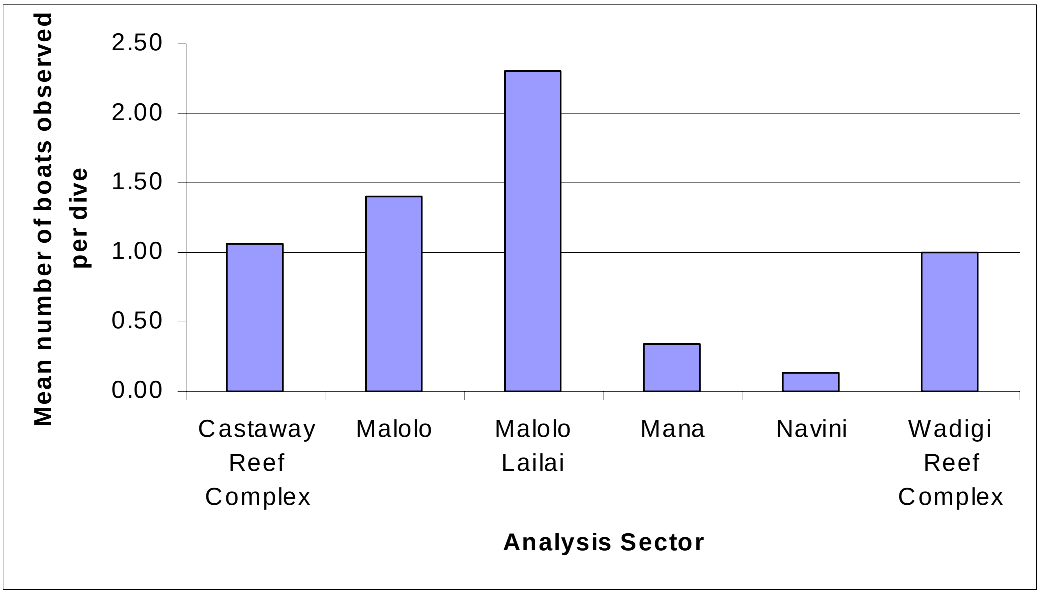


Figure 26. Mean number of boats observed per survey dive during Year 1 of FCRCP. Sample sizes: Castaway Reef Complex n=260; Malolo n= 257; Malolo Lailai n=168; Mana n=22; Navini n=4; Wadigi Reef Complex n=78

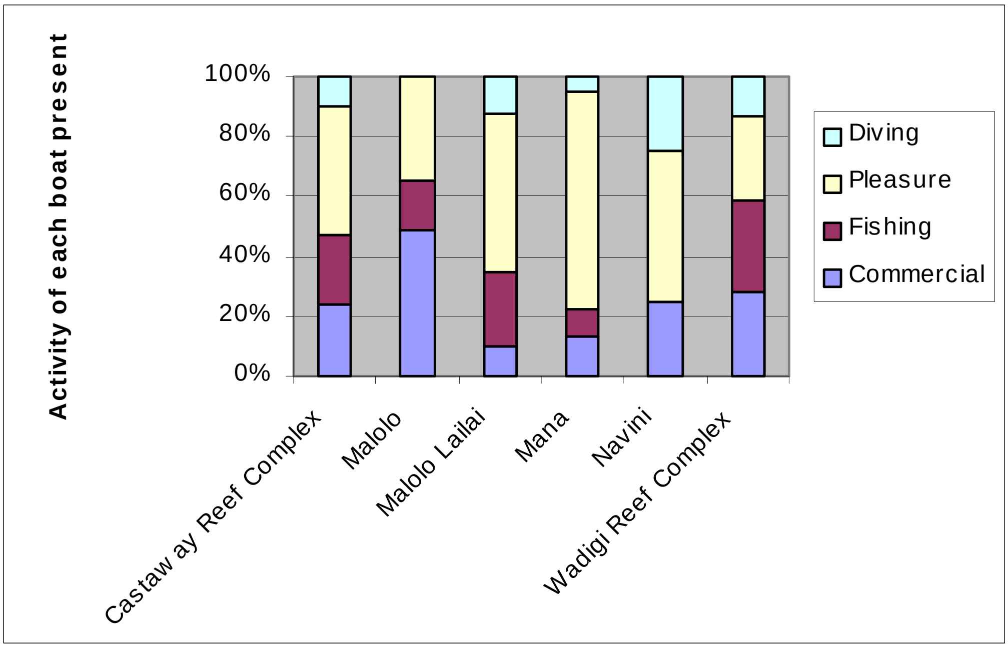


Figure 27. Summary of boat activities observed in each analysis sector during Year 1 of FCRCP. Sample sizes: Castaway Reef Complex n=260; Malolo n= 257; Malolo Lailai n=168; Mana n=22; Navini n=4; Wadigi Reef Complex n=78

Aesthetic and Biological Impressions

A summary of median aesthetic and biological ratings across all habitat types in each reef area are shown in Figure 28. Aesthetic values were assigned depending on, for example, an interesting reef topography and biological values reflected the abundance and diversity of the fauna and flora. Both ratings were assigned by divers using a scale from 0 (poor) to 5 (excellent). All median ratings were less then 1.5 (poor to average) with the exception of Navini, which just cleared a value of 2 (average) for both ratings. Biological rating was slightly greater than aesthetic rating at Castaway, Malolo and Wadigi. Lowest ratings were recorded at Malolo, followed by Malolo Lailai.

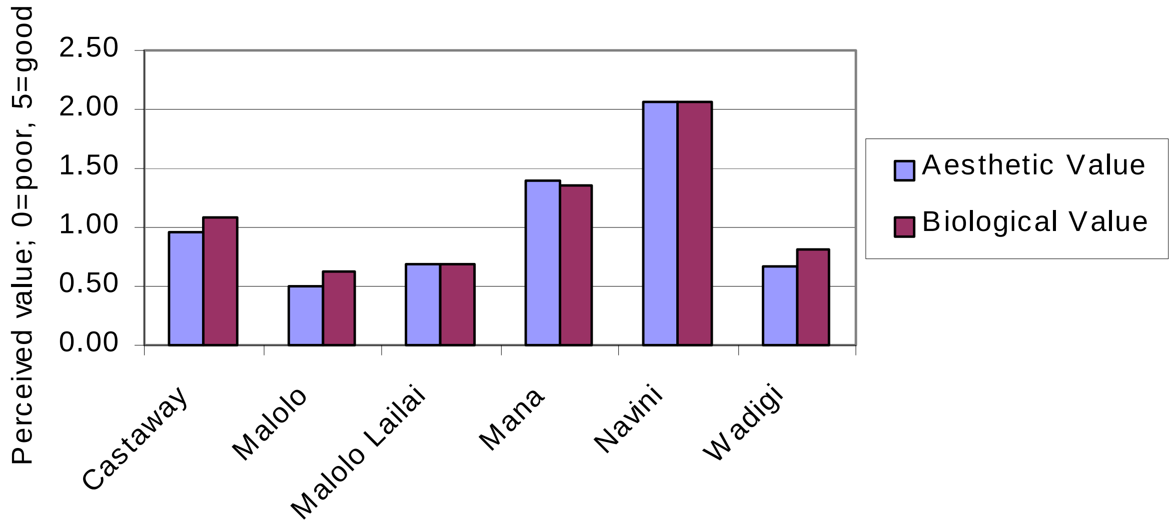


Figure 28. Summary of aesthetic and biological ratings in each analysis area. Ratings assigned from a scale 0-5 where 0 is poor and 5 is excellent. Sample sizes- Castaway Reef Complex n = 242; Malolo n = 183; Malolo Lailai n =48; Mana n = 63; Navini n = 30; Wadigi Reef Complex n = 93.

4.2 Multivariate analysis and benthic habitat definitions

The following sections present the dendrograms produced by agglomerative hierarchal cluster analysis for each assigned analysis area. One dendrogram is shown per analysis area. Using the characteristics of the benthic classes as defined by SIMPER and univariate analysis, a full and quantitative description of each habitat identified is presented in the following sections for each of the six analysis units.
The location and habitat composition of individual transects at each of the fourteen completed survey sectors are also depicted and are arranged into the analysis areas.

4.2.1 Castaway Reef Complex

A total of fifteen benthic classes were defined in the analysis area as depicted by the dendrogram (Figure 29). Breakdowns of the main biological and substratum constituents of each benthic class are shown in Table 10. The habitat composition of each transect is depicted by Figures 30 - 34 for the five areas that make up the Castaway Reef Complex.
Hard coral abundance was greatest in BC 3 on the lower reef slope where foliose corals were the most prevalent life-form. Hard corals were also prominent in benthic classes 1, 6 and 7. The brown macroalgae *Sargassum* spp. dominated the back reef (BC 2) and was twice as abundant, in relative terms, as hard coral. The reefs in this analysis area also support a mixed soft coral community. The lower reef slope habitat (BC 4) contains a mixed and diverse collection of hard and soft corals, sponges and frequent colonies of black coral (Antipatharia).

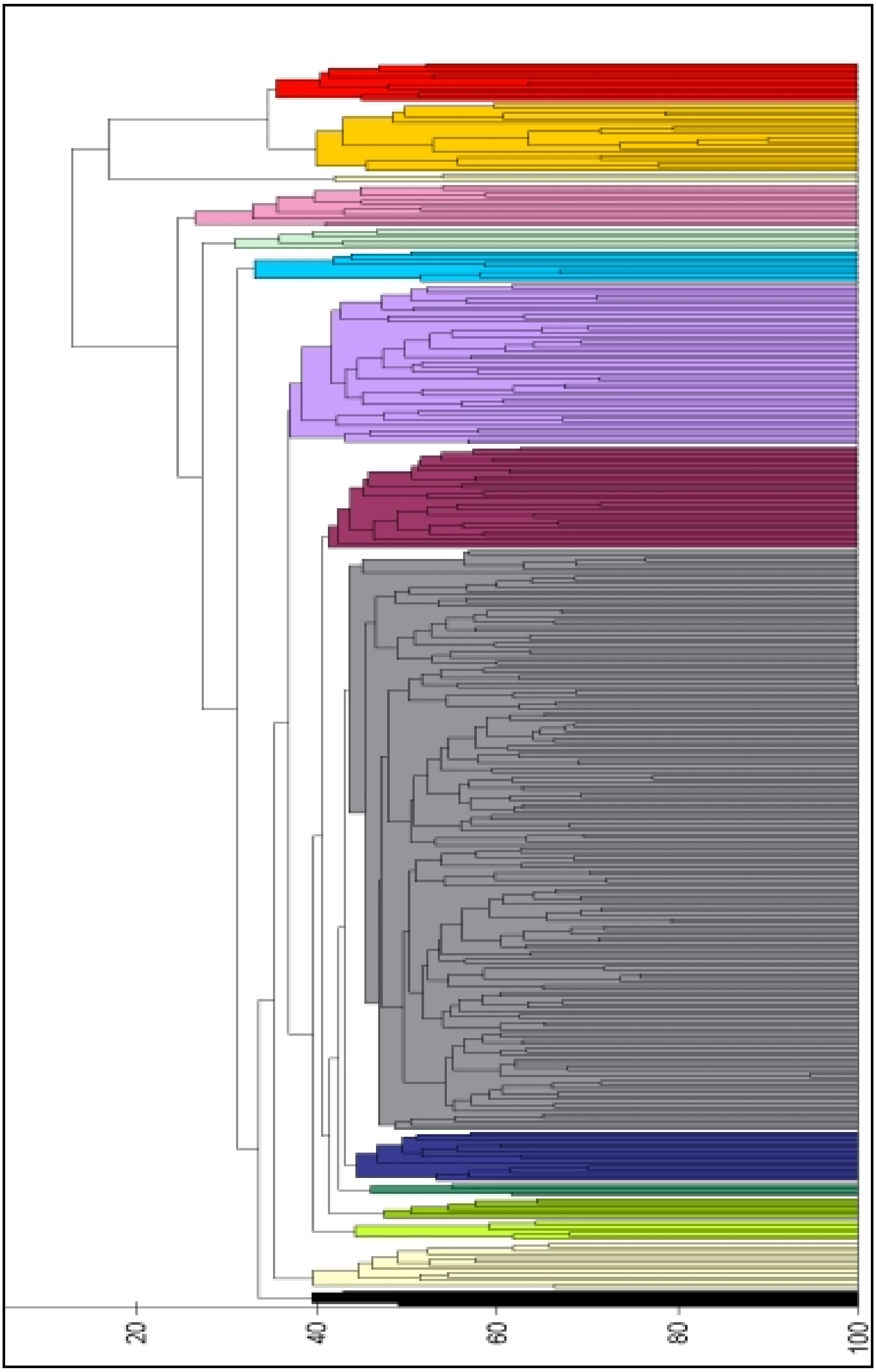


Figure 29. Dendrogram produced from cluster analysis of CCC baseline survey data collected in the Castaway Reef Complex analysis area. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%).

Habitat	# Surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
1- Sheltered upper reef slope supporting stress tolerant massive corals	5	7.8	Sand (1.4), Mud (1.2), Rubble (1.2)	LHC (2.8), Favites (1.4), Diploastrea heliopora (1.2)	Total cover (1.6), Sarcophyton sp. (0.8), Sinularia (0.8)	Black corals (1.6), Feather star (1.2)	Total cover (1.6), Lumpy (1.2)	Cover green algae (1.4), Green calcareous algae (1.0), Halimeda (0.6)
2- Macroalgae dominated shallow back reef area of bedrock and sand	13	2.6	Sand (2.8), Bedrock (2.2)	LHC (1.6), Acropora branching (1.2), Porites massive (0.8)	Total cover (0.5), Sarcophyton (0.4), Sinularia (0.2)	Linckia laevigata (1.1), Synaptid sea cucumber (0.8)	Total cover (0.8), Lumpy (0.5), Encrusting (0.3)	Sargassum (3.3), Brown filamentous algae (2.2)
3- Lower reef slope community on sand with a hard coral community dominated by foliose corals	6	20.5	Sand (2.3), Dead coral with algae (0.8)	LHC (3.0), Acropora branching (2.5), Mycedium elephantotus (1.2), Pachyseris speciosa (1.2)	Total cover (1.5), Xenia sp. (1.3)	Feather star (1.5), Black coral (1.3)	Total cover (1.3), Lumpy (1.2)	Green algae (1.9), Green filamentous algae (1.7), Brown filamentous algae (1.5)
4- Lower reef slope with significant bare bedrock, a diffuse coral community and frequent black coral	6	18.9	Bedrock (1.8), Sand (1.5)	LHC (2.3), Favites (1.5), Mycedium elephantotus (1.2), Favia (1.0),	Total cover (2.3), Sarcophyton (1.5), Dendronepthya (1.3), Gorgonaicea (1.3)	Black coral (3.2), Feather star (1.8)	Total cover (2.7), Lumpy (2.3), Branching (1.7)	Red coralline algae (2.2), Green calcified algae (2.0), Halimeda (1.8)
5- Shallow upper reef slope areas of predominately sand and rubble substrate with low coral and high macroalgae cover	4	10.9	Sand (3.0), Rubble (1.3)	LHC (1.5), Acropora branching (1.3), bottlebrush Acropora (1.3), Porites massive (1.3),	Total cover (1.5), Sarcophyton (1.0), Sinularia (1.0)	Basket star (1.3), Diadema urchin (1.0),	Total cover (1.5), Lumpy (1.5), Rope (0.8)	Brown filamentous algae (2.3), Green algae (1.8), Blue green algae (1.8)
6- Reef crest community with a significant presence of rubble and opportunistic Acroporid corals	14	5.6	Rubble (1.5), Sand (1.5), Bedrock (1.2),	LHC (2.6), Non-Acropora submassive (1.6), Acropora branching (1.4), Porites rus (1.9), Diploastrea heliopora (1.1)	Total cover (1.1), Sinularia (0.8), Sarcophyton (0.6)	Linckia laevigata (1.7), Feather star (1.7)	Total cover (1.2), Lumpy (1.2)	Green algae (1.4), Green calcareous algae (1.0), Brown filamentous algae (1.0)
7 Reef crest with frequent hard coral cover, mainly branching Acropora. Occasional soft corals and sponges also present	154	8.2	Sand (2.5), Dead coral with algae (1.6), Rubble (1.2)	Total cover (2.6), Acropora branching (2.0), Non-Acropora encrusting (1.5), Massive Porites (1.2), Favites (1.1),	Total cover (1.8), Sinularia (1.0), Xenia (0.9)	Feather star (1.3), Black coral (0.7), Hydroid (0.7)	Total cover (1.7), Lumpy (1.5), Encrusting (0.8)	Green algae (1.7), Green calcareous algae (1.5), Halimeda (1.2), Tydemania (1.2)
8 Lower reef slope dominated by sand and rubble with occasional hard coral and sponges	28	19.3	Sand (2.5), Rubble (1.8), Dead coral with algae (1.5)	Total cover (1.7), Acropora branching (1.3), Acropora encrusting (0.9), Favites (0.6),	Total cover (1.3), Sinularia (0.6), Dendronepthya (0.5)	Black coral (0.7), Hydroid (0.4)	Total cover (1.7), Lumpy (1.6), Encrusting (0.7)	Blue green algae (1.3), Red/ brown branching algae (0.9), Red coralline algae (0.6)

Table 10. Quantitative description of the fifteen benthic classes defined from the data collected in the Castaway Reef Complex analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

Habitat	# surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
9 Sand dominated lower reef slope with sparse coral cover but frequent calcified green algae	44	16.3	Sand (3.5), Rubble (0.9)	Total cover (1.6), Non-Acropora Encrusting (1.0), Favites (0.7), Seriatopora hystrix (0.3)	Total cover (1.3), Sinularia (0.6), Xenia (0.5)	Feather star (0.8), Black coral (0.6)	Total cover (1.6), Lumpy (1.3), Encrusting (0.7)	Green calcified algae (1.8), Green algae (1.5), Halimeda (1.7), Brown filamentous algae (1.3)
10 Lower reef slope with frequent coral cover dominated by encrusting and massive corals and soft corals	9	21.4	Sand (1.7), Dead coral with algae (1.2)	Total cover (2.3), Acropora branching (2.0), Non-Acropora encrusting (1.7), Favites (1.0), Diploastrea heliopora (0.9)	Total cover (1.6), Sinularia (1.3), Xenia (0.8)	Hydroid (1.3), Synaptid sea cucumber (0.6), Bryozoan (0.6)	Total cover (1.8), Lumpy (1.8)	Red coralline algae (1.6), Green algae (0.9), Green filamentous algae (0.9)
11 Lower reef slope of sand and mud with sparse hard coral cover dominated by branching Acropora	6	17.0	Sand (3.3), Mud (2.2)	Total cover (1.5), Acropora branching (1.2), Non-Acropora encrusting (0.8), Favites (1.0), Brain- small (0.5)	Total cover (0.5), Dendronepthya (0.3), Sinularia (0.2), Xenia (0.2)	Tunicates (0.5), Hydroid (0.5), Anemone (0.3)	Total cover (0.3), Lumpy (0.3)	Green algae (0.8), Seagrass (0.5), Red brown branching algae (0.5), Coralline algae (0.5)
12 Mid reef slope with sand and rubble. Sparse hard coral cover and mixed green algal assemblage	12	15.8	Sand (2.8), Rubble (1.9), Dead coral with algae (0.8)	Total cover (1.6), Non-Acropora encrusting (0.5), Acropora digitate (0.3), Acropora branching (0.3)	Total cover (0.7), Sinularia (0.3), Xenia (0.3)	Cone shell (0.2), Linckia laevigata (0.2), Feather star (0.2)	Total cover (0.5), Tube (0.2), Encrusting (0.2)	Green algae (2.3), Caulerpa (1.3), Brown filamentous (1.0), Green calcified algae (1.4)
13 Lower reef slope dominated by rubble and mud with sparse coral cover and red coralline algae	3	24.6	Rubble (2.3), Mud (1.7), Dead coral with algae (1.3)	Total cover (2.0), Acropora branching (1.3), Acropora digitate (1.3)	Total cover (1.3), Sinularia (1.3)	Nudibranch (0.7), Short spined urchin (0.7)	Total cover (0.7), Encrusting (0.7)	Red coralline algae (1.7), Green algae (1.7), Green calcified algae (1.7)
14 Largely bare lower reef slope substrates of sand and mud	22	23.1	Sand (3.9), Mud (1.8)	Total cover (0.7), Diploastrea heliopora (0.5), Favites (0.3)	Total cover (0.4), Sinularia (0.3)	Feather star (0.3)	Total cover (0.4), Lumpy (0.2)	Blue green algae (0.7), Green algae (0.6), Green filamentous (0.4)
15 Mid reef slope dominated by sand with mixed disparate hard coral cover and filamentous algae	11	17.7	Sand (3.5), Dead coral with algae (0.8)	Total cover (1.4), Non-Acropora branching (0.6), Non-Acropora massive (0.6), Seriatopora hystrix (0.6), Pocillopora small (0.5), Favites (0.5)	Total cover (1.0), Sinularia (0.5), Sarcophyton (0.5)	Feather star (0.5), Synaptid sea cucumber (0.4)	Sponge (0.9), Lumpy (0.7)	Blue green algae (1.8), Green algae (1.4)

Table 10 (Continued). Quantitative description of the fifteen benthic classes defined from the data collected in the Castaway Reef Complex analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

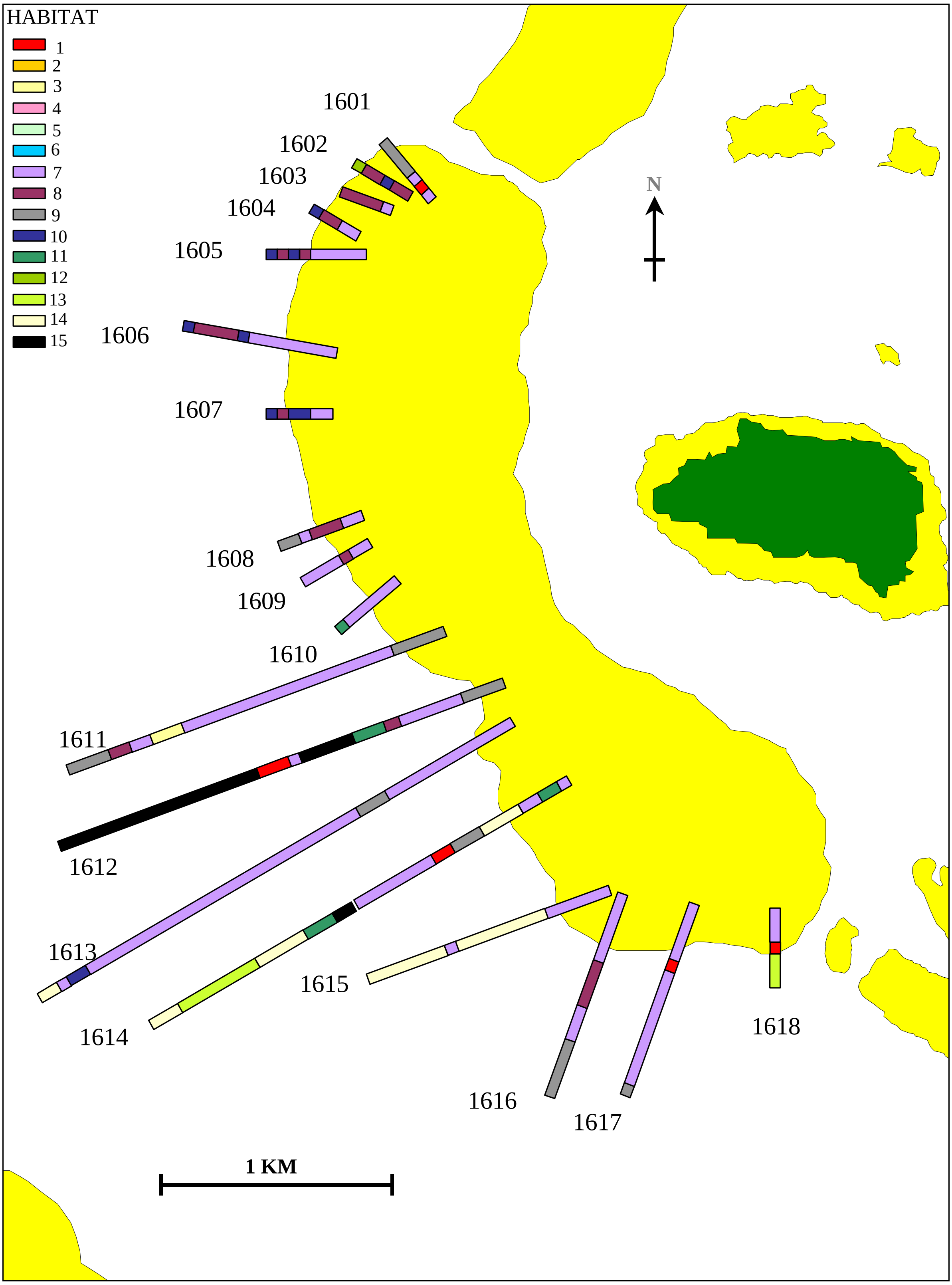


Figure 30. Location and habitat composition of baseline survey transects conduced around the Castaway Inner Barrier Reef during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

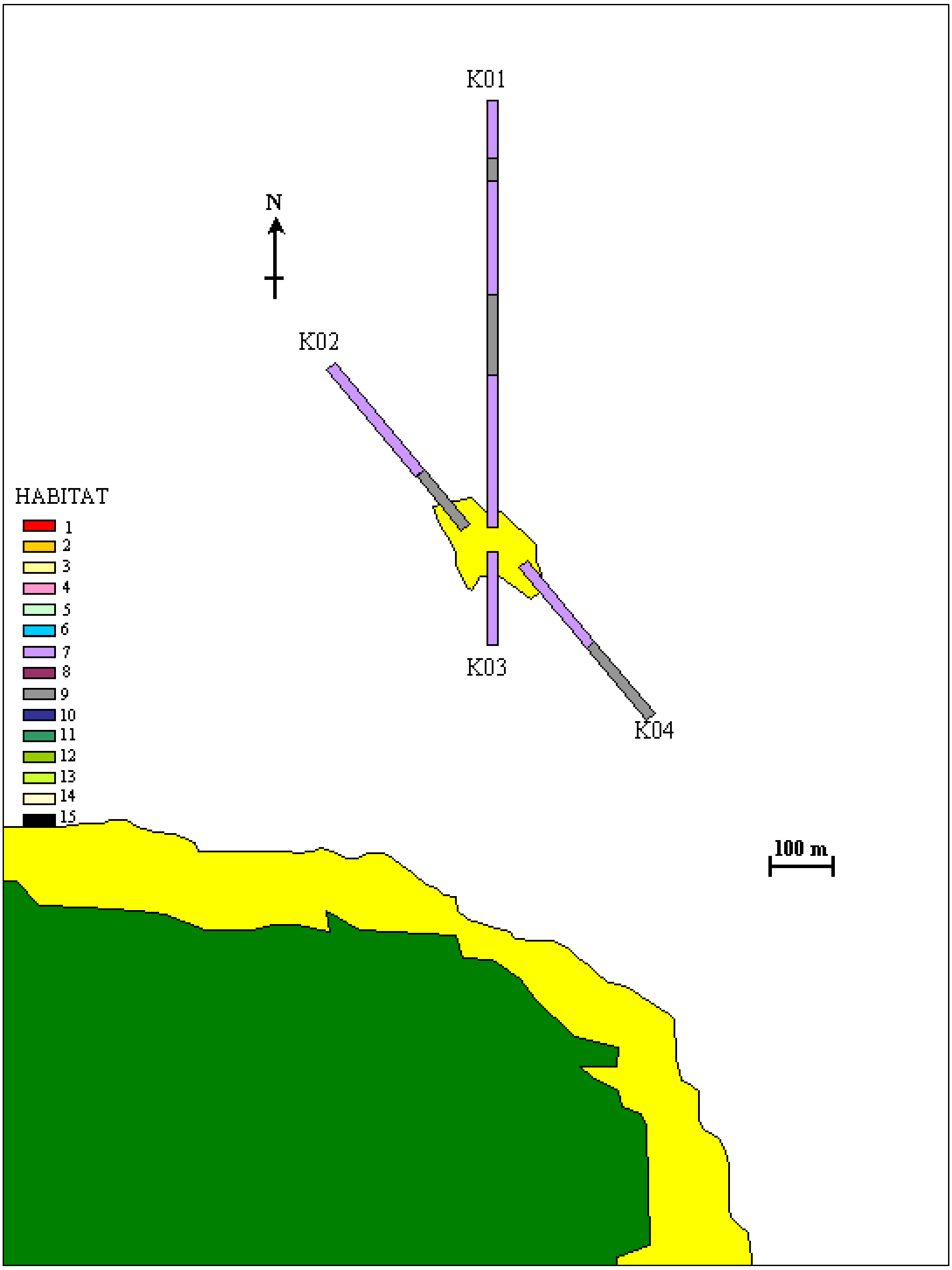


Figure 31. Location and habitat composition of baseline survey transects conduced around the K's Patch Reef during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

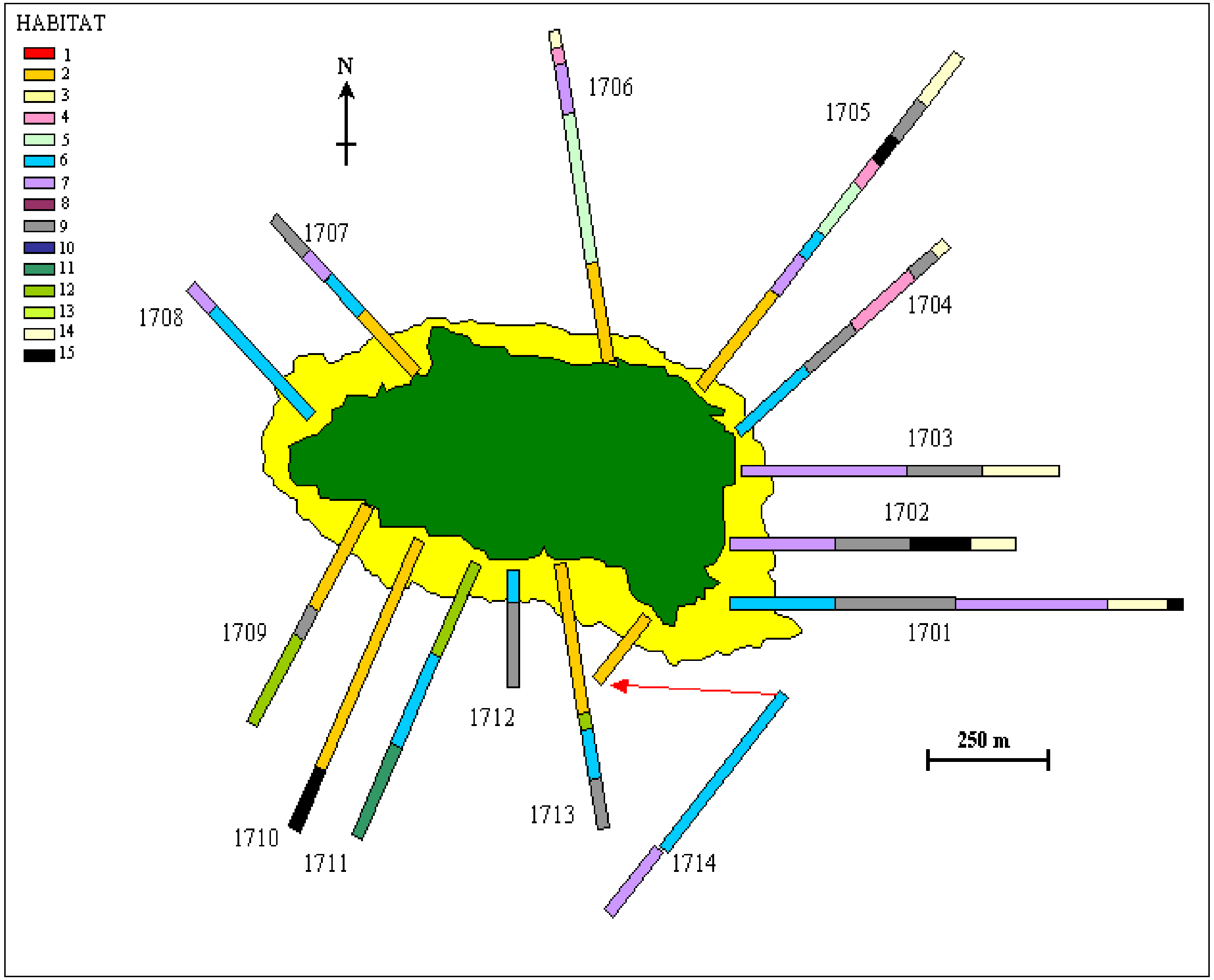


Figure 32. Location and habitat composition of baseline survey transects conduced around Castaway Island during Year One of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

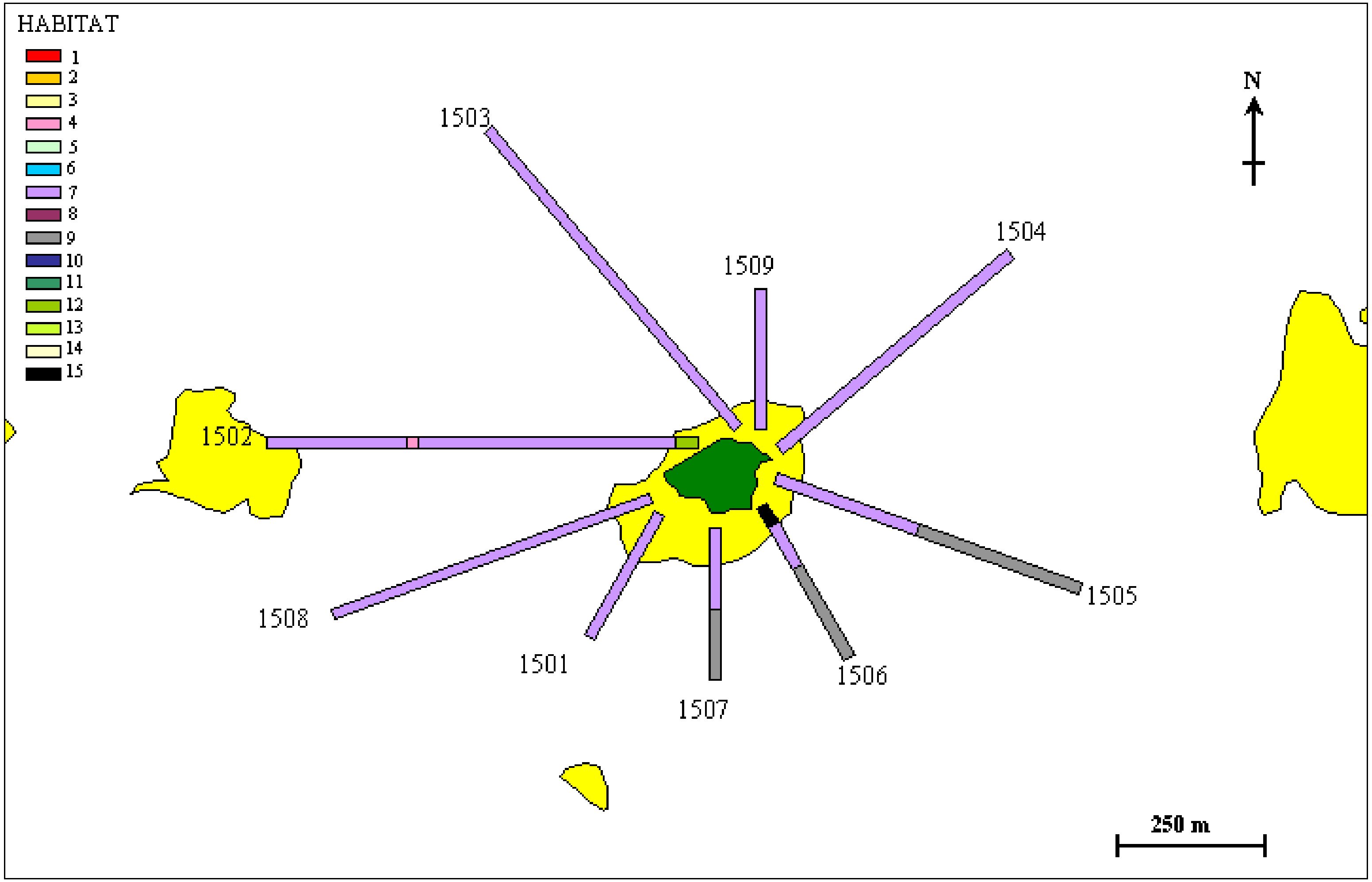


Figure 33. Location and habitat composition of baseline survey transects conduced around Mothui Island (Honeymoon) during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

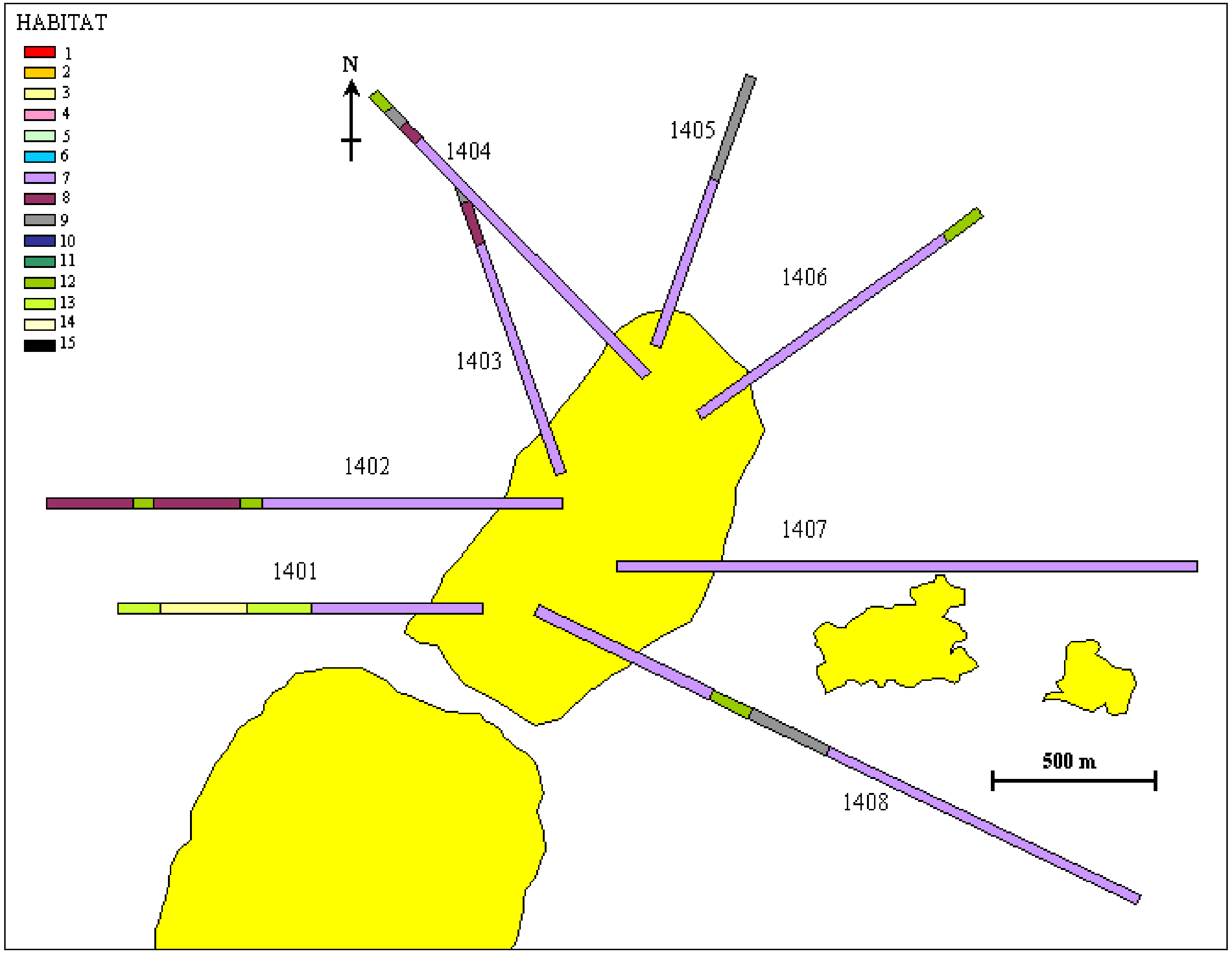


Figure 34. Location and habitat composition of baseline survey transects conduced around Yalodrivi Reef during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

Biodiversity indices calculated for the Castaway Reef Complex benthic classes indicate that four habitats highlighted in bold (BC 6 – BC 9) contain the highest diversity of marine flora and fauna in this analysis area (Table 11). A high number of species was also recorded in BC 4. When the individual reefs within the complex are scrutinised in terms of percentage habitat composition (Table 12) then a number of survey sectors stand out in terms of having a high percentage of biodiverse habitats. Yalodrivi, Mothui and K's Patch stand out as the reefs with the highest proportion of the four most diverse habitats (BC 6- BC 9) with 89%, 96% and 100% respectively.

Table 11 Univariate biodiversity measures calculated for benthic classes defined from data collected within Castaway Reef Complex analysis area

Benthic Class	Number of species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	43	16.5	0.92	3.80
2	56	23.6	0.89	4.06
3	52	15.7	0.93	3.84
4	71	17.4	0.93	4.02
5	58	18.7	0.95	4.11
6	**70**	**26.8**	**0.91**	**4.34**
7	**77**	**40.8**	**0.86**	**4.48**
8	**52**	**30.4**	**0.88**	**4.21**
9	**46**	**34.9**	**0.86**	**4.20**
10	31	20.0	0.88	3.76
11	29	16.7	0.88	3.56
12	28	17.1	0.87	3.54
13	10	5.3	0.73	1.87
14	12	13.4	0.67	2.36
15	17	17.1	0.82	3.22

Table 12 Percent composition of transects surveyed assigned to each Benthic Class by survey sector within the Castaway Reef Complex analysis area

Benthic Class	Yalodrivi (14)	Mothui (15)	Inner Barrier (16)	Castaway Island (18)	Ks Patch (K)	**Total**
1			3			1
2				21		4
3	3		1			1
4		1		3		1
5				5		1
6				**20**		**4**
7	**78**	**83**	**49**	**16**	**72**	**60**
8	**4**		**9**			**3**
9	**7**	**13**	**10**	**14**	**28**	**14**
10			4			1
11			4	2		1
12	8			5		3
13			4			1
14			9	10		4
15		3	8	6		3

4.2.2 Malolo Island

The dendrogram produced by cluster analysis of site records for Malolo Island into benthic classes is shown below (Figure 35). A total of 11 benthic classes were defined. Detailed descriptions of each habitat are provided in Table 13. The greatest relative abundance of hard corals was recorded on the reef crest and upper reef slope (BC 5-8). Hard corals were generally frequent in these four habitats. Again black coral was recorded on the lower reef slope but was less abundant at Malolo than at the Castaway Reef Complex in the same reef zone. A sparse to moderate covering of seagrass (*Halophila* spp.) characterised BC 11.

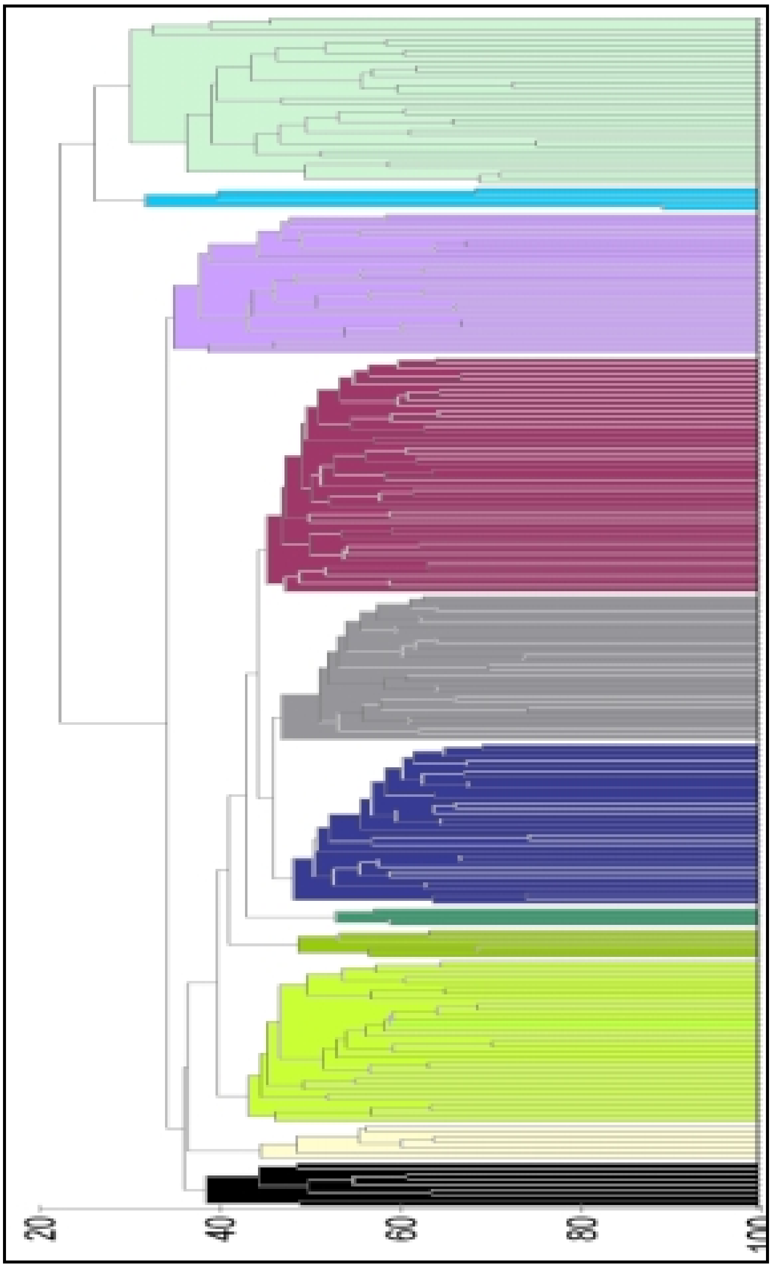


Figure 35. Dendrogram from cluster analysis of CCC baseline survey data collected in the Malolo Island analysis area. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%).

Habitat	# surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
1 Rubble dominated upper reef slope dominated by green calcified algae and sparse hard coral cover	9	6.9	Rubble (2.7), Sand (2.1), Dead coral with algae (2.0)	Total cover (1.8), Acropora branching (1.1), Non-Acropora massive (0.9), Diploastrea heliopora (0.7), Favites (0.7)	Total cover (0.2), Sinularia (0.1), Xenia (0.1)	Linckia laevigata (0.8), Tunicates (0.8)	Sponge (1.3), Lumpy (1.0), Rope (0.3)	Green calcareous algae (2.6), Halimeda (2.0), Tydemania (1.6)
2 Sand dominated upper reef slope with sparse hard coral cover	7	9.2	Sand (2.4), Rubble (1.1), Bedrock (1.1)	Total cover (1.6), Non-Acropora sub-massive (1.2), Porites rus (1.0), Porites cylindrical (0.6)	Total cover (0.7), Sinularia (1.0), Xenia sp. (0.6)	Linckia laevigata (1.0), Feather star (0.7)	Total cover (1.0), Tube (0.9)	Red coralline algae (0.6), Jania (0.6)
3 Sand dominated lower reef slope supporting dense green and brown macroalgae	31	13.3	Sand (3.3), Rubble (0.6)	Total cover (1.5), Non-Acropora massive (1.0), Non-Acropora mushroom (0.8), Porites massive (1.2), Favites (0.7)	Total cover (1.8), Sarcophyton (1.3), Xenia sp (0.7)	Feather star (0.9), Linckia laevigata (0.9)	Total cover (2.0), Lumpy (1.7), Elephants ear (0.8), Encrusting (0.8)	Brown filamentous algae (2.0), Padina (2.0), Green calcareous algae (1.9), Dictyota (1.7),
4 Upper reef slope/ reef crest dominated by sand and dead coral with algae and a moderate hard coral cover dominated by massive non-Acropora corals	6	5.6	Sand (2.7), Dead coral with algae (2.7), Rubble (2.0)	Total cover (2.2), Non-Acropora massive (1.8), Porites massive (1.8), Porites rus (1.2)	Total cover (0.3), Sarcophyton (0.3)	Linckia laevigata (2.2), Diadema (0.7), Synaptid sea cucumber (0.7)	Total cover (1.5), Lumpy (1.5)	Brown filamentous (1.5), Padina (1.3), Green algae (1.2)
5 Shallow back reef area with mixed high hard coral cover and green calcified algae	28	2.9	Dead coral with algae (2.5), Sand (1.7)	Total cover (3.2), Acropora branching (2.0), Acropora digitate (1.8), Seriatopora hystrix (1.5), Pocillopora damicornis (1.4), Favites (1.3),	Total cover (2.0), Sinularia (1.4), Xenia (0.6)	Linckia laevigata (1.2), Hydroid (0.5)	Total cover (1.2), Lumpy (0.9), Rope (0.2)	Green calcified algae (1.9), Halimeda (1.7), Brown filamentous algae (1.9), Turbinaria (1.3)
6 Upper reef slope/ reef crest with moderate hard coral cover and moderate abundance of macroalgae	38	8.5	Sand (2.2), Rubble (1.2), Bedrock (1.2)	Total cover (3.0), Non-Acropora branching (2.0), Non-Acropora massive (2.1), Acropora branching (1.6), Porites massive (2.3), Porites rus (1.7), Porites cylindrical (1.4)	Total cover (1.1), Sarcophyton (0.8), Sinularia (0.6)	Diadema (1.5), Linckia laevigata (1.2), Black coral (0.6)	Total cover (1.6), Lumpy (1.5), Encrusting (1.0)	Green algae (1.7), Tydemania (1.5), Padina (1.3), Blue green algae (1.1)

Table 13. Quantitative description of the eleven benthic classes defined from the data collected in the Malolo Island analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys.

Habitat	# surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
7 Upper reef slope habitat dominated bay sand and dead coral with algae and moderate hard coral cover	30	11.1	Sand (3.2), Dead coral with algae (2.2), Rubble (1.3)	Total cover (2.8), Acropora branching (2.0), Non-Acropora encrusting (1.8), Non-Acropora massive (1.6)	Total cover (1.5), Sinularia (0.6), Dendronepthya (0.5), Xenia (0.5)	Black coral (0.9), Hydroid (0.9), Linckia laevigata (0.7)	Total cover (2.5), Lumpy (1.9), Rope (1.9)	Green calcified algae (2.5), Halimeda (1.8), Tydemania (1.7), Red filamentous (1.0)
8 Upper reef slope dominated by sand and with diverse moderate hard coral cover	10	10.2	Sand (2.1), Bedrock (0.9), Rubble (0.7)	Total cover (3.1), Non-Acropora branching (2.2), Non-Acropora sub-massive (1.6), Non-Acropora massive (1.5), Porites cylindrica (1.9)	Total cover (0.7), Xenia (0.2), Sarcophyton (0.2)	Feather star (0.9), Black coral (0.8), Clam (0.7)	Total cover (1.6), Lumpy (1.4), Encrusting (0.6)	Green calcified algae (1.0), Tydemania (1.0),
9 Reef crest dominated by sand and calcified green algae	27	6.1	Sand (4.1), Rubble (1.1)	Total cover (1.4), Non-Acropora massive (0.9), Massive Porites (0.9), Favites (0.3)	Total cover (0.4), Sarcophyton (0.1), Xenia (0.1)	Linckia laevigata (1.0), Non-synaptid sea cucumber (1.0)	Total cover (1.3), Lumpy (0.8), Encrusting (0.3)	Green algae (2.4), Brown filamentous algae (2.0), Halimeda (1.9), Sargassum (1.1)
10 Sand and mud dominated lower reef slope with little benthic cover	5	15.9	Sand (4.4), Mud (1.6)	Total cover (0.4), Porites massive (0.2), Ctenactis echinata (0.2)	Total cover (0)	Tunicates (0.2)	Total cover (0)	Green algae (1.4), Caulerpa (1.4), Padina (0.8)
11 Sand and mud dominated mid reef slope with seagrass and sponges	32	11.6	Sand (4.3), Mud (1.3)	Total cover (0.2), Massive Porites (0.1)	Total cover (0.4), Xenia (0.2), Sarcophyton (0.2)	Segmented worms (0.2), Synaptid sea cucumber (0.5)	Total cover (1.0), Lumpy (0.7), Tube (0.2), Elephants ear (0.2)	Total seagrass (1.9), Halophila (1.5), Green calcified algae (1.5), Halimeda (1.4)

Table 13 (Continued). Quantitative description of the eleven benthic classes defined from the data collected in the Malolo Island analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

The following two figures (Figs. 36 & 37) indicate the position and habitat composition of individual transects around Malolo Island and Malolo Patch.

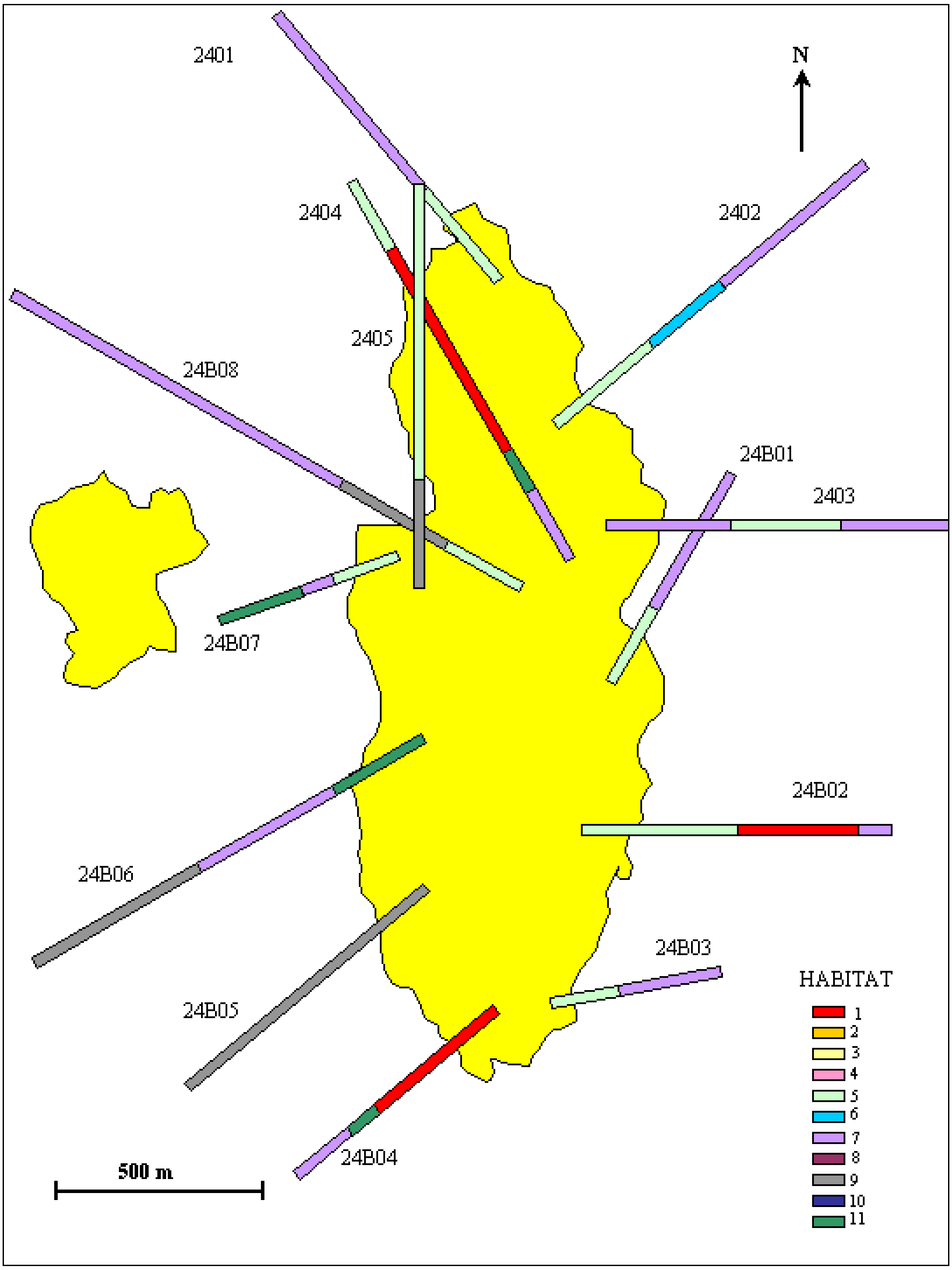


Figure 36. Location and habitat composition of baseline survey transects conduced around Malolo Patch Reef during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

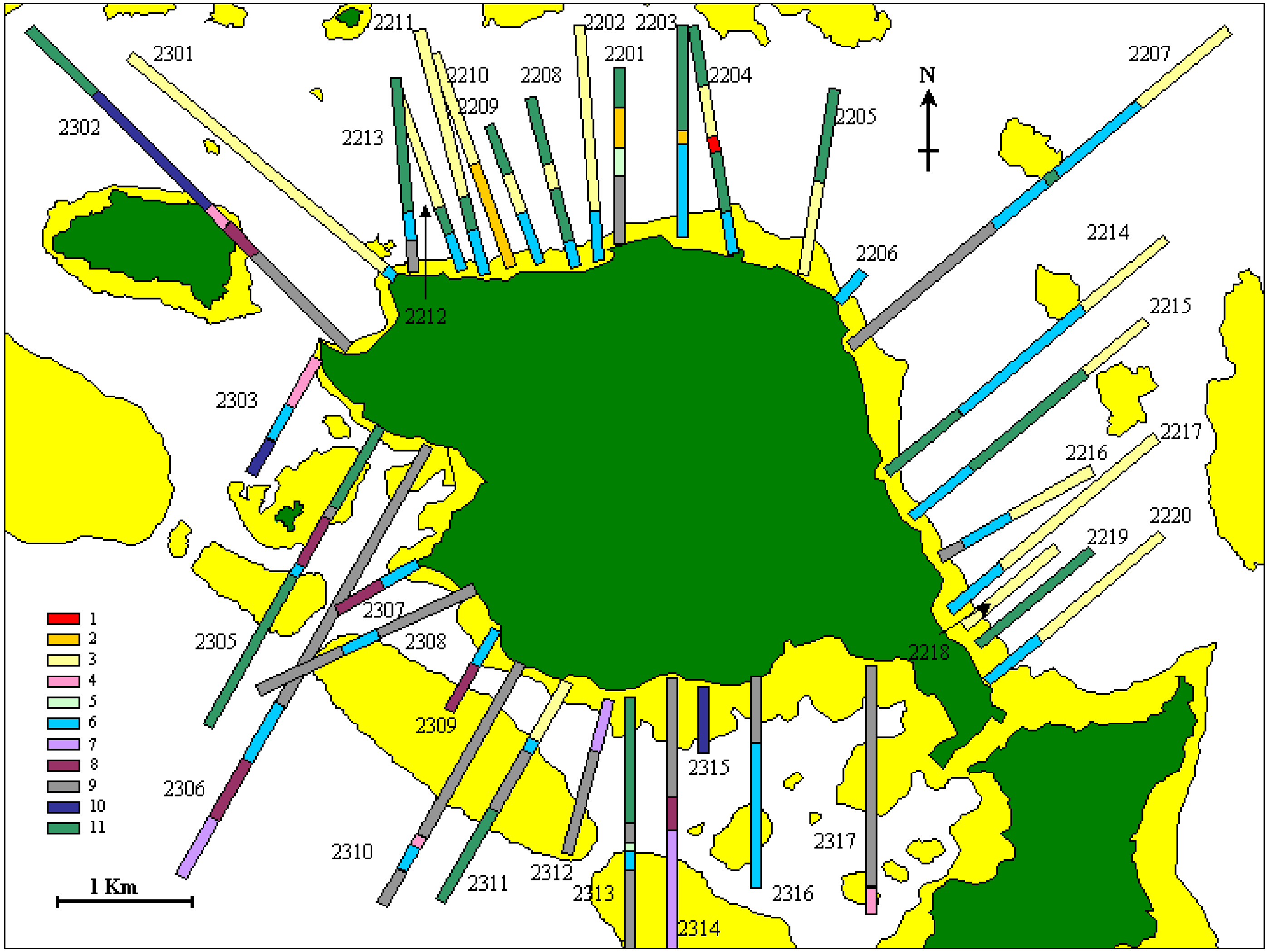


Figure 37. Location and habitat composition of baseline survey transects conduced around Malolo Island during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

Biodiversity indices for the benthic classes defined at Malolo are presented in Table 14. Three habitats (BC 5 – BC 7), highlighted in bold, contained the maximum number of species and highest values for diversity in terms of Marglef richness (d) and Shannon-Weiner (H'). Benthic class 3 was also notable.
Table 15 depicts the percent composition of habitats of each survey sector in the Malolo analysis area with the same four benthic classes highlighted (BC3, BC5-BC7). Malolo Patch (sector 24) contains the highest percentage (68%) of these diverse habitats. Transects at Malolo North (sector 22) also predominantly contained the four highlighted benthic classes with a total value of 61% but the majority of this was comprised of BC 3 (38%).

Table 14. Univariate biodiversity measures calculated for benthic classes defined from data collected within the Malolo Island analysis area.

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	39	17.8	0.89	3.72
2	47	18.9	0.93	4.01
3	**124**	**30.2**	**0.87**	**4.22**
4	60	15.4	0.90	3.70
5	**130**	**30.1**	**0.87**	**4.28**
6	**142**	**33.1**	**0.88**	**4.38**
7	**144**	**33.3**	**0.87**	**4.31**
8	99	24.3	0.92	4,19
9	113	29.6	0.85	4.04
10	22	8.0	0.79	2.45
11	87	25.4	0.81	3.62

Table 15. Percent composition of transects surveyed assigned to each benthic class by survey sector within the Malolo Island analysis area.

Benthic Class	Malolo North (22)	Malolo South (23)	Malolo Patch (24)	Total
1	1		11	4
2	5			2
3	**38**	**8**		**15**
4		3		1
5	**1**		**28**	**10**
6	**22**	**10**	**3**	**12**
7		**6**	**37**	**14**
8		7		7
9	7	46	16	23
10		6		2
11	27	14	6	16

4.2.3 Malolo Lailai Island

The dendrogram produced by cluster analysis of site records for Malolo Lailai into benthic classes is shown below (Figure 38). A total of 9 benthic classes were defined. Detailed descriptions of each habitat are provided in Table 16

Hard corals were most abundant on the upper reef slope (BC 3 and BC 8) but were equally matched by total octocoral abundance in this reef zone. Considerable levels of 'dead coral with algae' substrata were recorded at this survey site. A mix of backreef habitats were identified with moderate to sparse hard coral abundance.

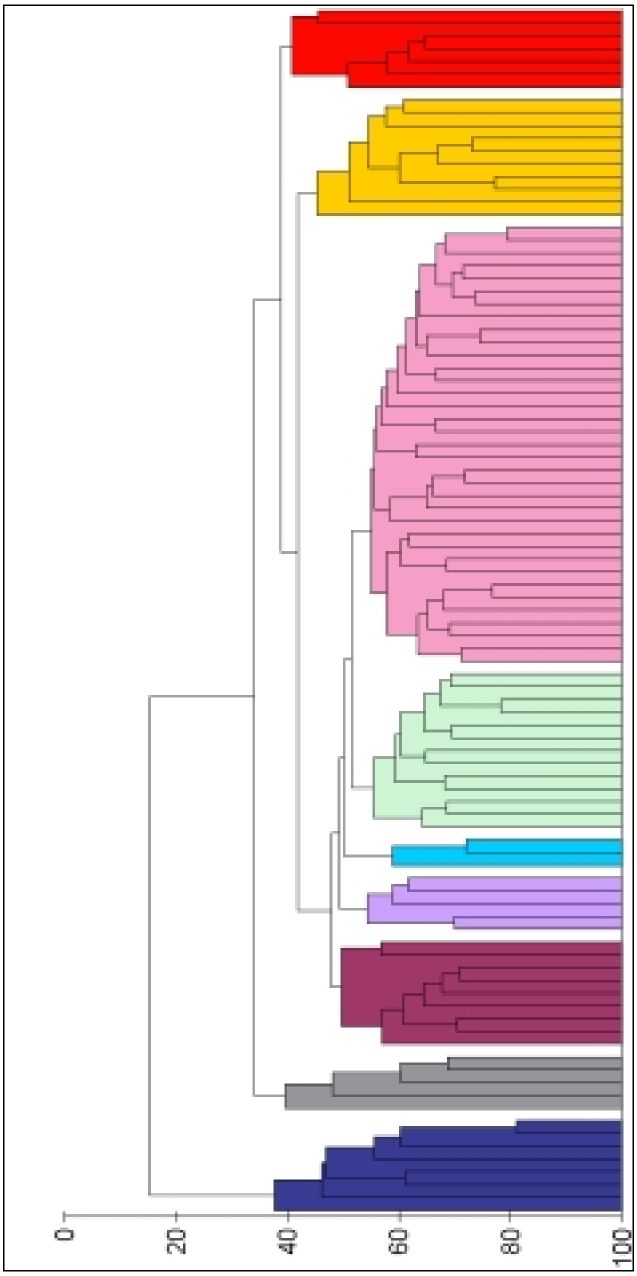


Figure 38. Dendrogram from cluster analysis of CCC baseline survey data collected in the Malolo Lailai analysis area. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%)

Habitat	# surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
1- Upper reef slope of largely bare sand and rubble	8	11.5	Sand (3.5), Rubble (1.1)	Total cover (0.1), Non-Acropora encrusting (0.1)	Total cover (0.0)	Jellyfish (0.5)	Total cover (1.3), Lumpy (0.3)	Green calcified algae (1.0), Red brown branching algae (0.8)
2- Shallow back reef of rubble frequently colonised by green calcified algae	5	1.0	Rubble (2.0), Mud (1.2)	Total cover (0.8), Non-Acropora massive (0.8), Porites massive (0.8)	Total cover (0.6)	Feather star (0.2), Linckia laevigata (0.2)	Total cover (2.4) Lumpy (1.6)	Green calcified algae (2.4), Halimeda (1.8), Green algae (1.6), Caulerpa (1.2)
3- Upper reef slope with mixed hard coral community	11	10.9	Sand (3.2), Dead coral with algae (2.5)	Total cover (3.1), Acropora branching (2.5), Non-Acropora massive (2.3), Porites massive (1.9), Pocillopora damicornis (1.6)	Total cover (1.4), Sarcophyton (0.6), Sinularia (0.5), Dendronepthya (0.5)	Tunicates (1.3), Black coral (0.7), Hydroid (0.7)	Sponge (2.5), Lumpy (2.0), Rope (1.3), Branching (1.3)	Green calcified algae (1.9), Tydemania (1.6), Halimeda (1.2), Red brown branching algae (0.7)
4- Shallow back reef areas of dead coral with algae and mud supporting a low diversity coral community	9	3.1	Dead coral with algae (2.6), Mud (2.5), Bedrock (2.5)	Total cover (2.6), Non-Acropora massive (1.7), Acropora branching (0.8), Porites massive (1.6), Diploastrea heliopora (0.6)	Total cover (2.6), Sinularia (2.1), Sarcophyton (0.5)	Synaptid sea cucumber (0.3), Diadema (0.2)	Total cover (1.8), Lumpy (1.6), Tube (0.2)	Green algae (1.2), Green filamentous algae (0.9), Padina (0.9), Turbinaria (0.9)
5- Upper reef slope dominated by dead coral with algae and mud supporting a hard and soft coral community equal in abundance	5	10.0	Dead coral with algae (1.8), Mud (1.8), Bedrock (1.8)	Total cover (1.8), Non-Acropora massive (1.6), Non-Acropora encrusting (1.2), Porites massive (1.6), Favia (0.8)	Total cover (1.8), Sinularia (1.5), Dendronepthya (0.4)	Linckia laevigata (1.0), Feather star (1.0), Tunicates (1.0)	Total cover (1.2), Rope (1.2)	Green algae (3.0), Caulerpa (2.3), Brown fleshy algae (3.0), Padina (1.4), Lobophora (1.2)
6- Upper reef slope dominated by dead coral with algae and mud supporting a sparse and low diversity hard coral community	3	9.9	Dead coral with algae (2.0), Mud (2.0), Bedrock (2.0)	Total cover (2.0), Non-Acropora encrusting (2.0), Non-Acropora massive (1.0), Favites (1.3), Porites massive (1.0)	Total cover (0.4), Sarcophyton (0.3)	Murex (0.7), Bivalvia (0.3)	Total cover (1.7), Tube (1.0), Lumpy (1.0)	Green calcified algae (1.3), Halimeda (1.6), Brown fleshy algae (0.7), Dictyota (0.7)

Table 16. Quantitative description of the nine benthic classes defined from the data collected in the Malolo Lailai analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

Habitat	# surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
7- Shallow back reef area, composed equally of dead coral with algae, mud and bedrock and supporting a moderate cover of hard and soft corals and a frequent occurrence of green algae	13	2.2	Dead coral with algae (2.5), Mud (2.5), Bedrock (2.5)	Total cover (2.5), Non-Acropora massive (1.3), Acropora branching (1.2), Non-Acropora branching (1.2), Favia (0.8), Porites massive (0.7), Pocillopora damicornis (0.5), Pocillopora verucosa (0.5)	Total cover (2.5), Xenia (0.8), Organ pipe (0.8), Sarcophyton (0.8)	Linckia laevigata (1.3), Synaptid sea cucumber (0.9)	Total cover (1.8), Elephant ear (0.4), Lumpy (0.7)	Green algae (2.9), Bornetella (1.7), Neomeris (1.3)
8- Upper reef slope/ reef crest with a frequent and mixed hard coral cover surrounded by a substrate dominated by mud and dead coral with algae	35	6.2	Mud (3.2), Dead coral with algae (3.2)	Total cover (3.1), Acropora branching (2.0), Non-Acropora branching (2.0), Non-Acropora massive (1.9), Acropora tabulate (1.7), Porites massive (1.7), Pocillopora damicornis (1.0),	Total cover (3.1), Sinularia (2.1), Xenia (0.8)	Linckia laevigata (1.0), Tunicates (0.9)	Total cover (1.5), Lumpy (1.1), Encrusting (0.6)	Green calcified algae (0.9), Tydemania (0.9), Brown filamentous (0.8)
9- Shallow back reef area with a moderate hard coral cover dominated by massive corals surrounded by a largely sandy substrate	8	2.7	Sand (2.6), Dead coral with algae (1.8), Rubble (1.5)	Total cover (2.4), Non-Acropora massive (2.1), Acropora branching (1.1), Non-Acropora branching (1.1), Porites massive (1.9), Goniopora (0.8)	Total cover (0.9), Sinularia (0.7), Sarcophyton (0.3)	Linckia laevigata (1.4), Synaptid sea cucumber (0.6)	Total cover (0.8), Lumpy (0.4), Elephant ear (0.2), Encrusting (0.2)	Brown fleshy algae (3.1), Padina (2.5), Hydroclathrus (1.4)

Table 16 (Continued). Quantitative description of the nine benthic classes defined from the data collected in the Malolo Lailai analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

The location and composition of each transect completed at Malolo Lailai is depicted in Figure 39 below.

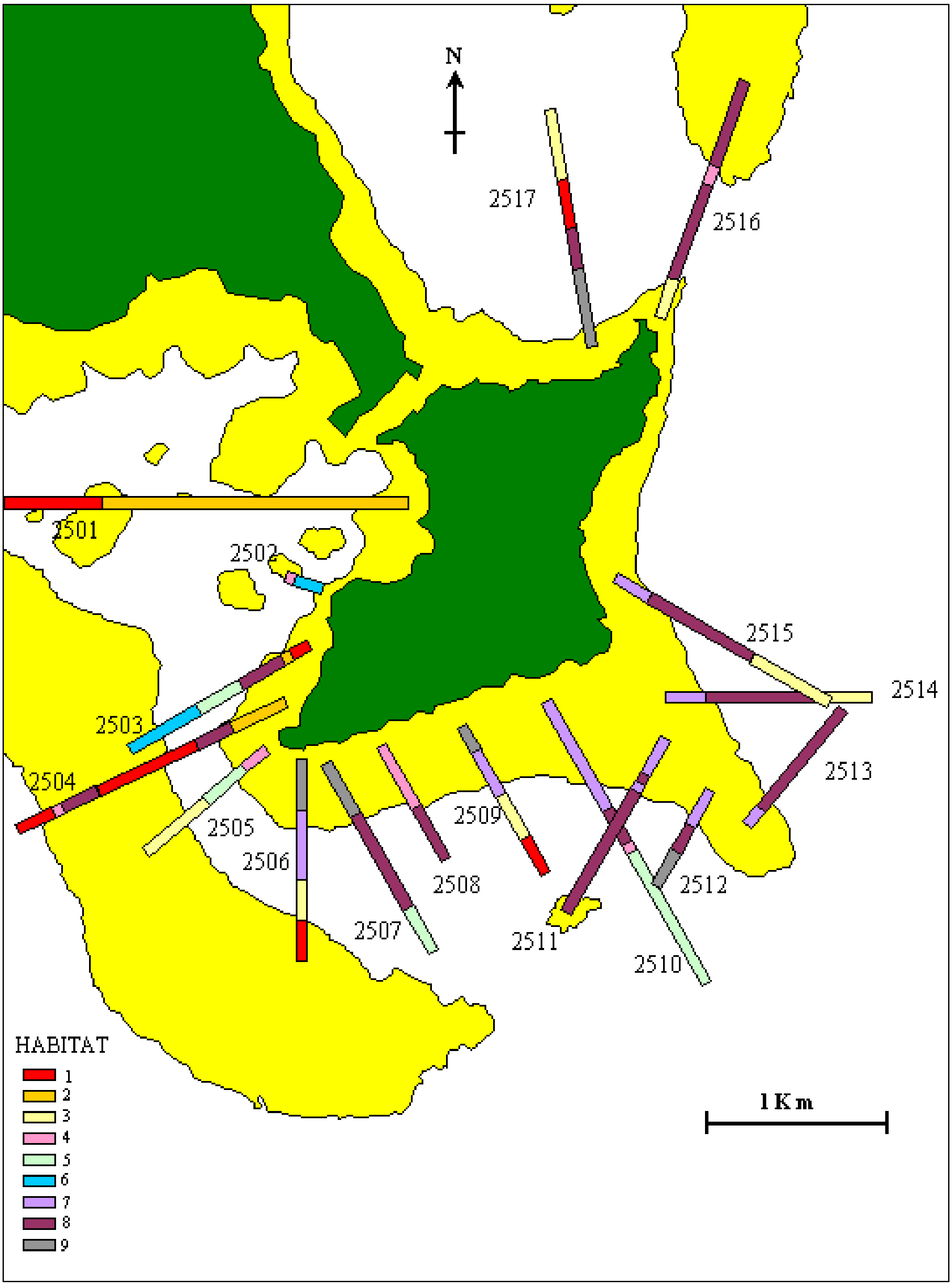


Figure 39. Location and habitat composition of baseline survey transects conduced around Malolo Lailai during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

Biodiversity indices for Malolo Lailai are presented below (Table 17). Three habitats (BC3, BC7 and BC8) were the most diverse in terms of species numbers, richness (d) and Shannon-Weiner (H') index.
The percent habitat composition of transects in Malolo Lailai (Table 18) indicates that the sector contains a rather mixed community. Just over half of the marine environment surveyed (51%) consisted of the three most diverse habitats (BC3, BC7 and BC8).

Table 17. Univariate biodiversity measures calculated for benthic classes defined from data collected within Malolo Lailai analysis area.

Benthic class	Number of species (N)	Marglef richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	26	10.5	0.84	2.99
2	36	12.0	0.92	3.50
3	**71**	**24.7**	**0.89**	**4.16**
4	40	16.2	0.86	3.54
5	58	17.8	0.93	3.98
6	45	12.9	0.95	3.72
7	**67**	**21.4**	**0.88**	**3.98**
8	**69**	**31.0**	**0.85**	**4.14**
9	55	17.7	0.90	3.87

Table 18. Percent composition of transects surveyed assigned to each benthic class within the Malolo Lailai analysis area.

Benthic Class	Malolo Lailai (25)
1	11
2	13
3	**12**
4	4
5	8
6	3
7	**12**
8	**31**
9	7

4.2.4 Mana Island

The dendrogram produced by cluster analysis of baseline data for Mana Island is shown below (Figure 40). A total of 7 benthic classes were defined. Detailed descriptions of each habitat are provided in Table 19
On the whole, hard coral relative abundance was higher at Mana than at the other five analysis units. In particular, hard corals were abundant on the upper reef slope (BC 5) with a rating of 4.4 (Abundant to Dominant) and were frequently recorded on the lower reef

slope. 'Dead coral with algae' was frequently recorded in the back reef habitats (BC3 and BC4) and was also notable on parts of the upper reef slope (BC6).

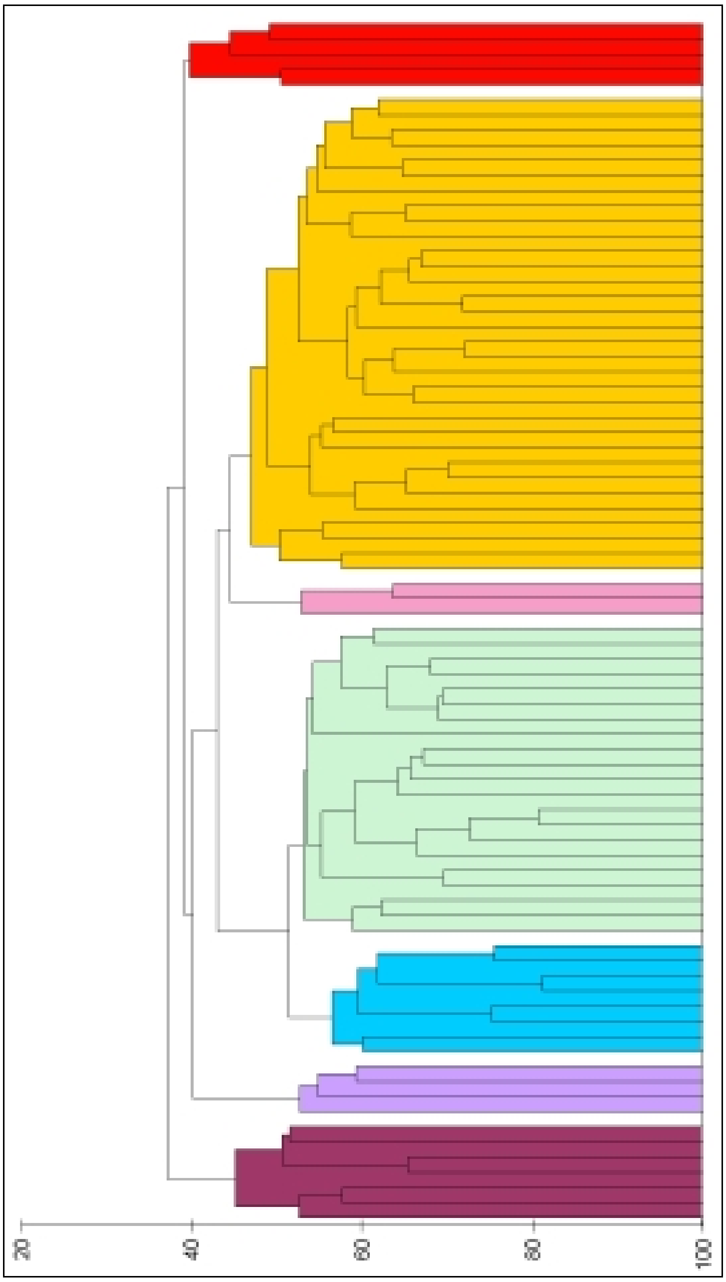


Figure 40. Dendrogram from cluster analysis of CCC baseline survey data collected in the Mana analysis area. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%).

The position and habitat composition of completed transects at Mana and Mana Island lagoon are depicted by Figures 41 and 42 respectively.

Habitat	# surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
1 Lower reef slope dominated by sand with frequent brown macro and micro algae	7	25.6	Sand (2.9), Dead coral with algae (1.3), Mud (0.6)	Total cover (1.3), Non-Acropora massive (0.9), Acropora branching (0.6), Porites massive (0.6), Galaxea (0.4)	Total cover (0.4), Sarcophyton (0.3)	Feather star (0.9), Anemone (0.3)	Total cover (1.3), Lumpy (1.1)	Padina (2.6), Brown filamentous algae (2.6), Green algae (2.3), Halimeda (1.0), Caulerpa (0.9)
2 Lower reef slope dominated by rubble with moderate hard and soft coral cover	4	28.0	Rubble (3.3), Sand (1.8)	Total cover (1.8), Acropora Branching (1.5), Porites massive (1.0), Non-Acropora mushroom (1.0)	Total cover (1.5), Sinularia (1.3), Dendronepthya (1.0)	Hydroid (0.8), Linckia laevigata (0.8)	Total cover (1.3), Tube (0.5), Encrusting (0.5)	Brown filamentous algae (1.0)
3 Shallow back reef area with mixed hard coral and green calcified algal cover	8	1.5	Dead coral with algae (3.5), Rubble (2.5), Sand (2.3)	Total cover (2.6), Non-Acropora massive (2.1), Porites massive (2.1), Acropora branching (0.9),	Total cover (2.4), Xenia (1.8), Xenia (1.5)	Clam (0.5), Non-synaptid sea cucumber (0.4)	Total cover (0.5), Lumpy (0.5)	Green calcified algae (3.5), Halimeda (3.1), Turbinaria (2.9), Red coralline algae (1.6)
4 Shallow back reef area with high and diverse hard coral cover	21	1.7	Dead coral with algae (3.0), Sand (2.3), Rubble (2.0)	Total cover (3.1), Non-Acropora branching (1.9), Acropora branching (1.4), Porites massive (1.1), Pocillopora damicornis (1.0)	Total cover (2.4), Sinularia (2.1), Sarcophyton (0.6)	Linckia laevigata (1.3), Zooanthid (0.1)	Total cover (0.5), Encrusting (0.3)	Brown filamentous algae (2.7), Green calcareous algae (2.1), Padina (1.5)
5 Upper reef slope/ reef crest with abundant to dominant hard coral cover dominated by Non-Acropora encrusting and Acropora tabulate	3	11.9	Rubble (0.7), Dead coral with algae (0.7)	Total cover (4.4), Non-Acropora encrusting (3.0) Acropora tabulate (2.3), Acropora branching (2.0),	Total cover (3.0), Sinularia (1.7), Dendronepthya (1.7), Xenia (1.3)	Hydroid (2.7), Tunicates (2.7)	Total cover (2.7), Tube (2.3), Encrusting (1.7)	Green algae (2.3), Dictyota (1.6), Red coralline algae (1.7)
6 Upper reef slope dominated by dead coral with algae with high, but low diversity coral cover	32	15.5	Dead coral with algae (2.4), Rubble (1.0)	Total cover (3.1), Acropora branching (1.7), Non-Acropora massive (1.5), Favites (1.5), Diploastrea heliopora (1.3),	Total cover (2.3), Sinularia (1.7), Xenia (1.0)	Feather star (1.3), Black coral (0.5)	Total cover (1.8), Lumpy (1.6)	Green algae (1.6), Green filamentous (1.2), Galaxaura (1.0),
7 Reef crest with low diversity, moderate hard coral cover	5	7.4	Dead coral with algae (1.0), Bedrock (0.8)	Total cover (3.2), Non-Acropora encrusting (1.6), Acropora branching (1.4), Acropora digitate (1.4), Porites massive (1.4)	Total cover (2.4), Sinularia (1.6), Xenia (0.4)	Feather star (0.8), Zooanthid (0.6), Coralliomorph (0.6)	Total cover (0.6), Lumpy (0.6)	Green filamentous (1.6), Red coralline algae (1.4)

Table 19. Quantitative description of the seven benthic classes defined from the data collected in the Mana Island analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys.

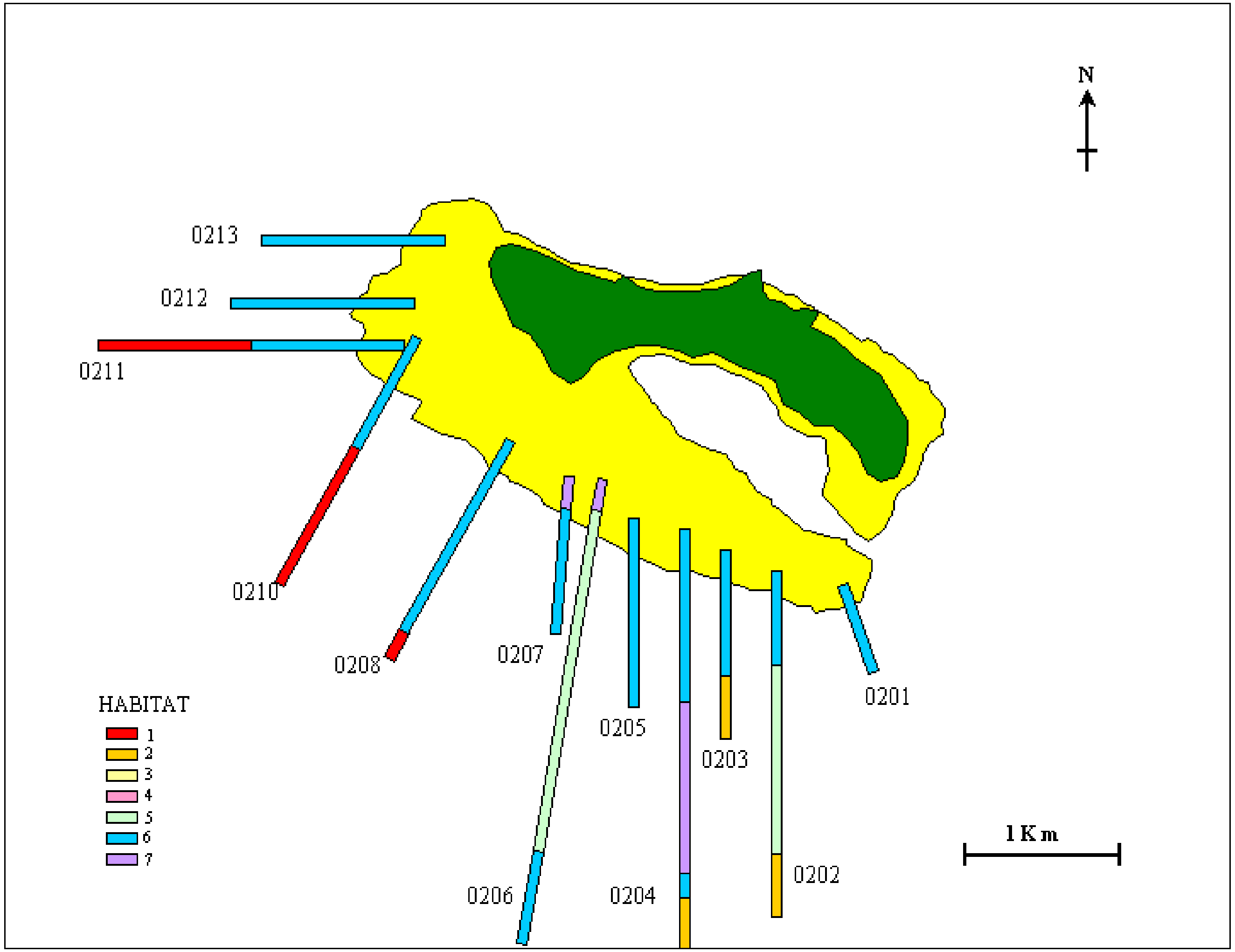


Figure 41. Location and habitat composition of baseline survey transects conduced around Mana Island during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

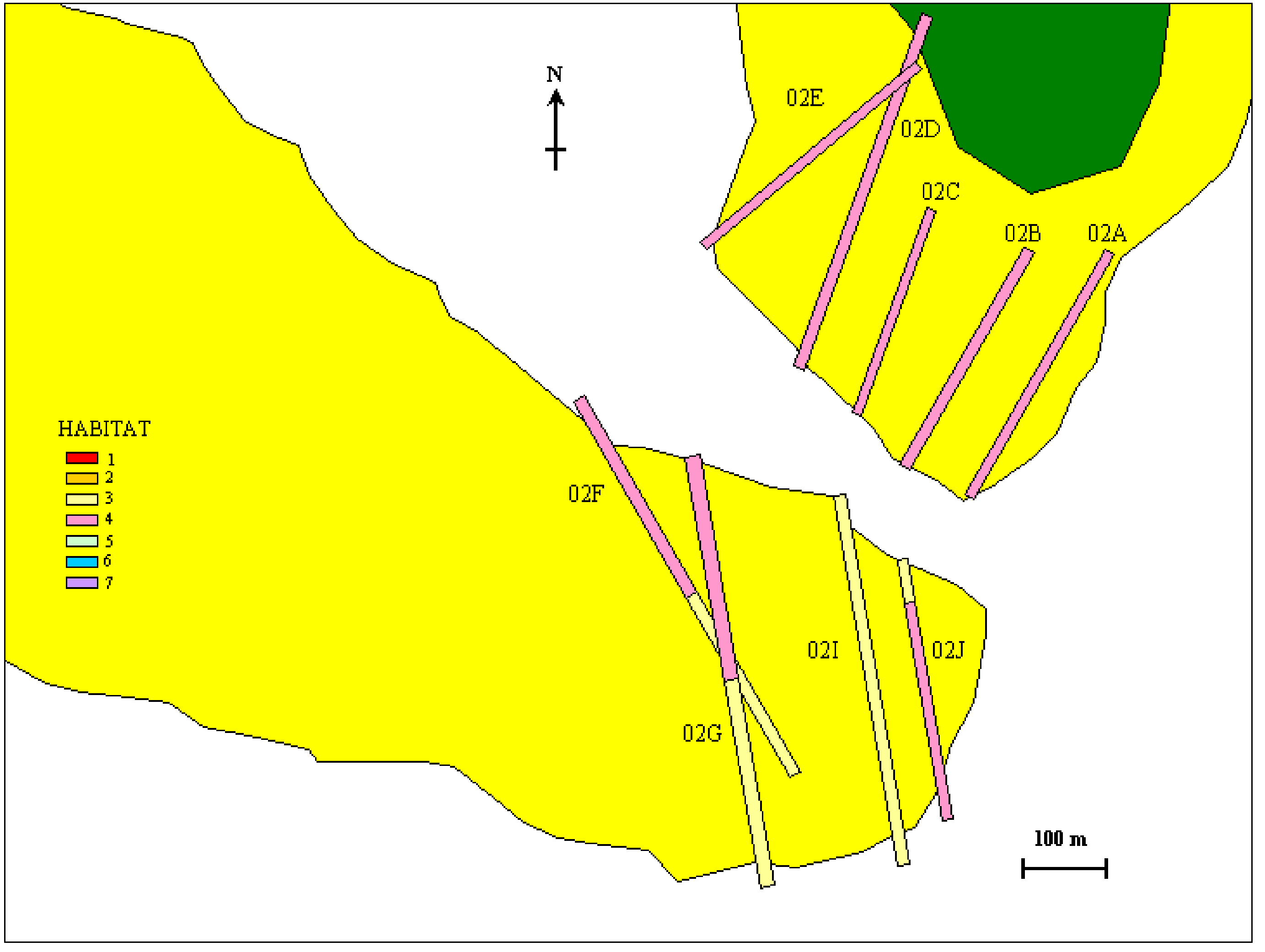


Figure 42. Location and habitat composition of baseline survey transects conduced around Mana Island Lagoon entrance during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

At Mana the highest values for species numbers and Shannon-Weiner index were recorded for BC 5 and BC 6, with BC 4 also noteworthy (Table 20). Over 100 species were recorded in Benthic Class 5, the upper reef slope and reef crest. However this habitat was a only small proportion (<10%) of the habitats recorded at Mana (Table 21). In contrast the combined proportion of BC 4 and BC 6 amounted to 62% of the habitats recorded on transects.

Table 20. Univariate biodiversity measures calculated for benthic classes defined from data collected within the Mana Island analysis area.

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	39	16.9	0.90	3.71
2	39	15.1	0.94	3.78
3	66	17.2	0.88	3.79
4	**66**	**24.6**	**0.87**	**4.04**
5	**102**	**19.9**	**0.95**	**4.31**
6	**66**	**30.8**	**0.88**	**4.26**
7	44	15.0	0.93	3.78

Table 21. Percent composition of transects surveyed assigned to each benthic class by survey sector within the Mana Island analysis area.

Benthic Class	Mana Island (02)
1	5
2	3
3	19
4	**36**
5	**8**
6	**26**
7	4

4.2.5 Navini Island

The results of the cluster analysis of baseline data for Navini Island are depicted by the dendrogram shown below (Figure 43). A total of 4 benthic classes were defined. Detailed descriptions of each habitat are provided in Table 22.

Mean total hard coral abundance was highest on the upper reef slope (BC 3) and rated as frequent to abundant. Hard coral was also frequent on the back reef (BC 1). However, macroalgal abundance, particularly fleshy brown algae, was slightly greater than that of hard corals in the shallow waters of the back reef. A few black coral colonies were recorded on the reef slope.

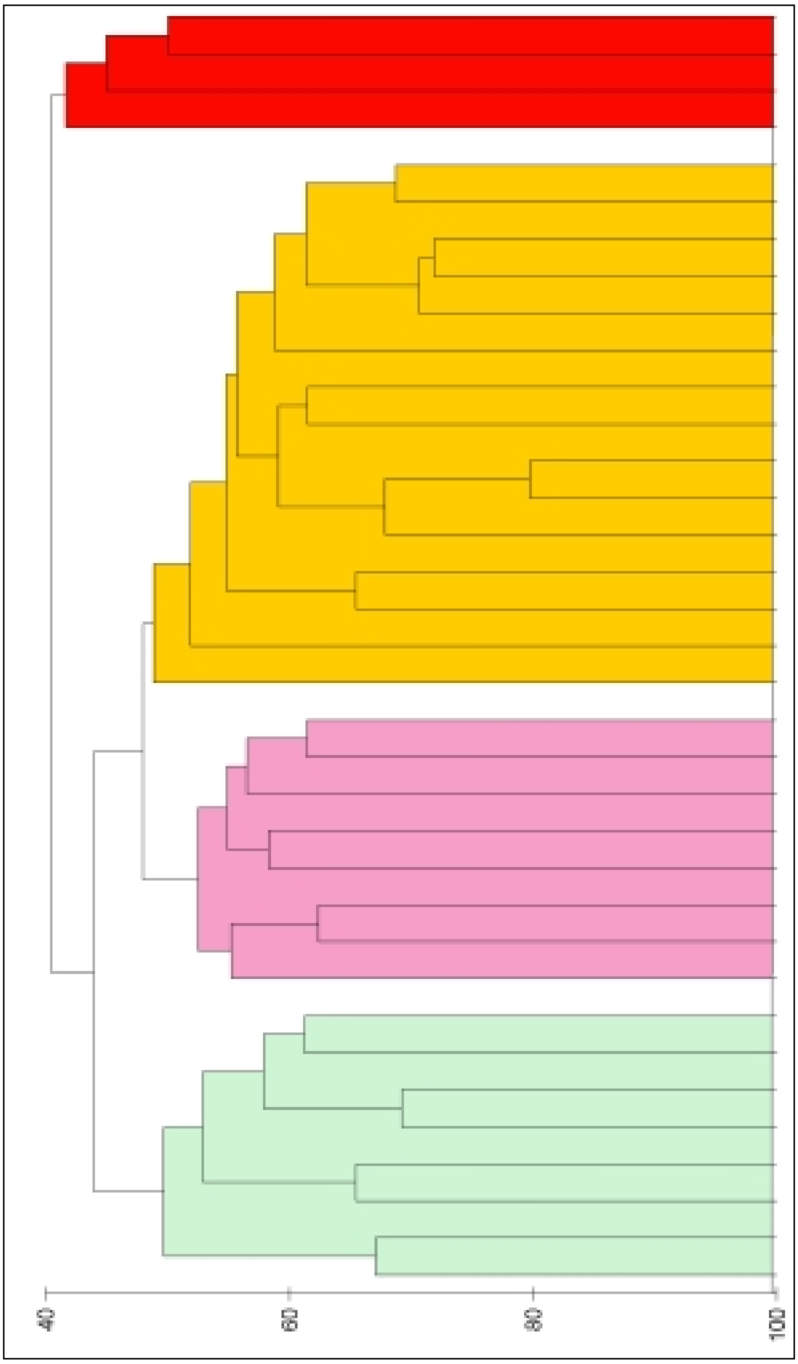


Figure 43. Dendrogram from cluster analysis of CCC baseline survey data collected in the Navini Island analysis area. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%).

Figure 44 shows the position and habitat composition of all completed transects at Navini Island.

Habitat	# surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
1 Shallow backreef area with high coral cover dominated by Acropora tabulate and calcified green algae	8	2.8	Sand (1.6), Bedrock (1.4), Rubble (1.3)	Total cover (2.9), Acropora tabulate (2.3), Acropora branching (1.9), Porites massive (1.9), Favia (1.4)	Total cover (1.4), Sinularia (1.0), Sarcophyton (1.0)	Synaptid sea cucumber (2.5), Diadema (0.9)	Total cover (0.9), Lumpy (0.9)	Green algae (3.0), Brown fleshy algae (3.1), Turbinaria (1.9), Padina (1.6)
2 Lower reef slope with sand and dead coral with algae and moderate hard coral cover	8	24.9	Sand (3.6), Dead coral with algae (1.4)	Total cover (2.5), Acropora branching (1.6), Non-Acropora massive (1.0), Favites (1.6), Porites massive (1.3)	Total cover (1.4), Xenia (1.0), Dendronepthya (0.9)	Feather star (0.9), Linckia laevigata (0.9)	Total cover (2.3), Lumpy (1.4), Rope (1.3)	Green algae (1.4), Halimeda (1.3), Padina (0.9)
3 Upper reef slope with abundant hard coral cover and brown macroalgae	15	13.4	Sand (2.5), Bedrock (1.1), Rubble (1.1)	Total cover (3.6), Acropora branching (2.3), Non-Acropora massive (2.1), Porites massive (1.9), Favites (1.7)	Total cover (1.9), Sinularia (1.7), Sarcophyton (1.2)	Linckia laevigata (1.5), Black coral (1.1)	Total cover (2.0), Lumpy (1.6), Tube (1.2)	Brown fleshy algae (2.1), Padina (2.1), Green calcified algae (1.3), Halimeda (0.9), Tydemania (0.7)
4 Lower reef slope dominated by sand with sparse hard coral cover	4	27.3	Sand (3.3), Rubble (1.0)	Total cover (2.0), Non-Acropora encrusting (1.8), Acropora branching (1.3), Favites (1.0), Porites massive (0.8)	Total cover (1.5), Sarcophyton (0.8), Dendronepthya (0.8)	Black coral (0.8), Linckia laevigata (0.5)	Total cover (1.8), Tube (1.0), Encrusting (1.0)	Green calcified algae (1.3), Halimeda (0.5), Tydemania (0.5)

Table 22. Quantitative description of the four benthic classes defined from the data collected in the Navini Island analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

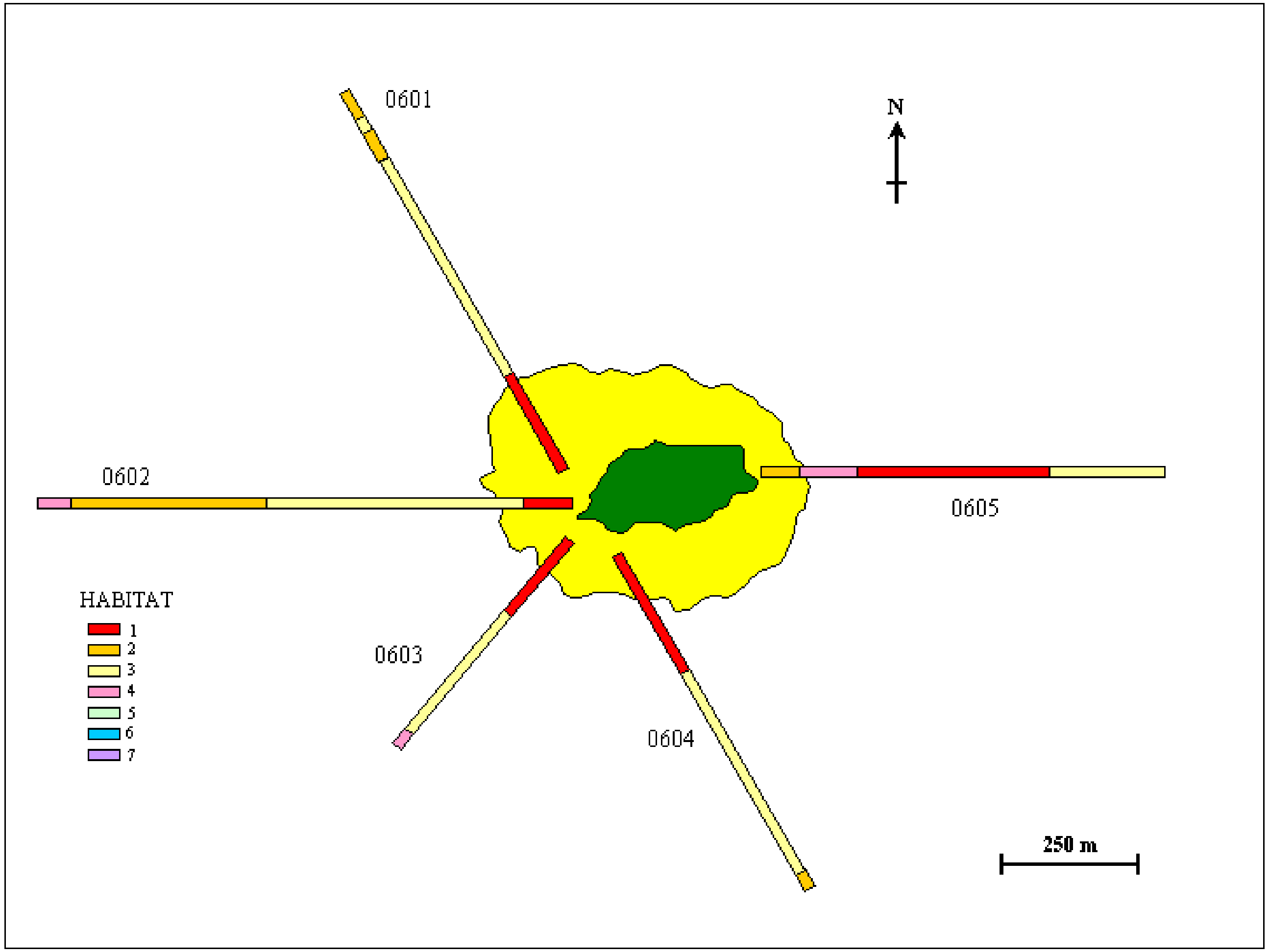


Figure 44. Location and habitat composition of baseline survey transects conduced around Navini Island during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

Biodiversity indices highlight the richness and value of Benthic Class 3 in Navini waters (Table 23) where the highest value for the Shannon-Weiner index (H') was revealed of all the six analysis units. In addition more than half of all habitats recorded on transects were within this benthic class (Table 24).

Table 23. Univariate biodiversity measures calculated for benthic classes defined from data collected within Navini Island analysis area

Benthic Class	Number of species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	72	19.9	0.92	4.10
2	56	21.4	0.91	4.07
3	**93**	**29.8**	**0.92**	**4.52**
4	41	17.8	0.93	3.93

Table 24. Percent composition of transects surveyed assigned to each benthic class by survey sector within the Mana Island analysis area

Benthic Class	Navini Island (06)
1	28
2	16
3	**51**
4	5

4.2.6 Wadigi Island Reef Complex

The results of the cluster analysis of baseline data for Wadigi Island Reef Complex are depicted by the dendrogram shown below (Figure 45). A total of five benthic classes were defined. Detailed descriptions of each habitat are provided in Table 25.

Hard coral abundance was less than at Mana Island but the reefs in the Wadigi complex consist of a diverse assemblage of hard corals. A diffuse bed of *Halophila* was recorded on the lower reef slope (BC 1 and BC 5).

Figures 46 - 48 show the position and habitat composition of baseline transects completed at Lana and Wadigi Patch reefs and Wadigi Island respectively.

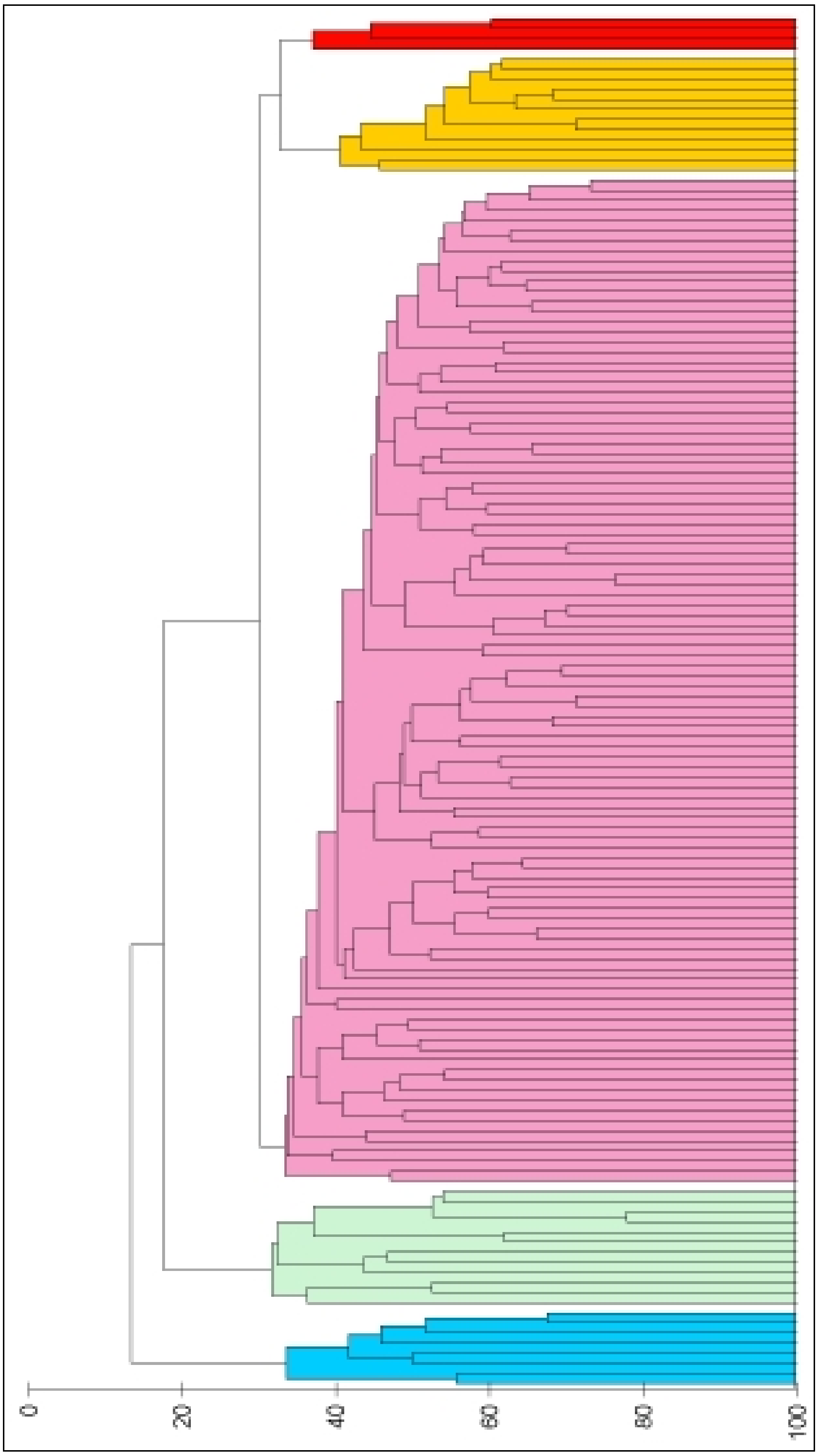


Figure 45. Dendrogram from cluster analysis of CCC baseline survey data collected in the Navini Island analysis area. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%).

Habitat	# surveys	Average depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
1 Mud dominated lower reef slope with sparse seagrass and minimal hard coral cover	8	21.7	Mud (5.0), Sand (0.3)	Total cover (0.1), Non-Acropora encrusting (0.1), Diploastrea heliopora (0.1)	Total cover (0.4), Dendronepthya (0.4)	Linckia laevigata (0.3)	Total cover (0.4), Tube (0.1), Rope (0.1), Lumpy (0.1)	Green algae (1.1), Green calcified algae (1.0), Halimeda (1.1), Brown filamentous algae (1.1), Padina (0.6)
2 Sand dominated upper reef slope with little biological cover	12	17.7	Sand (4.8), Dead coral with algae (0.6)	Total cover (0.4), Acropora branching (0.3), Pocillopora verrucosa (0.2)	Total cover (0.1), Dendronepthya (0.1)	Hydroid (0.2), Feather star (0.2)	Total cover (0.3), Lumpy (0.2)	Green algae (1.0), Green calcified (0.4), Caulerpa (0.7)
3 Upper reef slope dominated by sand with moderate hard coral cover	100	10.6	Sand (2.4), Dead coral with algae (1.7)	Total cover (2.6), Acropora branching (1.4), Non-Acropora massive (1.6), Non-Acropora branching (1.4), Pocillopora damicornis (0.7), Porites massive (1.4), Favites (0.9)	Total cover (1.3), Sinularia (0.4), Sarcophyton (0.4), Dendronepthya (0.4)	Linckia laevigata (1.0), Feather star (0.8), Tunicates (0.7)	Total cover (1.4), Lumpy (1.1), Encrusting (0.6), Rope (0.6)	Green calcified algae (1.5), Halimeda (1.0), Tydemania (0.9), Brown filamentous algae (1.0), Padina (0.7)
4 Upper reef slope dominated by sand and green calcified algae	12	7.6	Sand (3.9), Dead coral with algae (0.6), Rubble (0.6)	Total cover (0.8), Non-Acropora massive (0.7), Non-Acropora branching (0.4), Porites massive (0.7), Pocillopora damicornis (0.4)	Total cover (0.2), Sinularia (0.1), Dendronepthya (0.1)	Linckia laevigata (0.7), Synaptid sea cucumber (0.6)	Total sponge (0.8), Lumpy (0.7), Rope (0.2), Tube (0.2)	Green algae (2.5), Green calcified algae (2.3), Caulerpa (2.3), Halimeda (2.3), Red brown branching algae (1.2), Dictyota (1.0)
5 Sandy lower reef slope with occasional seagrass patches and sparse hard coral cover	4	18.5	Sand (4.5), Dead coral with algae (1.0)	Total cover (1.0), Non-Acropora encrusting (0.8), Non-Acropora branching (0.5), Porites rus (0.8), Porites massive (0.5)	Total cover (0.8), Sinularia (0.3), Pulsing (0.3)	Hydroid (0.8), Tunicates (0.8), Black coral (0.5),	Total cover (0.5), Elephants ear (0.3), Lumpy (0.3)	Total seagrass (1.8), Halophila (1.8), Green algae (1.3), Caulerpa (1.0), Hydroclathrus (0.8), Tydemania (0.5)

Table 25. Quantitative description of the five benthic classes defined from the data collected in the Wadigi Island Reef complex analysis area. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

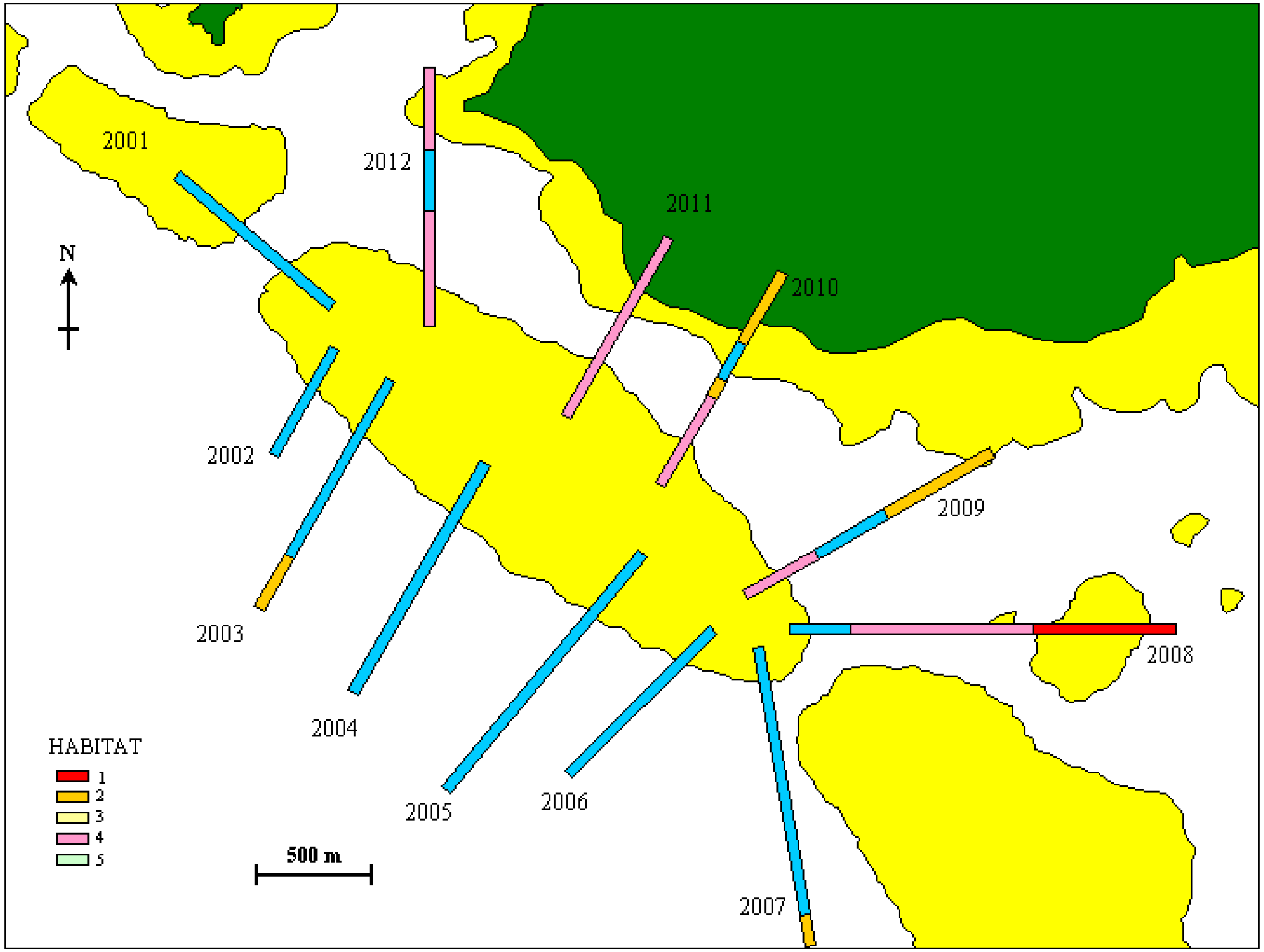


Figure 46. Location and habitat composition of baseline survey transects conduced around Lana Patch Reef during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted

Note: Habitat 3 is shown as blue on Figures x-y and not yellow as stated in the key.

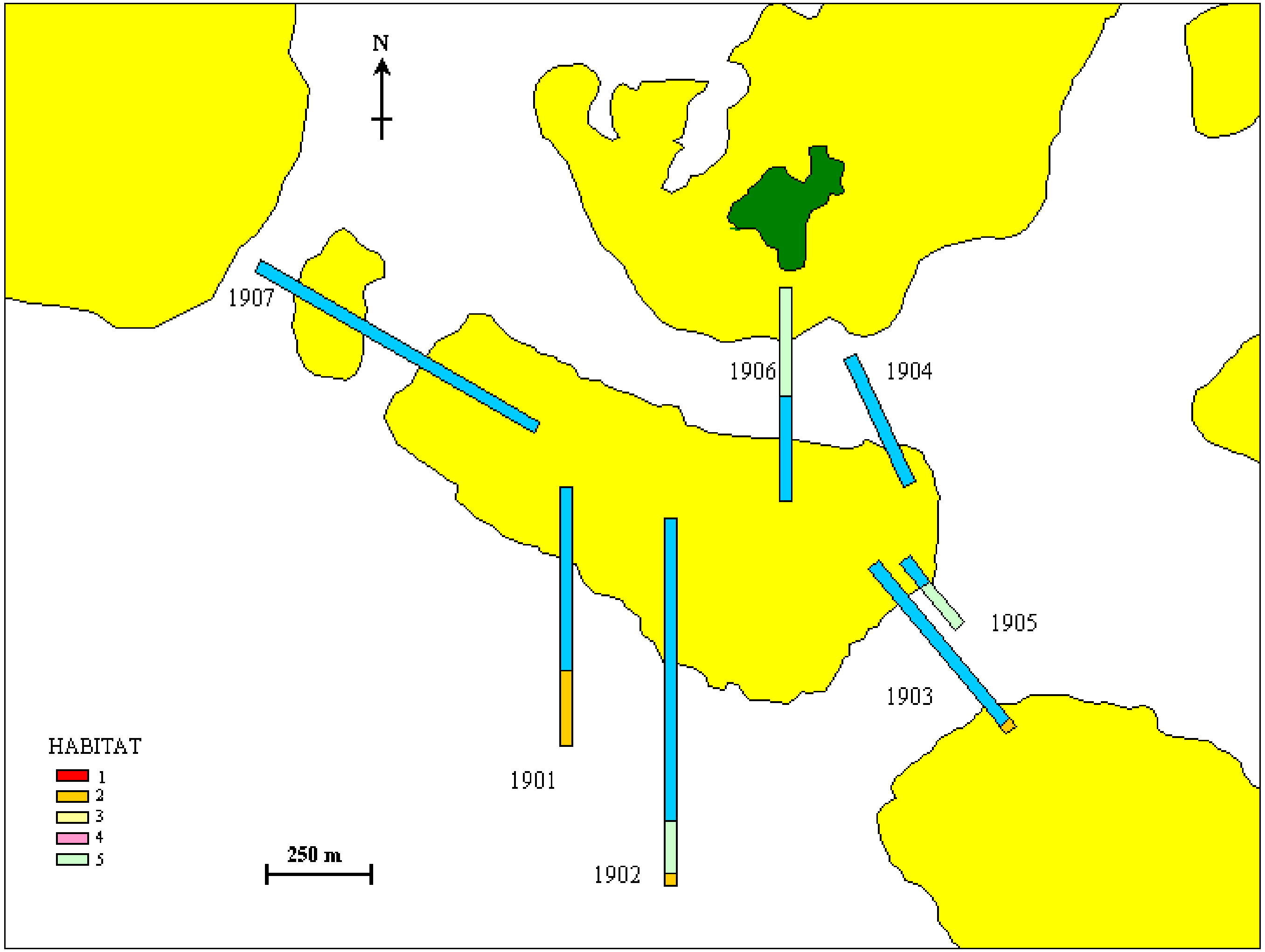


Figure 47. Location and habitat composition of baseline survey transects conduced around Wadigi Patch Reef during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

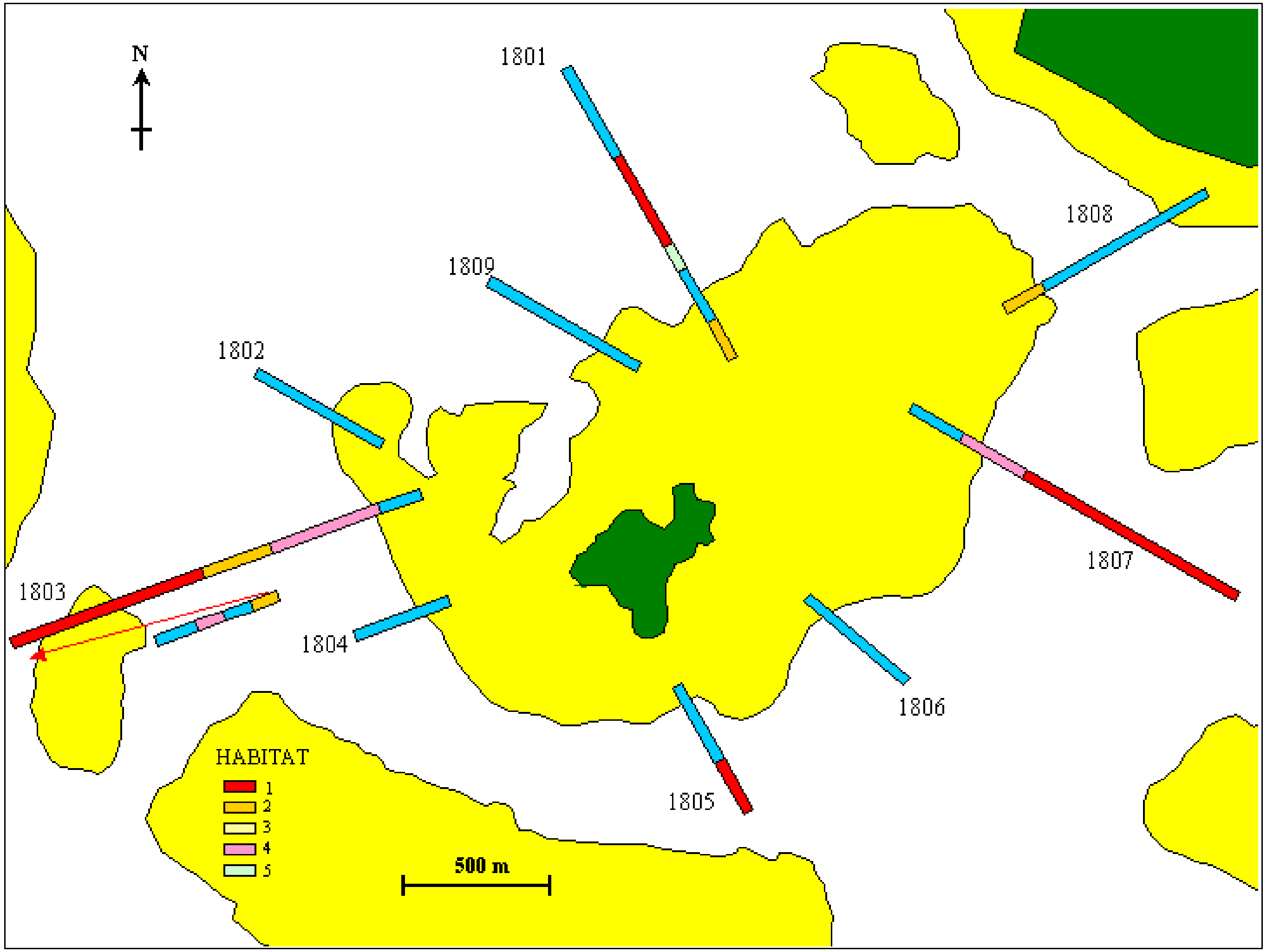


Figure 48. Location and habitat composition of baseline survey transects conduced around Wadigi Island during year one of the FCRCP. Note that whilst the transects are not to scale according to the basemap, they are spatially located correctly and reflect the bearing upon which transects were conducted.

Values for biodiversity indices in Wadigi Complex are shown below in Table 26. The upper reef slope (**BC 3**) stands out as the most diverse in terms of species numbers, richness (d) and Shannon-Weiner index (H'). This habitat also comprised the majority of the reefs surveyed in terms of % transect composition at all the reefs within the analysis unit (Table 27). In particular, Wadigi Patch Reef was dominated by habitat BC 3 (>80%).

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	16	12.9	0.79	2.87
2	15	15.9	0.79	3.00
3	**57**	**40.3**	**0.86**	**4.41**
4	31	16.8	0.84	3.46
5	31	14.9	0.91	3.60

Table 26. Univariate biodiversity measures calculated for benthic classes defined from data collected within Wadigi Reef Complex analysis area

Benthic Class	Wadigi Island (18)	Wadigi Patch reef (19)	Lana (20)	Total
1	28		5	11
2	9	6	10	8
3	53	82	61	65
4	10		25	12
5	1	12		4

Table 27. Percent composition of transects surveyed assigned to each benthic class by survey sector within the Wadigi Reef Complex analysis area.

4.3 Conservation Values

Ternary Diagrams of coral morphology showing the coral reef conservation value for baseline transects in thirteen Survey Sectors (Figures 49 – 61). Each diagram depicts the conservation value of individual selected transects within the survey sector.

Note: labels and arrows are depicted on Figure 49 only.

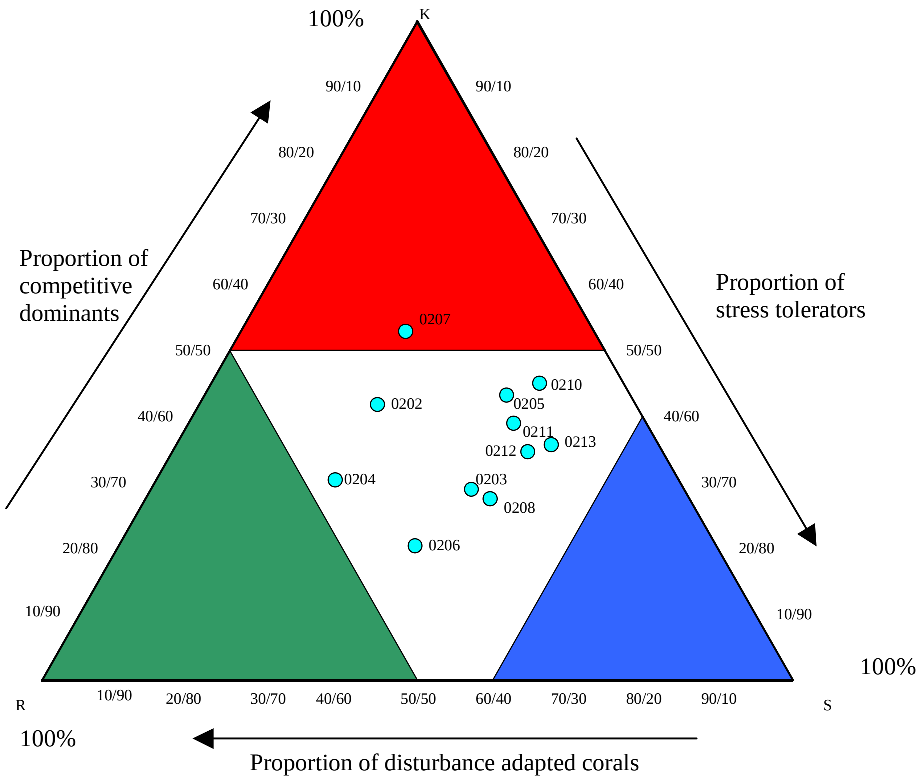


Figure 49. Mana Island

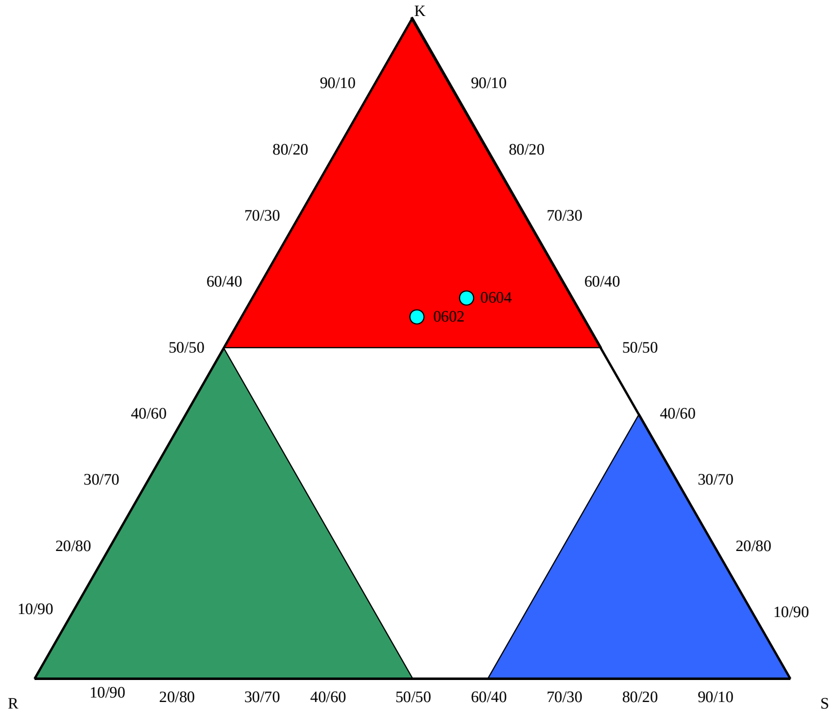


Figure 50. Navini Island

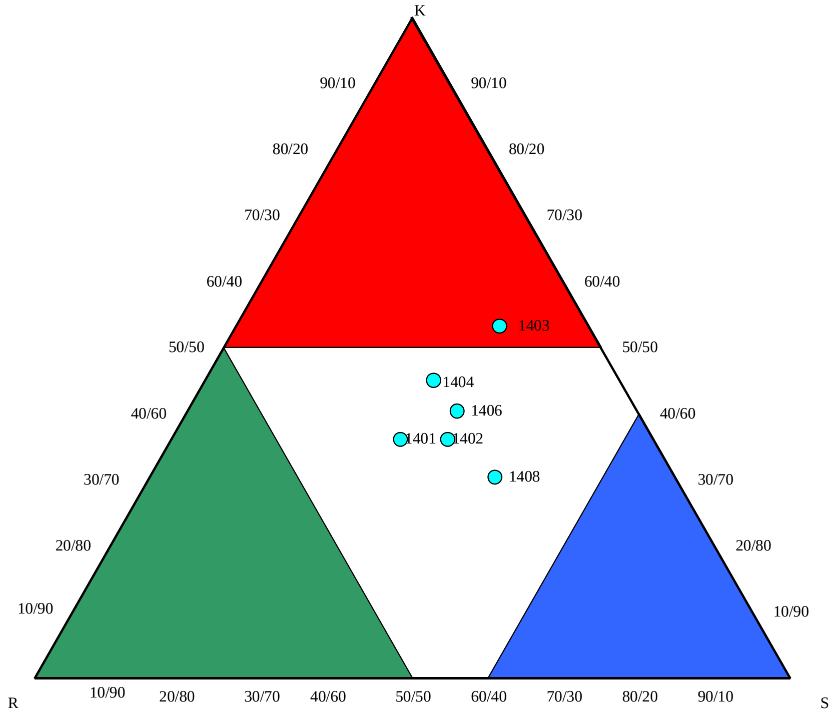


Figure 51. Yalodrivi Reef

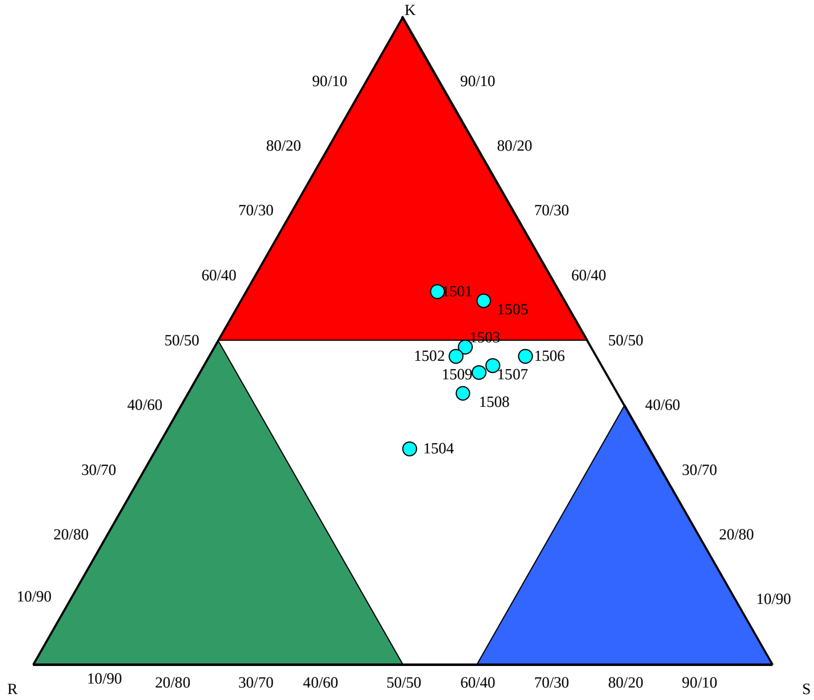


Figure 52. Mothui Island

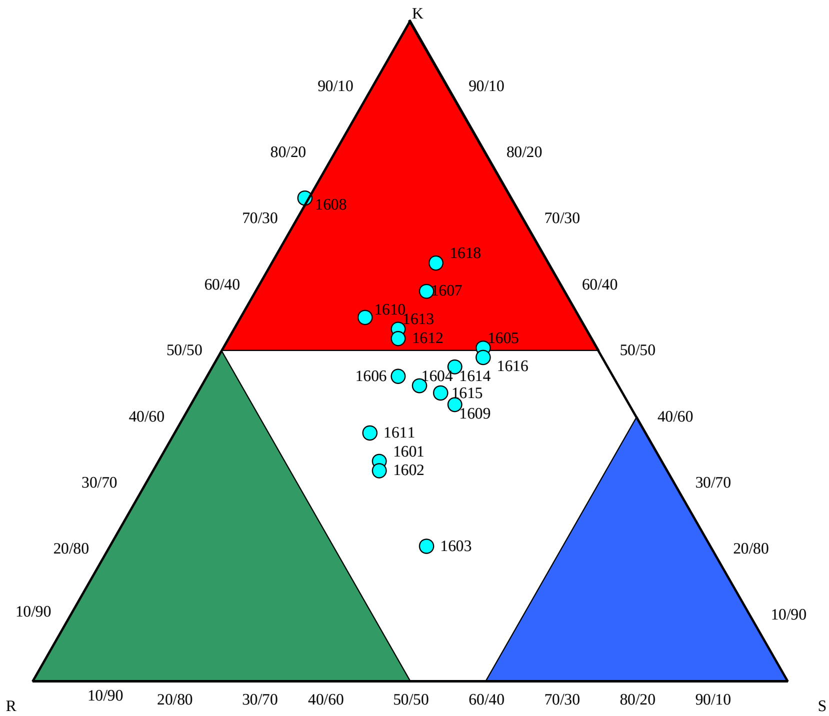


Figure 53. Castaway Barrier Reef

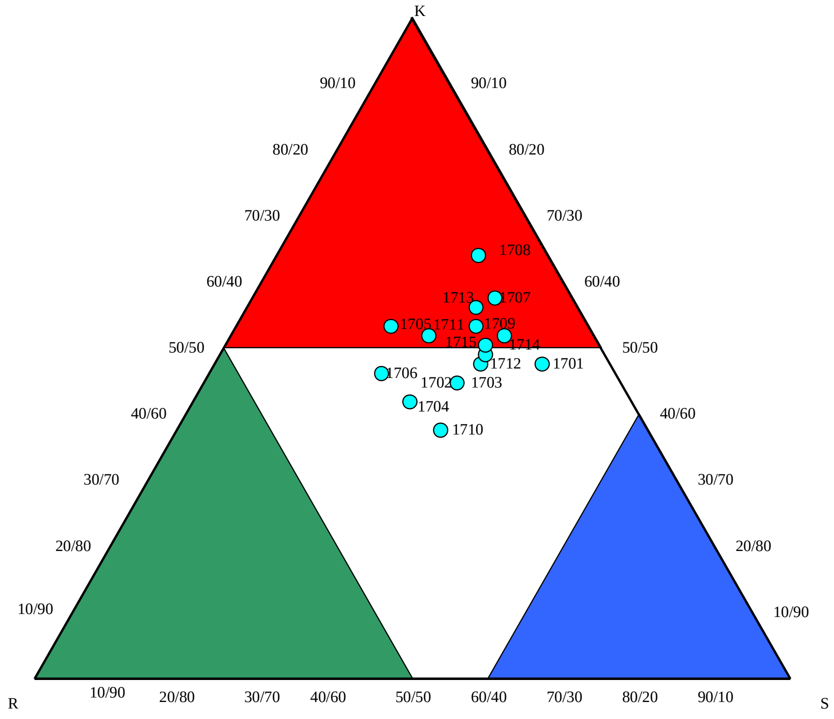


Figure 54. Castaway Island

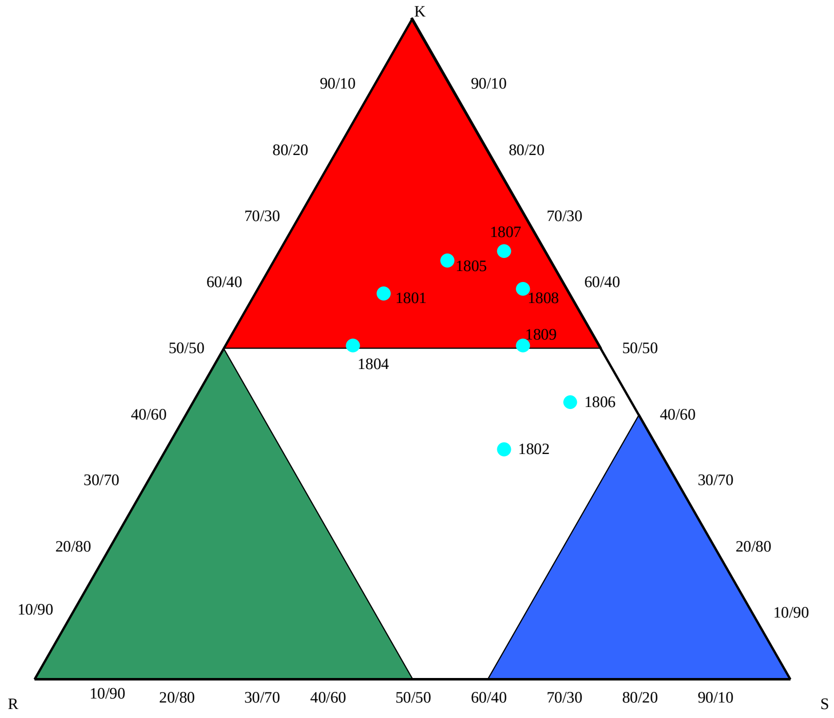


Figure 55. Wadigi Island

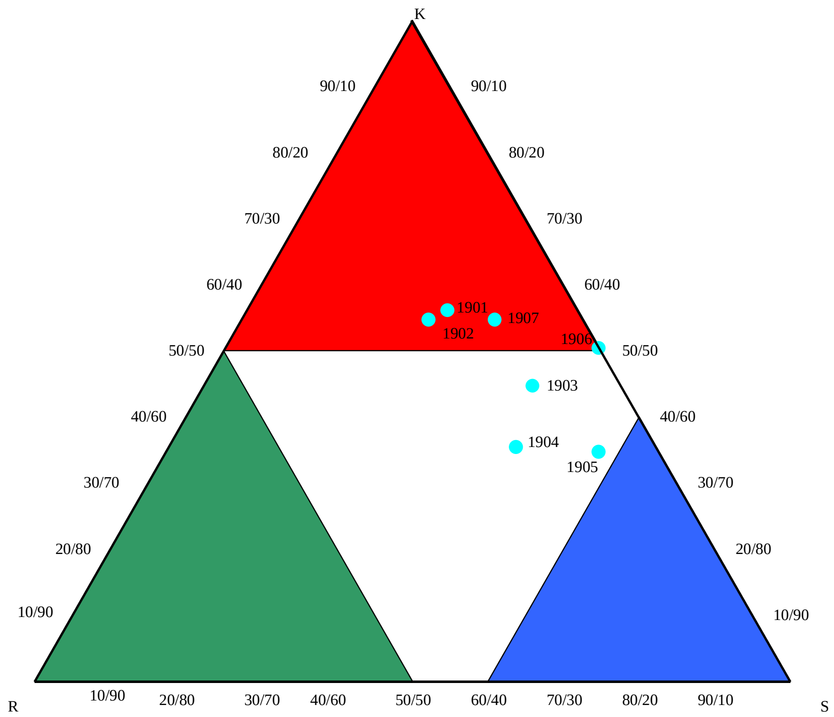


Figure 56. Wadigi Patch Reef

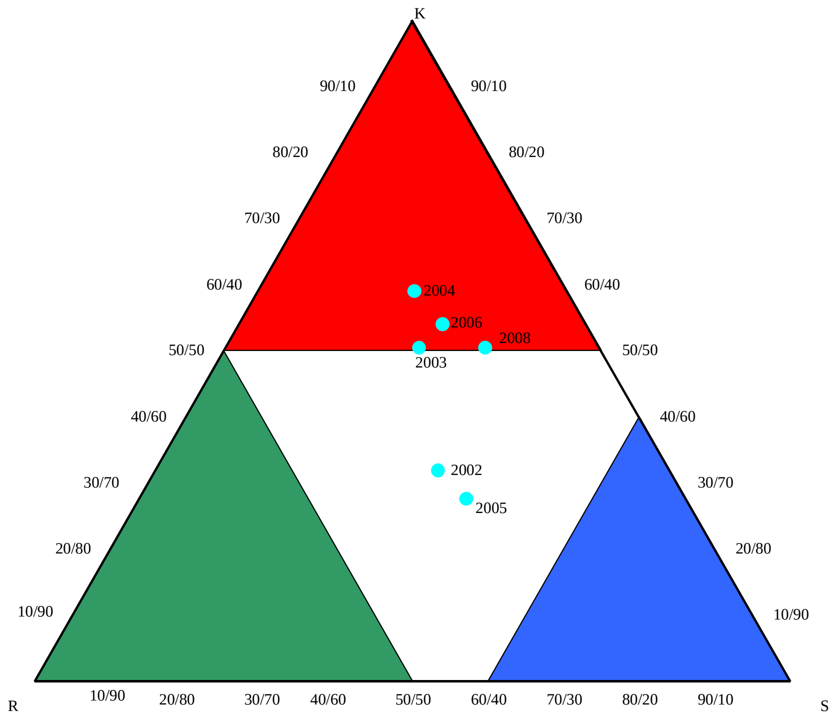


Figure 57. Lana Reef

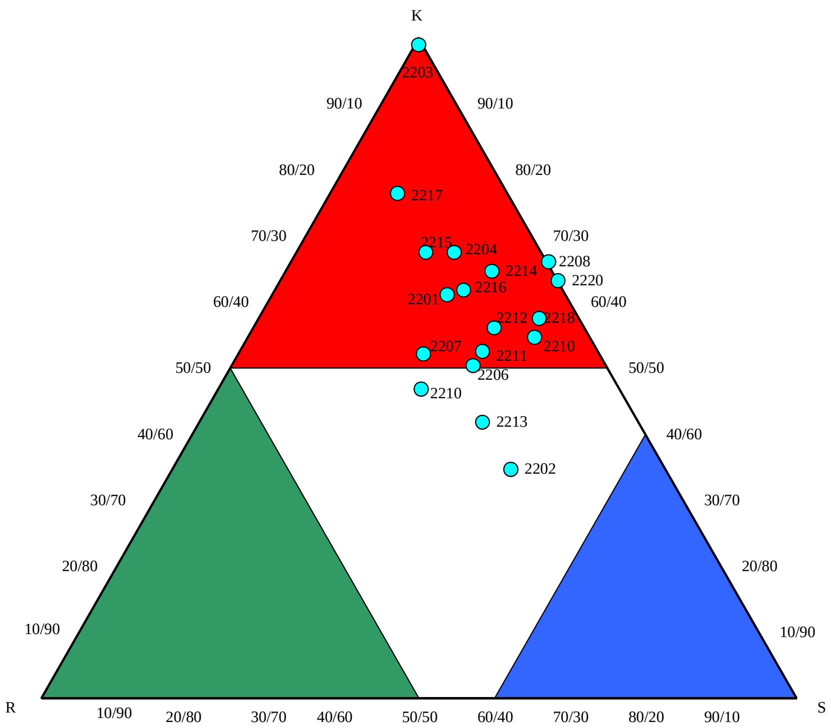


Figure 58. Malolo Island North

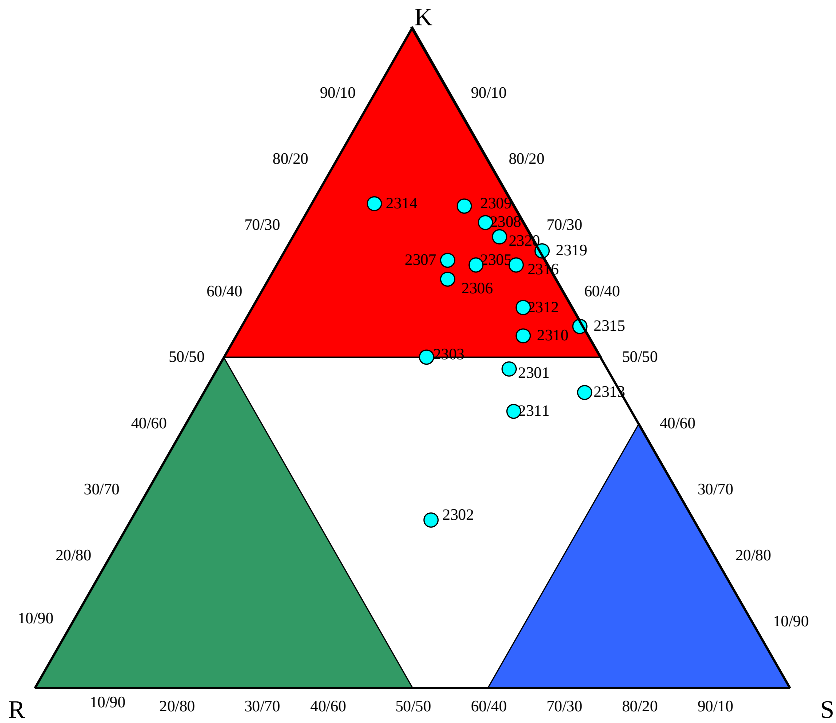


Figure 59. Malolo Island South

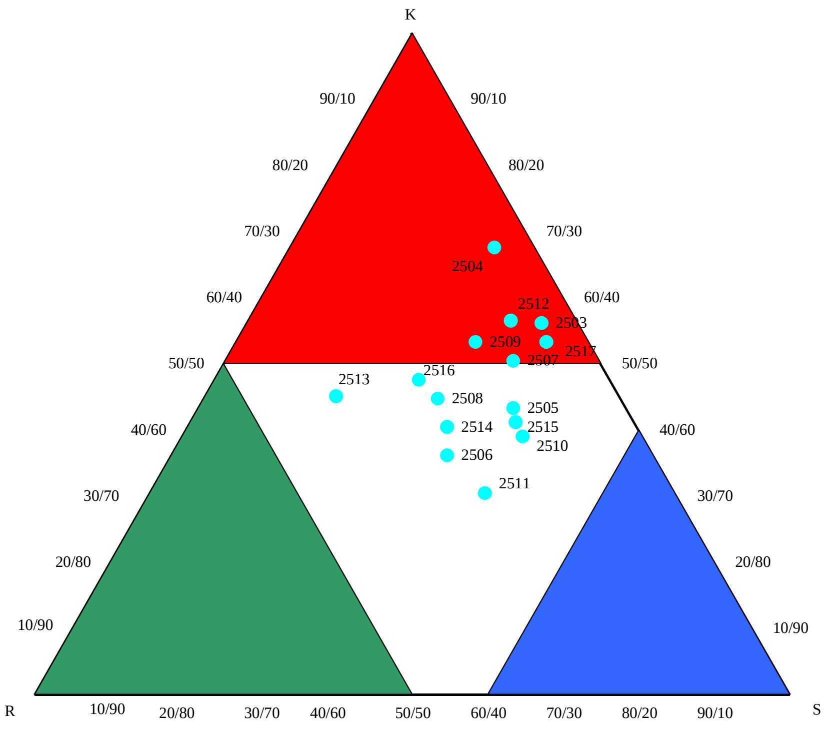


Figure 60. Malolo Lai Lai

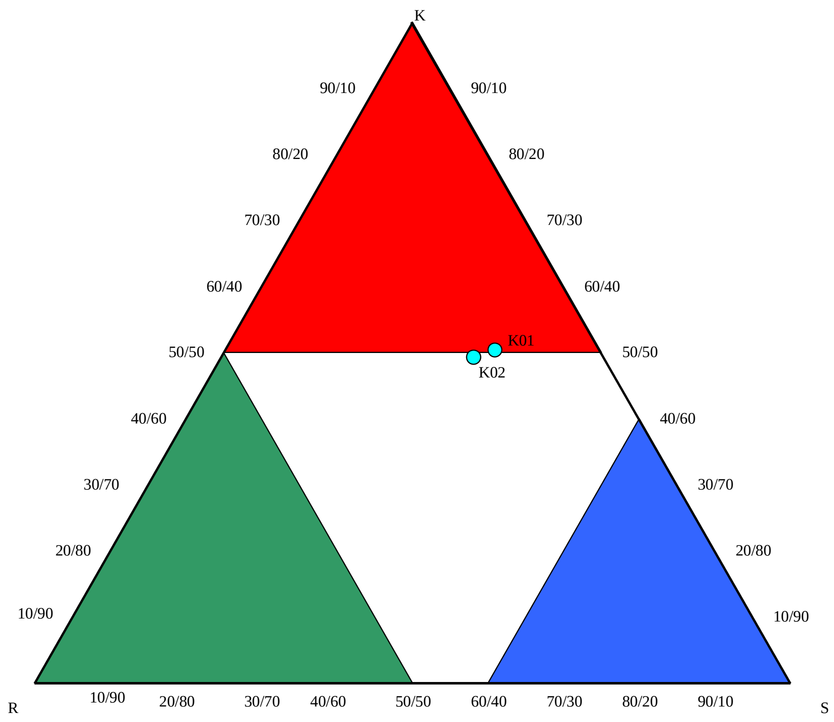


Figure 61. ‘K’s’ Patch Reef

Table 28. Summary of the conservation values (CV) of selected transects from the fourteen Survey Sectors surveyed in Year One of the FCRCP.

Sector Name	Sector Number	CV2		CV4	
		Number of Transects	% of Transects	Number of Transects	% of Transects
Mana North	2	1	9.1	10	**81.9**
Navini Island	6	2	100	0	0
Mothui Island	15	2	25	6	**75**
Yalodrivi	14	1	16.7	5	**83.3**
Castaway Barrier	16	7	41.2	10	**58.8**
Castaway Island	17	8	53.3	7	46.7
Wadigi Island	18	6	75	2	25
Wadigi Patch	19	4	57.1	3	42.9
Lana	20	4	66.7	2	33.3
Malolo North	22	15	83.3	3	16.7
Malolo South	23	13	76.5	4	23.5
Malolo Patch	24	5	38.5	8	**61.5**
Malolo Lailai	25	6	40	9	**60**
‘K’s’ Patch	(K)	1	50	1	50

The breakdown of transects into conservation values for each survey sector is shown by Table 28. For all sectors only conservation values 2 (moderate value) and 4 (high value) were recorded. CV2 indicates that the transect was dominated by foliose and non-Acropora branching corals whilst CV4 suggests a reef with a mixed, more diverse coral morphology. Sectors with the highest proportion of CV4 transects are highlighted in bold.

Of the reefs surveyed in the Castaway Complex, 62.8% exhibited a conservation value of 4. This analysis area was dominated by reef crest habitat with frequent coral cover. Highest overall coral morphology and species richness was found on Yalodrivi and Mana reef systems. Malolo Patch and Malolo Lailai also contained a greater proportion of CV4 than CV2 classified habitats on completed transects.

4.4 Reef Fish Populations

Fish population data collected during baseline surveys in the first year of the FCRCP have been analysed in a number of ways. The data is presented firstly in a general format showing the:

- Most abundant fish recorded in all survey areas
- Mean abundance of the commonest and commercially most valuable families of fish in each of the fourteen survey sectors

Kruskal-Wallis comparisons indicate whether the variation observed between survey sectors represent significant statistical differences.
One commonly observed feature of coral reef fish assemblages is the relationship between the benthic habitat and the fish population found associated with it. This has high importance for management. Habitats with close statistical relations with fish populations should be conserved as a matter of priority, whilst seemingly excellent candidates for protection as indicated by benthic cover; but do not have a high fish assemblage association, may not be as high priority for management initiatives.

4.4.1 Fish Family and selected species Abundance

The ten most abundant reef fish categories are depicted in Tables 29 and 30 in terms of mean abundance for all year one baseline surveys Damselfish (Pomacentridae) were the most abundant reef fish family within the surveys conducted over the first year of the project, followed by Wrasse (Labridae). A number of particular species of Pomacentrids were recorded most often (Table 30). The distribution of Gobies was largely centred on areas of sediment deposition, with many of the species recorded living in burrows in soft substrata, often in deeper water areas. The vast majority of Pomacanthids recorded on surveys were *Centropyge bicolor,* the bicolour angelfish, with a mean abundance of 0.42.

Table 29. Mean abundances of the most commonly observed fish families throughout all survey areas in year one of the FCRCP as recorded during baseline surveys. Mean abundances correspond to the semi quantitative 0-5 DAFOR scale.

Reef Fish Family		Mean Abundance
Damselfish	Pomacentridae	2.55
Wrasse	Labridae	1.09
Surgeonfish	Acanthuridae	0.83
Butterflyfish	Chaetodontidae	0.77
Goby	Gobiidae	0.53
Angelfish	Pomacanthidae	0.49

Table 30. Mean abundances of the most commonly observed Pomacentrids throughout all survey areas in year one of the FCRCP as recorded during baseline surveys. Mean abundances correspond to the semi quantitative 0-5 DAFOR scale.

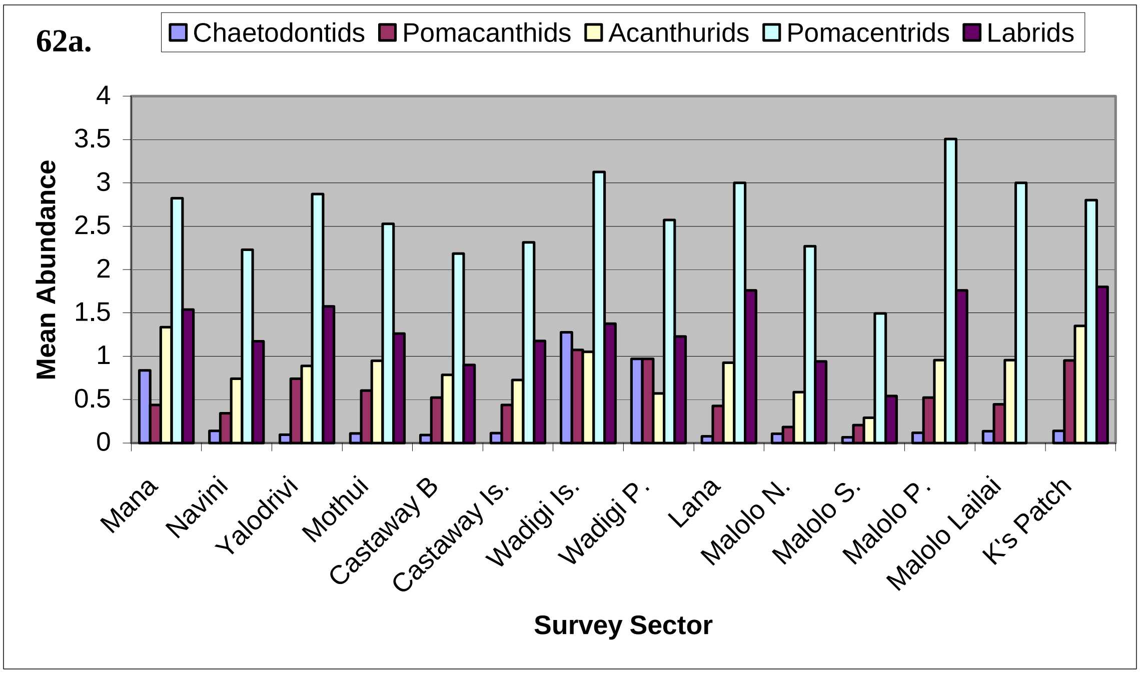
Pomacentrid	Mean Abundance
Humbug Dascyllus (*Dascyllus aruanus*)	0.80
Chromis spp.	0.62
Lemon Damselfish (*Pomacentrus moluccensis*)	0.39

The most notable point from Table 29 and Figure 62 is the general low relative abundance of many fish families recorded on baseline surveys. On the DAFOR scale only damselfish (Pomacentrids) were recorded as more than frequent sightings. Of these, three were recorded most often (Figure 30) with the Humbug Dascyllus the most common species seen. The highest abundance ratings for damselfish were recorded at Malolo Patch and Wadigi Island (Fig 62a.). Many of the families targeted by fishers, such as Triggerfish, Groupers or Snappers, were very rarely seen, with abundance ratings all less than 1 (Fig. 62b.). Highest ratings for Groupers were recorded at K's Patch and Navini Island. Lowest ratings for all presented families were found at Malolo South (Fig. 62a,b.).

Kruskal-Wallis analysis of mean abundance between survey sectors indicates that of the fish families, only Damselfish differ significantly in their abundance (Table 31). The highest abundance of this family was observed around Malolo Lailai, whilst the lowest was recorded around Ks patch. This corresponds closely with the coverage of hard corals and the abundance of bare hard substrata within these survey areas. Despite the lack of significance in all other fish populations, it should be remembered that the Kruskal-Wallis test is not a particularly powerful statistical test and that there may be more subtle differences that are not being displayed by this test. The overall low abundance of many families can also make statistical comparison difficult.

Table 31. Results of Kruskal-Wallis test comparing the abundance of major fish families between survey sectors. Degrees of freedom= 13 for all tests. Results shown in bold indicate significance.

Fish Family	Kruskal-Wallis statistic (H)	P-value (adjusted for ties)
Angelfish	10.7	0.63
Butterfly fish	12.6	0.48
Damselfish	97.3	**<0.01**
Goatfish	9.6	0.73
Groupers	16.0	0.25
Parrotfish	0.5	1.00
Rabbitfish	0.8	1.00
Snapper	2.5	1.00
Surgeonfish	7.2	0.89
Triggerfish	5.9	0.95



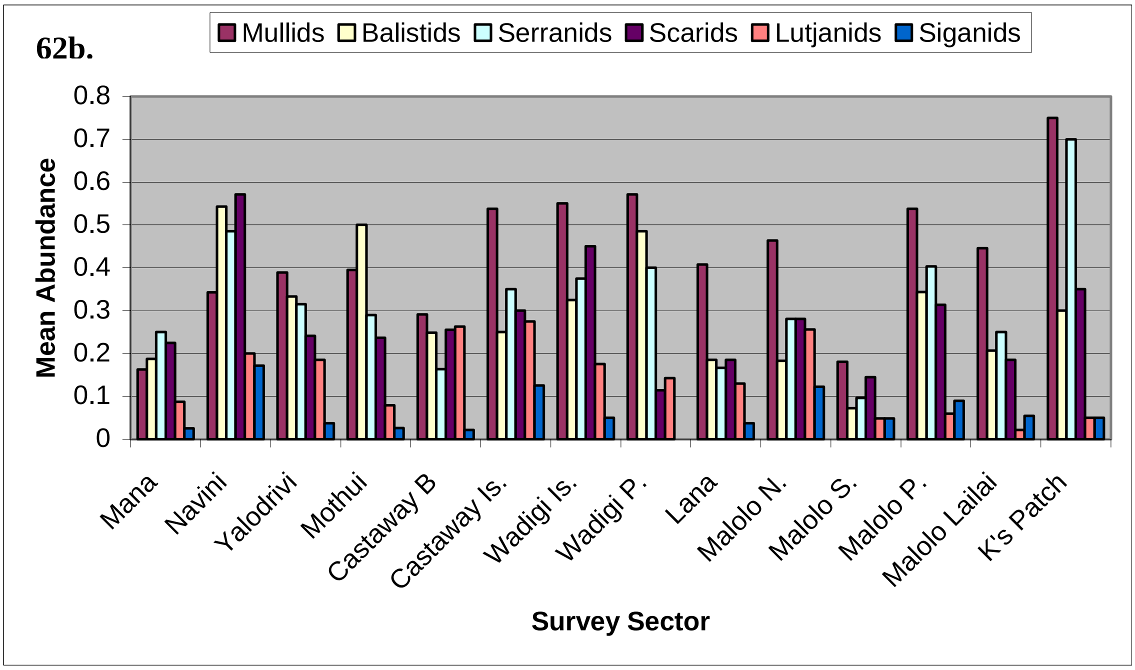


Figure 62. Mean abundance of commonly observed (62a.) or commercially important (62b.) fish families by Survey Sector. Mean abundance refers to the values recorded on the 0-5 DAFOR semi quantitative abundance scale.

4.4.2 Fish Assemblage Variation Between Analysis Sectors

Comparison between the fish assemblages found in the different analysis sectors indicates that there is highly significant difference overall (Global R0.6, p-value <0.01). More detailed analysis examining pairwise relationships between the fish assemblages found with each survey sector indicates that there is a significant difference between the assemblages found in all sectors.

4.4.3 Fish Assemblage Variation Between Habitats

ANOSIM analysis shows any significance in the fish assemblages found associated with different habitats. This is represented by the Global R and associated P-values in the following sections. More detailed pairwise analysis then indicates if there is a statistical difference in the fish assemblages found associated with each habitat individually. The results of this test are summarised in Tables 32 - in the following sections.

Castaway Reef Complex

ANOSIM analysis examining the overall difference in fish assemblage structure across all habitats defined within the Castaway reef complex analysis sector indicates that there is a highly significant difference in fish assemblages (Global R statistic= 0.30, P-value= <0.01).

The fish assemblages associated with habitats 6 and 7 are statistically different from the greatest number of assemblages found associated with other habitats. A comparison of biodiversity indices for the benthic classes in Castaway Reef Complex clearly shows that BC 7 (reef crest) is the richest habitat in terms of reef fish (Table 33). The number of fish species recorded in BC 7 was almost 1.8 times greater than the next richest habitat (BC 9).

Table 33. Univariate biodiversity indices calculated for fish assemblages associated with each habitat defined from data collected in the Castaway Reef Complex analysis area.

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	45	14.5	0.91	3.45
2	61	20.6	0.87	3.59
3	33	11.8	0.90	3.15
4	50	14.9	0.89	3.48
5	54	15.3	0.94	3.74
6	73	20.3	0.88	3.78
7	**145**	**44.3**	**0.82**	**4.07**
8	81	28.6	0.86	3.77
9	82	30.0	0.85	3.75
10	54	19.2	0.92	3.66
11	31	12.8	0.90	3.09
12	34	14.9	0.94	3.30
14	14	14.8	0.79	2.08
15	25	13.7	0.90	2.89

BC	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	0.4 **0.004***													
3	0.3, **0.01***	0.4, **0.002***												
4	0.3, **0.024***	0.3 **0.008***	0.2, **0.06**											
5	0.2 **0.2**	0.1 **0.2**	0.2, **0.095**	0.2 **014**										
6	0.6 **0.003***	0.3 **0.001***	0.7, **0.001***	0.4, **0.002***	0.3 **0.06**									
7	0.1, **0.16**	0.07, **0.20**	0.3, **0.03***	0.03, **0.38**	0.01, **0.41**	0.2, **0.99**								
8	0.2, **0.041***	0.2, **0.007***	0.1, **0.21**	0.07, **0.26**	0.2, **0.14**	0.08, **0.11**	0.1, **0.046***							
9	0.07, **0.29**	0.021, **0.59**	0.02, **0.43**	0.02, **0.54**	0.08, **0.64**	0.009, **0.41**	0.2, **0.001***	0.04, **0.098**						
10	0.2 **0.11**	0.2 **0.02***	0.1, **0.8**	0.1, **0.88**	0.02 **0.4**	0.4 **0.001***	0.1, **0.1**	0.02, **0.39**	0.03, **0.56**					
11	0.3 **0.04***	0.5 **0.001***	0.1, **0.8**	0.2, **0.048***	0.3 **0.08**	0.8 **0.001***	0.4, **0.001***	0.3, **0.006***	0.02, **0.53**	0.1 **0.30**				
12	0.02 **0.395**	0.2, **0.008***	0.2, **0.97**	0.0, **0.42**	0.2, **0.92**	0.5, **0.001***	0.5, **0.001***	0.4, **0.003***	0.2, **0.03***	0.02, **0.314**	0.04, **0.62**			
13	1.0 **0.02***	1.0 **0.002***	0.9, **0.012***	1.0, **0.012***	0.9 **0.03***	1.0 **0.001***	1.0, **0.001***	0.9, **0.001***	0.6 **0.004***	1.0 **0.006***	0.9 **0.012***	0.4, **0.018***		
14	0.5 **0.002***	0.6 **0.001***	0.5, **0.002***	0.5, **0.001***	0.3 **0.07**	0.7 **0.001***	0.9 **0.001***	0.8, **0.001***	0.5, **0.001***	0.5 **0.001***	0.4 **0.006***	0.4, **0.004***	0.3 **1.0**	
15	0.2 **0.072**	0.43 **0.001***	0.1, **0.17**	0.2, **0.058**	0.02 **0.5**	0.6 **0.001***	0.7, **0.001***	0.6, **0.001***	0.2, **0.014***	0.2 **0.028***	0.1 **0.7**	0.03 **0.262**	0.02 **0.4**	0.2 **0.031***

Table 32 Results of pairwise analysis on the fish assemblages found associated with each habitat defined within the Castaway Reef complex. Number in normal font represents R-statistic; figure in bold represents P-value. P-values marked with an asterisk indicate significant results.

Malolo Island

ANOSIM analysis examining the overall difference in fish assemblage structure across all habitats defined within the Malolo Island analysis sector indicates that there is a highly significant difference in fish assemblages between habitats (Table 34). The reef fish assemblage recorded in BC 5 (shallow back reef) and BC 7 (upper reef slope) were significantly different to all other habitat's fish assemblages.
In terms of biodiversity, habitats 5, 6 and 7 were comprised of the most diverse reef fish assemblages, whilst BC 3 was also notable (Table 35).

Table 34. Results of pairwise analysis on the fish assemblages found associated with each habitat defined within the Malolo Island analysis area. Number in normal font represents R-statistic; figure in bold represents P-value. P-values marked with an asterisk indicate significant results.

BC	1	2	3	4	5	6	7	8	9	10
2	0.4 **0.019***									
3	0.2 **0.03***	0.2 **0.001***								
4	0.2 **0.04***	0.3 **0.019***	0.1 **0.180**							
5	0.3 **0.02***	0.6 **0.003***	0.4 **0.001***	0.7 **0.001***						
6	0.2 **0.03***	0.0 **0.406**	0.2 **0.001***	0.3 **0.04***	0.1 **0.003***					
7	0.2 **0.02***	0.6 **0.001***	0.3 **0.001***	0.6 **0.001***	0.2 **0.001***	0.2 **0.001***				
8	0.2 **0.004***	0.1 **0.182**	0.3 **0.001***	0.1 **0.13**	0.6 **0.001***	0.1 **0.19**	0.6 **0.001***			
9	0.1 **0.17**	0.1 **0.193**	0.13 **0.001***	0.1 **0.7**	0.4 **0.001***	0.3 **0.001***	0.4 **0.001***	0.3 **0.006***		
10	0.8 **0.001***	0.9 **0.002***	0.8 **0.001***	0.3 **0.04***	1.0 **0.001***	0.9 **0.001***	1.0 **0.001***	0.7 **0.001***	0.4 **0.01***	
11	0.3 **0.003***	0.4 **0.001***	0.4 **0.001***	0.1 **0.298**	0.6 **0.001***	0.6 **0.001***	0.6 **0.001***	0.4 **0.001***	0.1 **0.002***	0.0 **0.514**

Table 35. Univariate biodiversity measures calculated for fish assemblages associated with each habitat defined from data collected in the Malolo Island analysis area.

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	53	16.5	0.86	3.41
2	31	11.4	0.88	3.02
3	71	24.7	0.87	3.69
4	33	12.8	0.92	3.20
5	**87**	**25.2**	**0.84**	**3.74**
6	**89**	**29.2**	**0.86**	**3.85**
7	**87**	**24.7**	**0.84**	**3.75**
8	52	18.2	0.91	3.58
9	59	24.0	0.84	3.43
10	4	3.8	0.81	1.12
11	47	28.1	0.79	3.03

Malolo Lailai Island

ANOSIM analysis examining the overall difference in fish assemblage structure across all habitats defined within the Malolo Lailai Island analysis sector indicates that there is a highly significant difference in fish assemblages between habitats (Table 36). The assemblages recorded in habitats 1, 2 and 3 produced the most number of significant differences (6) when compared to all other habitats. Five significant differences were found for habitats 7 and 8. The latter two habitats, along with BC 3, were the most diverse reef fish assemblages recorded at this site (Table 37).

Table 36. Results of pairwise analysis on the fish assemblages found associated with each habitat defined within the Malolo Lailai analysis area. Number in normal font represents R-statistic; figure in bold represents P-value. P-values marked with an asterisk indicate significant results.

BC	1	2	3	4	5	6	7	8	9
2	0.1 **0.73**								
3	0.8 **0.001***	0.8 **0.001***							
4	0.1 **0.50**	0.5 **0.06**	0.4 **0.10**						
5	0.7 **0.001***	0.6 **0.001***	0.3 **0.03***	0.3 **0.20**					
6	0.5 **0.01***	0.6 **0.01***	0.2 **0.13**	0.01 **0.43**	0.1 **0.12**				
7	0.02 **0.33**	0.1 **0.23**	0.8 **0.003***	0.1 **0.50**	0.7 **0.05**	0.7 **0.02***			
8	0.8 **0.001***	0.6 **0.002***	0.3 **0.001***	0.3 **0.1**	0.04 **0.67**	0.02 **0.55**	0.6 **0.01***		
9	1.0 **0.001***	0.9 **0.001***	0.14 **0.09**	0.4 **0.05**	0.2 **0.03***	0.2 **0.14**	0.9 **0.01***	0.3 **0.01***	
10	0.6 **0.001***	0.4 **0.004***	0.3 **0.01***	0.2 **0.17**	0.1 **0.77**	0.1 **0.30**	0.4 **0.02***	0.1 **0.80**	0.3 **0.01***

Table 37. Univariate biodiversity measures calculated for fish assemblages associated with each habitat defined from data collected in the Malolo Lailai analysis area.

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J’)	Log_e Shannon-Weiner (H’)
1	10	7.9	0.86	1.97
2	8	5.0	0.89	1.84
3	**67**	**19.6**	**0.90**	**3.77**
4	38	13.1	0.88	3.19
5	45	13.5	0.91	3.45
6	6	3.6	0.91	1.63
7	**60**	**20.0**	**0.89**	**3.63**
8	**82**	**24.0**	**0.84**	**3.70**
9	42	14.0	0.91	3.40

Mana Island

As for the previous analysis areas, ANOSIM analysis examining the overall difference in fish assemblage structure across all habitats defined within the Mana Island analysis area indicates that there is a highly significant difference in fish assemblages between habitats (Table 38). BC 1 proved to be the least similar to all other defined habitats in terms of reef fish recorded and was the least diverse habitat present for fish assemblages (Table 39). Conversely, the most diverse habitats in terms of reef fish were BC 6, followed by BC 4.

Table 38. Results of pairwise analysis on the fish assemblages found associated with each habitat defined within the Mana Island analysis area. Number in normal font represents R-statistic; figure in bold represents P-value. P-values marked with an asterisk indicate significant results.

BC	**1**	**2**	**3**	**4**	**5**	**6**
2	0.6 **0.003***					
3	0.5 **0.002***	0.7 **0.01***				
4	0.8 **0.001***	0.8 **0.001***	0.2 **0.06**			
5	0.5 **0.02***	0.3 **0.14**	0.6 **0.01***	0.7 **0.001***		
6	0.4 **0.001***	0.3 **0.04***	0.06 **0.30**	0.2 **0.001***	0.05 **0.32**	
7	0.3 **0.03***	0.4 **0.06***	0.4 **0.02***	0.6 **0.001***	0.4 **0.09**	0.03 **0.39**

Table 39. Univariate biodiversity measures calculated for fish assemblages associated with each habitat defined from data collected in the Mana Island analysis area.

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	23	11.0	0.87	2.72
2	31	11.1	0.90	3.10
3	34	11.3	0.85	3.00
4	**65**	**20.1**	**0.81**	**3.40**
5	34	10.7	0.93	3.28
6	**96**	**31.7**	**0.83**	**3.80**
7	25	9.3	0.86	2.76

Navini Island

As for the previous analysis areas, ANOSIM analysis examining the overall difference in fish assemblage structure across all habitats defined within the Navini Island analysis area indicates that there is a highly significant difference in fish assemblages between habitats (Table 40).

Of the four habitats defined, the reef fish assemblage in BC 3 (upper reef slope) was the only one that was significantly different to all three other habitats at Navini and also proved to be the most diverse (Table 41).

Table 40. Results of pairwise analysis on the fish assemblages found associated with each habitat defined within the Navini Island analysis area. Number in normal font represents R-statistic; figure in bold represents P-value. P-values marked with an asterisk indicate significant results.

BC	**1**	**2**	**3**
2	0.1 **0.083**		
3	0.4 **0.001***	0.6 **0.001***	
4	0.5 **0.004***	0.3 **0.07**	0.9 **0.001***

Table 41. Univariate biodiversity measures calculated for fish assemblages associated with each habitat defined from data collected in the Navini Island analysis area.

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	47	15.2	0.90	3.48
2	37	15.0	0.89	3.21
3	**84**	**23.3**	**0.91**	**4.05**
4	9	5.5	0.92	2.02

Wadigi Reef Complex

As for the other analysis areas, ANOSIM analysis examining the overall difference in fish assemblage structure across all habitats defined within the Wadigi Reef Complex area indicates that there is a highly significant difference in fish assemblages between habitats (Table 42). The reef fish assemblage in BC 3 (upper reef slope) was the only one that was significantly different to all four other habitats at Navini and also proved to be the most diverse (Table 43). Reef fish diversity was nearly three times higher in BC 3 than the second most diverse habitat (BC 4).

Table 42. Results of pairwise analysis on the fish assemblages found associated with each habitat defined within the Wadigi reef complex analysis area. Number in normal font represents R-statistic; figure in bold represents P-value. P-values marked with an asterisk indicate significant results.

BC	**1**	**2**	**3**	**4**
2	0.2 **0.05**			
3	0.8 **0.001***	0.5 **0.001***		
4	0.5 **0.002***	0.1 **0.09**	0.3 **0.01***	
5	0.4 **0.03***	0.2 **0.18**	0.5 **0.01***	0.4 **0.08**

Table 43. Univariate biodiversity measures calculated for fish assemblages associated with each habitat defined from data collected in the Wadigi Reef Complex analysis area.

Benthic Class	Number of Species (N)	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	8	4.2	0.91	1.88
2	23	10.4	0.89	2.78
3	**111**	**33.2**	**0.84**	**3.96**
4	38	14.4	0.85	3.09
5	12	4.7	0.96	2.38

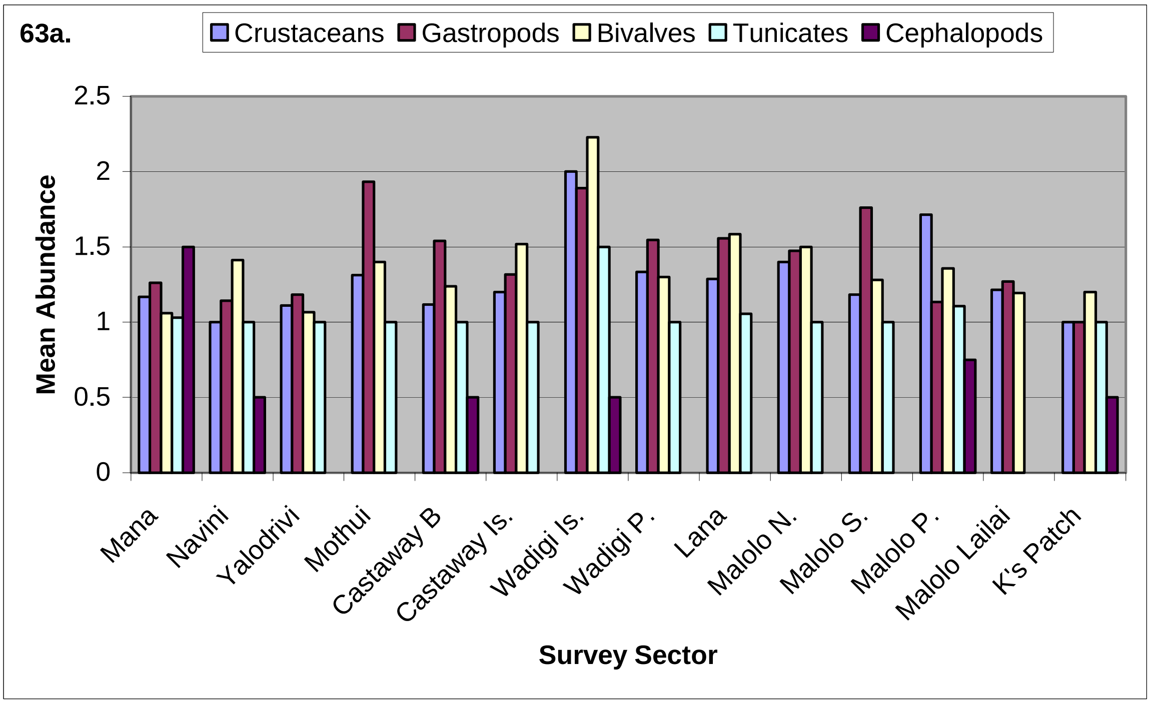
4.5 Invertebrate Populations

The mean abundance ratings for the ten most commonly observed invertebrate taxa over the first year of the project for all survey sectors combined are depicted in Table 44. All ratings were below a value of 1, equivalent to rare on the DAFOR scale. Echinoderms were the more abundant invertebrates observed on survey dives, particularly Feather Stars, the blue seastar *Linckia laevigata* and non-synaptid Holothurians. Very few giant clams and Crown-of-Thorns seastars were recorded.

Table 44. Mean abundances of the ten most commonly observed invertebrate groups recorded throughout all survey areas in year one of the FCRCP during baseline surveys. Mean abundances correspond to the semi quantitative 0-5 DAFOR scale.

Invertebrate Group	Mean abundance
Feather stars (Crinoids)	0.89
Blue seastar (*Linckia laevigata*)	0.87
Non-Synaptid sea cucumber	0.63
Diadema spp. sea urchin	0.40
Giant Clam	0.24
Short spine sea urchins	0.22
Crown of Thorns seastar (*Acanthaster planci*)	0.19
Shrimps	0.19
Oysters	0.18
Synaptid sea cucumbers	0.15

When the individual results of each sector are scrutinised for the major invertebrate groups (Figure 63a,b) then the two most often recorded Echinoderm taxa (Fig. 63b.) are sea urchins (Echinoidea) and sea stars (Asteroidea). Again all abundance ratings, apart from sea stars, were rather low generally falling below 2 (occasional) on the DAFOR scale and many taxa were observed very rarely. The highest abundance ratings were recorded at K's Patch and Wadigi Island for sea stars. The former survey sector also produced the highest ratings for other invertebrate groups, namely Bivalves Tunicates and Crustaceans (Fig. 63a.). Highest numbers of Cephalopods were seen at Mana.



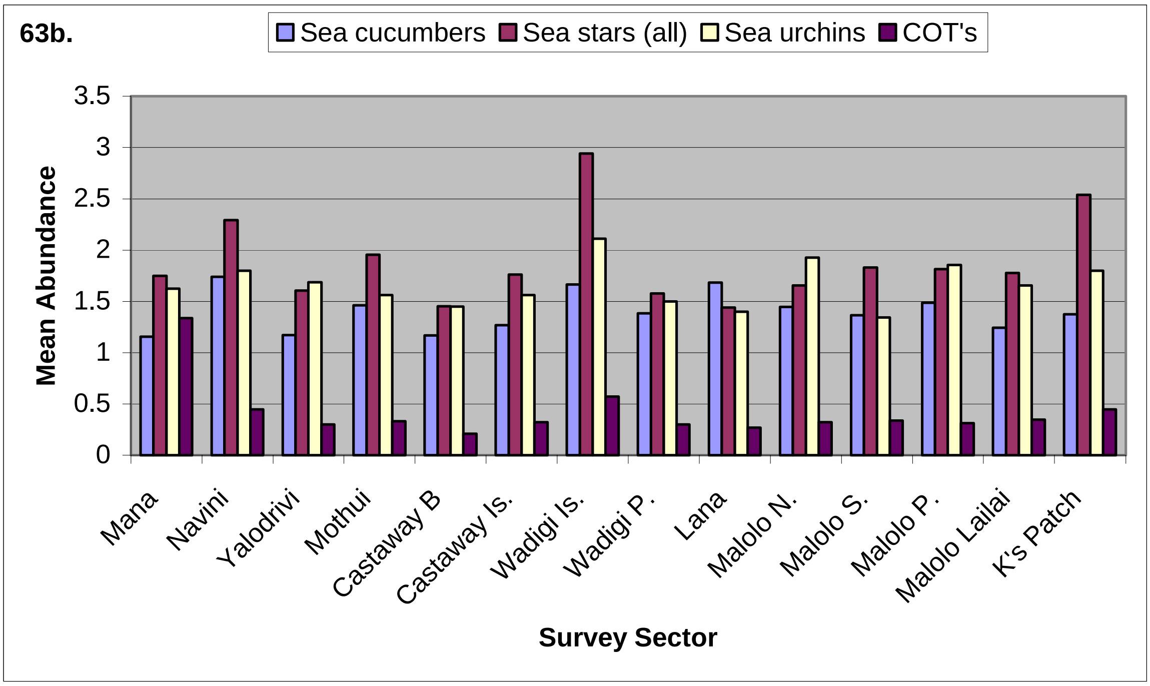


Figure 63. Mean abundance ratings for the major invertebrate groups (63a.) and Echinoderms (63b.) recorded on baseline surveys for each survey sector. Mean abundance refers to the values recorded on the 0-5 DAFOR semi quantitative abundance scale.

Statistical comparison of mean abundance ratings between survey sectors for invertebrate groups indicates that only seastar abundance was significantly different between sectors (Table 45).

Table 45. Results of Kruskal-Wallis test comparing the abundance of major invertebrate taxa between survey sectors. Degrees of freedom= 13 for all tests. Results shown in bold indicate significance.

Invertebrate Group	Kruskal-Wallis statistic (H)	P-value (adjusted for ties)
Bivalves	9.0	0.77
Cephalopods	0.6	0.99
Crustaceans	1.5	1.00
Sea Cucumbers	12.3	0.51
Urchins	5.1	0.97
Seastars	32.0	**<0.01**
Gastropods	5.0	0.98

4.6 Megafauna

A wide range of megafauna were recorded over the first year of the FCRCP (Table 46). Reef sharks, barracuda and spinner dolphins were observed most often. A full breakdown of the location and time of sighting by month is provided in Appendix 3.

Megafauna	**Number of Sightings April 2002- April 2003**
Black Tip Reef Shark	37
Nurse shark	1
White Tip Reef Shark	52
Grey Reef Shark	26
Leopard Shark	3
Eagle Ray	13
Blue spotted ribbon tail ray	4
Sting ray	12
Turtles (general)	8
Green Turtle	2
Hawksbill Turtle	2
Olive Ridley Turtle	1
Spinner Dolphins	138
Humpback whale	1
Giant Trevally	4
Humphead Wrasse	3
Barracuda	>100
Bumphead Parrotfish	2

Table 46. Summary of the number of Megafaunal sightings over Year 1 of the FCRCP.

5. DISCUSSION

5.1 Training

The training programme used during the first year of the FCRCP 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 office

5.2 Oceanography and anthropogenic impacts

The coral reefs of the Mamanucas are subject to a wide and varied source of both anthropogenic and natural impacts. Some of these impacts occur at a local scale and include direct impacts such as coral trampling or anchor damage. In contrast, others are at a much wider and arguably uncontrollable scale. Perhaps the best example of the latter type of impact is the occurrence of coral bleaching which affected the Mamanuca Islands in 2000-2001. Whilst the causes of bleaching are slowly becoming understood, treating the likely cause, global warming, using localised management of reef resources is not practical. Bleaching does however present a good example of what can be done at the local scale. There is increasing evidence to suggest that proper management of reef resources and the mitigation of synergistic anthropogenic impacts can firstly reduce the scale and severity of bleaching events as well as aiding the rapid and thorough recovery of coral reefs following such an event (Westmacott *et al.*, 2000).

The data on vertical visibility as recorded during year one of the FCRCP combined with the river discharge data obtained from the Public Works department, Nadi highlights one of the major impacts on the reefs of the Mamanucas. This data provides back up to the observation made in the Pilot Phase report for the MCRCP that there is evidence of significant turbidity around the Mamanuca Islands.
Malolo Lailai, situated closest to the mainland of all the areas surveyed in year one of the FCRCP displays some classic signs of sedimentation. All the high coral cover benthic classes identified have *Porites* massive as one of their most dominant corals comprising the assemblage of corals found. Massive *Porites* has a series of physiological mechanisms that enables it to tolerate a high sediment environment. These include the production of mucus by its polyps, which is subsequently sloughed from the colony. This process removes any sediment that has settled on the colony. If left to settle the sediment would act to reduce the efficiency of suspension feeding as well as the beneficial effects of the photosynthetic symbiosis the colony relies on for much of its metabolic energy requirement. In addition to the composition of the coral community, it is interesting to note that within the Malolo Lailai analysis area, mud contributes the greatest abundance to substrate cover in seven of nine habitats identified by multivariate analysis.

Coastal zone development and conversion of natural landscapes is widely acknowledged as one of the major threats acting on coral reefs adjacent to inhabited coastlines. Whilst it should be expected that there would be an increase in turbidity after a period of rainfall on mainland Viti Levu, the graph outlined in this report indicates a very strong correlation between peak river discharge and decreased vertical visibility in the water column. Indeed, using the graph, a four-day time delay can clearly be observed between peak river discharge and lowered secchi disc readings. With the decline of the sugar cane industry on mainland Fiji, many fields that were previously covered in lush vegetation now lie fallow. Tropical rainfall subsequently acts to wash the overlying soil into gullies and eventually rivers like the Nadi River. In addition, coastal zone development combined with the rerouting of rivers and their embayment in concrete negates the sediment filtering action of riparian mangrove systems, thereby exacerbating the problem of nearshore sedimentation. Whilst this effect in the Mamanucas Islands is difficult, if not impossible to quantify, the strong evidence produced in this report indicates the need for further investigation. One possible research activity that could be undertaken is the examination of the origin of sediments found on the reef structures. If the sediments prove to be terrestrial in origin, then one of the key management actions that would need to be taken would be to reduce the level of sediment input from the mainland. Sedimentation rates could also be measured using submerged sediment traps. Comparison of sedimentation rates in the Mamanucas to data from other 'undisturbed' regions with similar catchment areas but may indicate whether the rates occurring in the Mamanucas exceed the expected natural rates after periods of heavy rainfall.

The most abundantly observed surface impact recorded during year one of the FCRCP was the presence of large mats of floating macroalgae, most commonly of the *Sargassum sp.* and *Graciliaria sp.* genera. Whilst the presence of these features is not uncommon and their occurrence is driven largely by surface current patterns, the high levels found in the Mamanucas may indicate the presence of an excess level of nitrogenous and phosphorus nutrients in the water column. Working on the Coral Coast in Viti Levu, Mosley and Aalbersberg (2002) showed that the presence of abundant populations of both these genera is closely linked with the elevated levels of nutrients at sites close to population centres and resort complexes. An increase on inshore nutrient levels combined with a decrease in herbivory through overfishing of herbivores can enable large stands of macroalgae to become established, particularly on shallow reef flats.

Litter is a conspicuous source of pollution in the marine environment. In addition to the aesthetic degradation it causes, there are known direct impacts such as the shading of benthic communities and the release of toxins during its bacterial mediated breakdown. Data presented in this report shows that the occurrence of litter pollution is concentrated around population centres such as local villages and the transient populations of resort destinations. Mitigation of this impact is most easily achieved through the environmental education practises. Community workshops conducted by CCC during year one of the FCRCP have significantly contributed to this process.

Generic coral damage and litter were the most observed underwater impact especially within the Castaway and Malolo analysis areas. Although many of the indices used to assess impacts to the reef are general and qualitative, they do provide a gross impression of damage. What the factors used cannot demonstrate is the nature of some of the origins of damage. The high incidence of coral damage at Malolo for example cannot be attributed just to anthropogenic impacts, but instead is likely to arise as a combination of anthropogenic and natural disturbance such as storm damage. Overall, the factors presented indicate that there is moderate damage overall in the areas surveyed, but that these impacts are highly localised in nature. Again, it is interesting to note that all of the high occurrences of these impacts can be found around population centres; be they resorts or indigenous populations.

Of the analysis areas investigated for surface and subsurface impacts, Navini has the overall lowest occurrence of both. This is reflected by the impression of CCC dive teams, who ranked Navini as having the highest aesthetic and biological value of all analysis areas. Whilst in its self this method of assessment of reef health is highly subjective in nature and does not account for morphological variations in reef structure, it does provide a valuable source of information.

Despite elevated sea surface temperatures recorded across the survey areas, no noticeable increase in the incidence of bleaching was observed as an underwater impact. More details on the recovery of the reefs of the Mamanuca Islands following the 2000-2001 bleaching event can be found in a previously released CCC report (Walker *et al*., 2002)

5.3 Benthic Data

The total number of benthic classes found in the baseline data recorded during year one of the FCRCP can be summarised by analysis area (Table 47)

Table 47. Number of Benthic Classes defined for each Analysis Area of Survey Sectors.

Analysis Area	Number of Benthic Classes
Castaway Reef Complex	15
Malolo	11
Malolo Lailai	9
Mana	7
Navini	4
Wadigi Reef Complex	5

Analysing the data by analysis area, as undertaken in this report, allows a much more detailed comparison of the benthic classes in all areas. One inevitable result of the use of the semi quantitative scale is the occurrence of 'noise' in the data set associated with observer bias. The use of discreet analysis sectors minimises this noise, allowing true benthic classes to be more accurately identified.

The results reported in the pilot phase project report do not include those shallow reef crest and backreef areas that cannot be surveyed by SCUBA diving. The data set in this case is more complete because it takes account of all areas regardless of depth. With the quantity and thorough spatial coverage of the data presented, it is likely that all benthic classes have been classified.

The Castaway Reef Complex analysis area has the highest number of discreet habitat classes as defined with multivariate analysis. One of the most likely explanations for this is the difference in reef morphology of the areas surveyed. Unlike, for example, Navini where only homogenous fringing reef was surveyed, the reef complex around Castaway included the fringing reefs of Castaway and Mothui Islands. It also incorporates the patch reefs of the inner barrier systems, which in themselves display a large degree of morphological variation in response to prevalent environmental conditions. These range from the sheltered patch reef of K's patch to the moderately wave and current exposed sites of the outer face of Castaway Barrier.

The habitats with the greatest diversity and coral cover seen throughout the analysis areas were the upper reef slope and reef crest areas. Coral growth and morphological variation in these areas is highest because of the advantageous prevalent environmental conditions found associated with the shallow water depths of these sites. All of the reef crest habitats defined have greater mean abundances of individual life forms of hard corals when compared to those results reported in the pilot phase report. The highest single coral life form observed had a median abundance of 3.0 on the DAFOR semi-quantitative abundance scale. This result was recorded in the Mana Island analysis area within Benthic Class 5. Possible causes of the increase in abundance of coral cover observed could be either as a result of the sample strategy or could represent a natural trend. During the pilot phase, the number of surveys conducted was much lower. Combined with the multivariate 'noise' described earlier, only seven benthic classes could be drawn from the data set and all were relatively coral poor, with no coral life form recorded with an abundance greater than 1.8. The more thorough examination of the reefs conducted thus far may have led to the discovery of more coral rich areas.

The second explanation is that there has been an overall increasing trend in coral cover between the pilot phase and the first year of the FCRCP. This may be as a result of the recovery of the reefs since the 2000-2001 bleaching event when coral die back was observed in the area.

Table 48. Summary statistics of the Benthic Classes with highest potential management value selected from each analysis sector. Where two benthic classes are selected per analysis sector, then the corresponding data is contained within thick horizontal lines. Benthic Class, hard coral cover, cover of most abundant coral life form, and Shannon-Weiner diversity indices for benthic organisms and fish are shown for all records in each benthic class within the analysis area. % of transects in each benthic class and % of transects with Conservation Class 2 or 4 are shown per survey sector within each analysis sector. Average hard coral and life form abundance given to one decimal place, Shannon-Weiner diversity Indices given to two decimal places

Analysis area/ survey area (survey number)	Benthic Class	Mean Hard Coral cover	Mean cover of most abundant hard coral lifeform	Shannon-Weiner Diversity of Benthic Organisms	Shannon-Weiner Diversity of Fish	% of transects in survey area in Benthic Class	% of transects with Conservation Class 2 or (4)
Castaway Reef Complex	6	2.6	Non-Acropora submassive- 1.6	4.34	3.78		
Yalodrivi (14) Mothui (15) Castaway Barrier (16) Castaway Island (18) Ks Patch (K)						0 0 0 20 0	17 (83) 25 (75) 41 (59) 53 (47) 50 (50)
Castaway Reef Complex	7	2.6	Acropora branching- 2.0	4.48	4.07		
Yalodrivi (14) Mothui (15) Inner Barrier (16) Castaway Island (18) Ks Patch (K)						78 83 49 16 72	17 (83) 25 (75) 41 (59) 53 (47) 50 (50)
Malolo	5	3.2	Acropora branching- 2.0	4.28	3.74		
Malolo North (22) Malolo South (23) Malolo Patch (24)						1 0 28	83 (17) 76 (24) 38 (62)
Malolo	6	3.0	Non-Acropora branching-2.0	4.38	3.85		
Malolo North (22) Malolo South (23) Malolo Patch (24)						22 10 3	83 (17) 76 (24) 38 (62)
Malolo Lailai	3	3.1	Acropora branching- 2.5	4.16	3.77		
Malolo Lailai (25)						12	40 (60)

Analysis area/ survey area (survey number)	Benthic Class	Mean Hard Coral cover	Mean cover of most abundant hard coral lifeform	Shannon-Weiner Diversity of Benthic Organisms	Shannon-Weiner Diversity of Fish	% of transects in survey area in benthic class	% of transects with Conservation Class 2 or (4)
Mana	5	4.4	Non-Acropora encrusting- 3.0	4.31	3.28		
Mana (02)						8	9 (82)
Navini	3	3.6	Acropora branching- 2.3	4.52	4.05		
Navini (06)						51	100 (0)
Wadigi Reef Complex	3	2.6	Non-Acropora massive- 1.6	4.41	3.96		
Wadigi Island (18) Wadigi Patch Reef (19) Lana (20)						53 82 61	75 (25) 57 (43) 67 (33)

Table 48 (Continued). Summary statistics of the benthic classes with highest potential management value selected from each analysis sector. Where two benthic classes are selected per analysis sector, then the corresponding data is contained within thick horizontal lines. Benthic class, hard coral cover, cover of most abundant coral life form, and Shannon-Weiner diversity indices for benthic organisms and fish are shown for all records in each benthic class within the analysis area. % of transects in each benthic class and % of transects with Conservation Class 2 or 4 are shown per survey sector within each analysis sector. Average hard coral and life form abundance given to one decimal place, Shannon-Weiner diversity Indices given to two decimal places

5.4 Management Findings

The data collected during year one of the FCRCP is spatial data. It corresponds to spatially discreet survey areas. The analysis conducted in this report has examined the relative management value of discreet survey areas, with the aim to outline areas that should be recommended as candidate sites for designation as Marine Protected Areas.

The culmination of this analysis is given in Table 48. Extracted from each analysis area is the benthic class with highest potential management value. Given for each benthic class is a range of univariate statistics that summarise their management potential. None of the statistics given are, in themselves totally conclusive. Management is not solely about hard coral cover or reef fish diversity. Instead, for management to be successful and to achieve the goals it sets out to satisfy, it must be a holistic approach that takes into account a range of these statistics. Accordingly, the areas outlined in the following section take into account all of the factors outlined.

Benthic class 5 identified within the Mana analysis area has the highest single value for abundance of hard coral cover as well as the highest single abundance for coral life form; Non-Acropora encrusting with an abundance of 3.0. It has the second highest % of transects whose corals found between 5-12 meters (generally accepted as the most productive area of reef) have a conservation class of 4 (82%). However, in terms of its overall diversity as measured by the Shannon-Weiner diversity of both benthic organisms and fish, it does not have the most diverse community associated with it. In fact, its benthic organisms have only the 6th highest from a total of 8 benthic classes identified as having a potential high conservation value; the fish have the lowest of all diversities of the benthic classes outlined.

This low diversity could be as a result of a number of variables. Low coral diversity can often be found in areas that are exposed to frequent and catastrophic physical damage by storms and waves. The escarpment on which this benthic class was found faces directly to the prevailing wind direction, making this an exposed site. This may explain the low diversity but high coral cover observed. The second possible explanation for the low diversity indices can be explained by the small sample size in which this habitat has been observed. If more of this habitat were encountered and the close link between coral cover and benthic and fish diversity found in all other sectors were to remain true, then the diversity values calculated for this benthic class are likely to be greater than those recorded. The low fish diversity in comparison to the high hard coral cover may be as a result of fishing pressure from the residents of the village of Yarolevu on Mana Island.

Benthic class 5 was however found covering only 8% of the area surveyed within the Mana Island survey sector (02). These results would indicate that this benthic class is extremely rich in hard coral cover. The high conservation value of the corals found here, together with the heterogeneous distribution of this habitat, indicates that the south east corner of the reef surrounding Mana Island should be recommended as the first area for the establishment of a Marine Protected Area. Patchy valuable habitat areas such as those found in this area enable it to act as a source of larvae that, in turn, can repopulate some of the surrounding degraded habitats.

Two benthic classes have been identified within the Castaway analysis sector as having high potential management value – BC 6 and BC 7. Though mean abundance of hard coral cover between these benthic classes is identical, the Shannon-Weiner diversity indices of both benthic organisms and fish found associated with BC 7 is much higher; 4.48 and 4.07 respectively. This high value makes BC 7 the second most diverse benthic class in terms of benthic organisms and most diverse class in terms of fish populations. It is therefore recommended that, of these two benthic classes, areas characterised by BC 7 be given a higher management importance.

Amongst the survey sectors within Castaway analysis area, Mothui and Yalodrivi have the highest amount of area surveyed that falls into this benthic class (83 and 78% respectively). Within all areas surveyed, Mothui has the highest proportion of their transect sections between 5 and 12 meters classified as having a conservation value of 4 (83%), with Yalodrivi having the third highest proportion of its transects with a conservation class of 4 (75%). Both Mothui and Yalodrivi are therefore recommended as potential sites for the establishment of MPAs.

A total of 52 fishing vessels were observed across the analysis area during the first year of the FCRCP. The majority of the fishing pressure is localised along the Castaway Inner Barrier System, with the fishing pressure at Mothui and Yalodrivi minimal if any. Boat activity is however dominated by pleasure and diving traffic, accounting for 136 of the recorded 260 boats. The benefits to both Yalodrivi and Mothui from the establishment of these areas as MPAs would therefore be to mitigate against the potential impacts caused by recreational users of the resource. Mitigation in this way would require a more complex management system than a simple no-take zone, but would instead have to be based on a use restricted use zoning scheme.

Within the Malolo analysis sector, two benthic classes stand out as having high conservation value- 5 and 6. Benthic class 5 has slightly higher average abundance of live coral cover (3.2 and 3.0 respectively). Comparison of the Shannon-Weiner diversity indices associated with the benthic communities and fish assemblages found associated with each of these benthic classes indicates that there is little difference in terms of overall diversity (4.28, 4.38 and 3.74 and 3.85 for benthic communities and fish in benthic classes 5 and 6 respectively).

Examination of the spatial distribution of these key benthic classes indicates that of the transects completed on Malolo Patch (survey sector 24), these benthic classes in combination cover 31% of the total surveyed area. This is in comparison to 23% and 10% for Malolo North and Malolo South; the two remaining survey sectors analysed in the Malolo analysis area. In addition, within all areas surveyed, Malolo Patch has the fourth highest proportion of transect sections between 5 and 12 meters with a conservation value of 4. The third recommended site for the establishment of an MPA is therefore the area defined in this report as sector 24- Malolo Patch.

The potential for the successful establishment of Malolo Patch area as a no-take zone is high. Recent community education efforts with the villagers of Solevu and Yaro have resulted in the creation of a temporary no-take area immediately in front of the population centres. This demonstrates that community support for local marine resource management is strong. The emphasis of this no-take area has been placed on community based marine management and thus the area was selected for its convenience rather than its scientific validity as a potential protected area. The recommendations being made in this report would be for the continuation and extension of this existing area to incorporate Malolo Patch.

Malolo Lailai analysis area has only one benthic class that has high potential management value- class 3. Benthic class 3 has a moderate to high overall mean hard coral cover abundance of 3.1, but the Shannon-Weiner diversity index of both the benthic community and the fish community associated with it are low (4.16 and 3.77 respectively). In addition, this benthic class covers only 12% of the total area surveyed within survey sector 25- Malolo Lailai. Examination of the habitat map for this analysis area indicates that benthic class 3 is largely distributed along the East and North facing reef areas around Malolo Lailai. The areas described as benthic class 3 are patchy in their distribution and therefore, the protection of this one valuable habitat would involve the establishment of an MPA that covers a large area. This would ultimately make it unviable because of socio-economic considerations.

Wadigi reef complex has only one benthic class that displays good management potential. Benthic class three has a moderate to high diversity of both benthic and fish communities associated with it (4.41 and 3.96 respectively), but it has low hard coral cover (2.6). In addition, the ternary diagrams drawn from the hard coral community structure found on transects with depths from 5-12 meters in this area show the reef to have low conservation value (43, 33 and 25% in conservation class 4 for Wadigi Patch reef - sector 19; Lana Patch - sector 20 and Wadigi Island - sector 18 respectively).

Navini Island has had a no-take restriction placed on it for the past 17 years. At present the system is managed by the local staff that operate the resort. Surveillance is continually operated although there is little reported conflict with the operation of the reserve. There is one benthic class defined within the Navini analysis area that has potential management importance. Benthic class three has an average abundance of hard coral cover of 3.6, with Acropora branching being the most commonly observed life form with an average abundance of 2.3. This benthic class has the highest Shannon-Weiner diversity of all benthic communities found in this study (4.52). It also has the second highest diversity of fish communities associated with it (4.05). In addition, this benthic class comprised 51% of the total area encountered during the surveys conducted at Navini during year one of the FCRCP. The habitat maps shows that this benthic class is evenly distributed around the island and no one side is depurate in the abundance of this habitat. Perhaps surprisingly however, none of the transects encountered between 5 and 12 meters had a coral community of a conservation value of 4. Instead, 100% of these transect areas had a conservation value of 2. Evidence recorded during the studies suggests that vertical visibility around Navini Island is exceptionally good in comparison to that found in other survey areas. It appears that a diverse coral assemblage can be found around Navini in water depths between 18 and 30 meters. These assemblages fall below that depth range used in the calculation of conservation values. The exceptionally high diversity of benthic communities and fish populations found around Navini may be due in part to the success of the restrictions currently in place. Accordingly, it is a recommendation to enhance the management plans already in place at Navini and establish the area under the integrated protected area scheme included in this report.

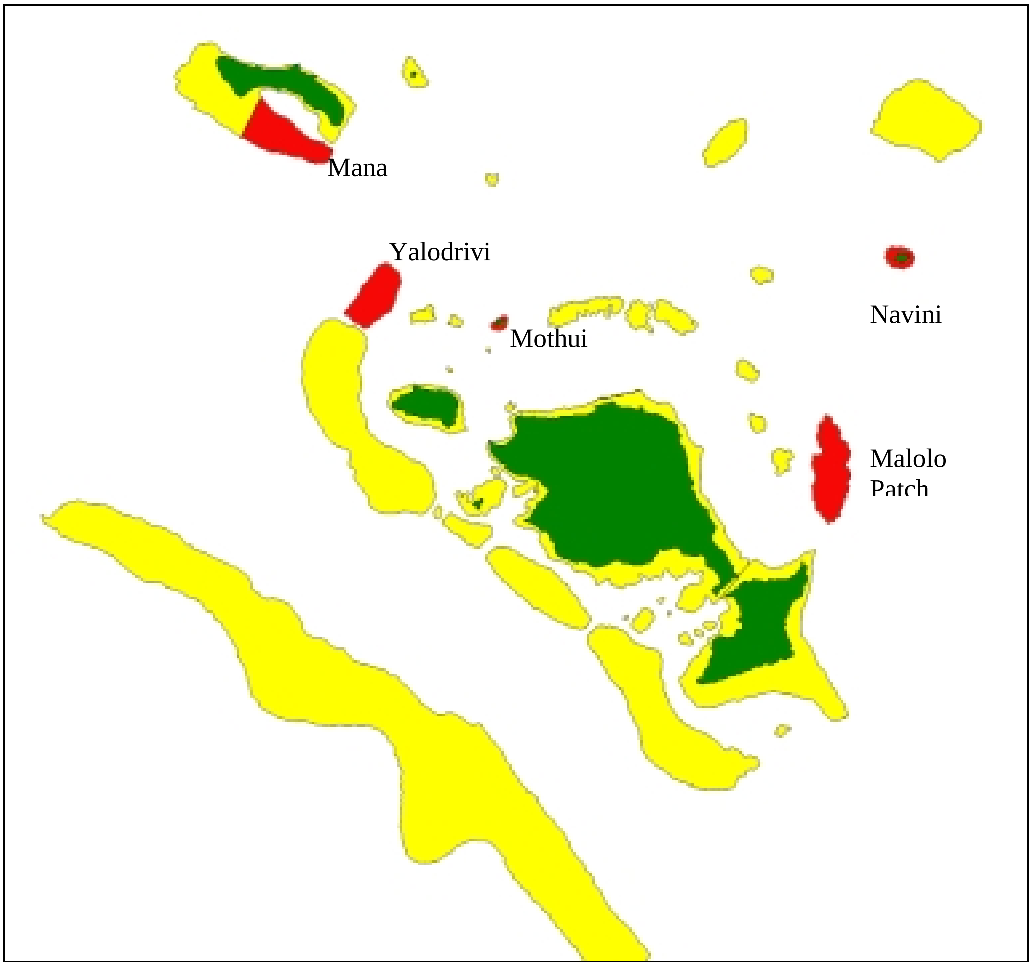


Figure 64. The locations of areas recommended for establishment as MPAs based on data collected during year one of the FCRCP.

MPA Recommendation	Area (km^2)	Perimeter (km)	Boundaries			
			Lower left	Lower right	Upper left	Upper right
Yalodrivi	0.89	3.87	8040785, 512431	8040785, 513650	8040785, 512431	8040785, 513650
Mothui	0.08	1.12	8040796, 515469	8040796, 515838	8041106, 515469	8041106, 515838
Malolo Patch	1.25	5.82	8036980, 522090	8036980, 522917	8039243, 522090	8039243, 522917
Navini	0.22	1.85	8042271, 523652	8042271, 524271	8042733, 523652	8042733, 524271
Mana	1.31	5.43	8,044,149, 510,157	8,044,149, 512,242	8,045,593, 510,157	8,045,593, 512,242
Total	**3.75**	**18.09**				

Table 49. Spatial statistics on the MPA recommendations made in this report from data collected during year one of the FCRCP. Boundary coordinates are given in Universal Transverse Mercator Zone 60, WGS-84 Geodetic projection.

5.5 Integrated Management Recommendations

One of the key recommendations that came from the Pilot Phase project of CCC's involvement in the Mamanuca Islands was the establishment of an integrated approach to marine resource conservation. The recommendation was made that, based upon theoretical spatial models of marine protected area population dynamics, 20% of the shallow reef areas of the Mamanuca Islands should be decreed a no-take zone. With 70 km^2 of such area found in the Mamanucas, this equates to a spatial coverage of 14 km^2.

Contained in this report is the analysis and documented recommendations based upon the first year of a three-year programme by Coral Cay Conservation. In the first year, approximately one third of the shallow water areas that could support reef growth have been surveyed. The findings outlined in the subsequent section detail a spatial area of 3.75 km^2 that should provide the basis of the implementation of phase one of no-take zone implementation (see Table 49 for spatial details). Having covered one third of the potential reef area, these recommendations fall below the 5.7 km^2 area that should have been identified by the first year of survey work. However, Figure 64 illustrates that the areas identified are spatially well distributed with regard to the resource use activities that occur in the Mamanucas. In addition, Figure 19 showing the survey progress during year one illustrates that many of the large areas of coral reef communities have yet to be fully surveyed and are not contained in this report.

One such example, and one that will continue to grow in importance as more quantitative data is recorded is the Malolo outer barrier reef. This region is more geographically removed from the population centres that have been outlined throughout this report as being epicentres of anthropogenic disturbance. It is therefore likely that reef health on the outer barrier is greater than that found within the geographical constraints of the inner Malolo reef complexes. One of the emerging concepts of coastal and aquatic living resource management is that of the role of source and sink reefs within entire biogeographic regions. Naturally, some reefs in good health act to export larvae that is able to repopulate reefs that through natural or anthropogenic impacts are denuded. It is likely in this instance that the outer barrier can act as an important source reef in this manner, with the degraded inner Malolo Reef complexes benefiting from a net influx of larvae, which will facilitate the recovery of these areas.

The role of no-take regions in the Mamanucas does however need to be treated with caution. The concept of a no-take region is not an entirely holistic one. It is not and should not be considered as such a 'holy grail' that will allow unlimited abuse of surrounding areas. The whole of the Mamanuca region must be considered as a single unit. The ultimate goal must be the creation of a multi-use zoning scheme that permits the use of certain defined areas for some activities, but excludes others. This approach has two benefits. On a scientific and ecological basis, it allows the identification of key management areas in respect of the fragility of the biological communities it contains. To allow over-fishing in exceptionally healthy reef areas will negate the benefits to surrounding areas. The content of this report is aimed at the identification of such areas. The second benefit of multi-use zoning schemes occurs not at the scientific but at the socio-economic and social acceptability level. The partition of a resource into stakeholder units reduces the conflict between stakeholder parties. The ultimate effect of this is that social acceptability of the management plan is increased and the likelihood of success of the scheme is greatly enhanced.

In the context of the Mamanuca Islands, the two main stakeholder groups are the tourism industry and the local landowners. Whilst at present there is amicable exchange of wealth and benefit from the marine resources found in the Mamanucas this relationship needs to be formalised in a structured manner to ensure stakeholder conflicts are eliminated.
It is therefore a recommendation that a series of multi-stakeholder workshops and visioning exercises is undertaken to ensure that throughout the process the expectations and visions of both parties are complimentary in content as well as time scale over which they are expected to be achieved.

Coral Cay Conservation's role in the forwarding of the prospects of an integrated approach to marine resource conservation in the Mamanuca Islands is four fold:

- To continue baseline surveys in areas that, until now have not been surveyed extensively enough to allow a full inventory of the marine resources they contain to be made. The output from this process will be of a similar format to that presented here. It will contain in each in each of two annual reports further areas that are identified based upon their biological and therefore potential management value. Likewise in this report, these recommendations and findings will be based on an extensive and exhaustive data set together with latest and most appropriate analysis techniques to ensure that the areas identified are based on a sound scientific footing.

- To continue community education efforts with all stakeholder groups. Education is the key to successful management. Throughout year one of the FCRCP, stakeholder education programmes have been conducted with all stakeholder parties. These programmes have laid the foundation towards an understanding of the benefits of marine resource management and have kindled a sense of purpose that has facilitated a move towards sustainable resource use. As management actions progress, education becomes more essential. It is often found that education forms an important role in keeping interests high when plans seem to be overcoming a series of hurdles.

- To continue monitoring to examine the recovery of the marine resources of the Mamanucas following episodes of natural and anthropogenic disturbance. In addition to the baseline data set contained in this report, reference is frequently made to reports prepared based on quantitative data collected using the Reef Check methodology. This data source has illustrated the recovery of the reefs in the project area following the 2000-2001 beaching and illustrates just one use of the monitoring data that is collected by Coral Cay Conservations teams of survey divers.
  One facet of management planning is the incorporation of a monitoring programme. Such a programme illustrates at an early stage the successes and failures of management plans and allows the dynamic nature of such a plan to be utilised to make changes that improve the efficiency and eventual outcome of the management process. Coral Cay Conservation in collaboration with other NGOs will play an important role in the creation of such a monitoring programme.

- To assist and support any other body or organisation that displays a willingness and interest in the management of the resources of the Mamanuca Islands. This assistance and support will take a wide variety of forms; not least those specific aims contained in the previous three aims. In addition however, Coral Cay Conservation trained personnel will remain as an permanent resource able to provide help and assistance with the final goal of achieving sustainable resource use in the Mamanuca Islands.

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APPENDIX 1

Recording forms used for data collected during CCC standard baseline surveys.

BOAT FORM

DATE: ____________________ **COX:** ____________________
STUDY: ____________________ **BM:** ____________________
TRANSECT: ____________________ **BUOY:** ____________________
SUBZONE: ____________________

COORDINATES

START: **GPS Unit:** ____________________
Datum: ____________________

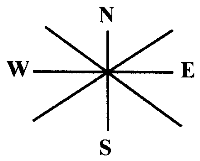
	Latitude (UTM)	Longitude (UTM)	Time	Est. error	Waypoint
1.					
2.					
3.					

END:

	Latitude (UTM)	Longitude (UTM)	Time	Est. error	Waypoint
1.					
2.					
3.					

CURRENT STRENGTH
none
weak
medium
strong

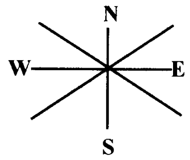
CURRENT DIRECTION (towards)



WIND STRENGTH (1-12)

1	5
2	6
3	7
4	8

WIND DIRECTION (from)



Temperature: °C at depth of: m **Surface temperature:** °C **Secchi disc:** m

Salinity: at depth of: m **Surface salinity:**

SURFACE ACTIVITY

BOAT	No. OCCUPANTS	PROXIMITY (m)	ACTIVITY eg. diving/fishing/pleasure/commercial
1.	____________	____________	____________
2.	____________	____________	____________
3.	____________	____________	____________
4.	____________	____________	____________

SURFACE IMPACTS

	LITTER	SEWAGE	DRIFTWOOD	ALGAE	NETS / POTS
(please tick)	☐	☐	☐	☐	☐

Other Impacts/Details..

OTHER COMMENTS:..

PHYSICAL RECORDING FORM

Study. Transect No. Zone Code.

Date: ____/____/____ Start Time: __________ End Time: __________

Recorder's Name: __________ Phys.
__________ Fish
__________ Corals
__________ Algae/Inverts.

Depth Limits - Min: ______m
- Max: ______m
Underwater visibility ______m
Repeat visit? Y/N

TYPE OF SURVEY

- Spot dive ☐
- Transect ☐
- General ☐
- Mapping ☐
- Photography ☐
- Sounding ☐
- Other ☐

ZONE (Tick all that apply)

- Backreef ☐
- Reef crest ☐
- Spur & groove ☐
- *Low spur & groove* ☐
- *High spur & groove* ☐
- Forereef ☐
- Escarpment ☐
- Patch reef ☐
- *Dense patch reef* ☐
- *Diffuse patch reef* ☐
- Lagoon floor ☐
- *Shallow lagoon* ☐
- *Deep lagoon* ☐

Italics indicate a sub-class of a main class

IMPACTS

- Litter ☐
- Sewage ☐
- Coral damage ☐
- Lines / nets ☐
- Fish traps ☐
- Sedimentation ☐
- Coral disease ☐
- Bleaching ☐
- Dynamite ☐
- Other: __________

YOUR IMPRESSION OF THE SITE

	AESTHETIC	BIOLOGICAL
Excellent		
Very good		
Good		
Average		
Poor		

Other comments:

Navigation bearing: _____°

Depth buoy tied: ______m

Buoy colour/I.D.: ______

SITE DESCRIPTION (Describe general location of the site, topography and main habitats - coral, sand, etc.)

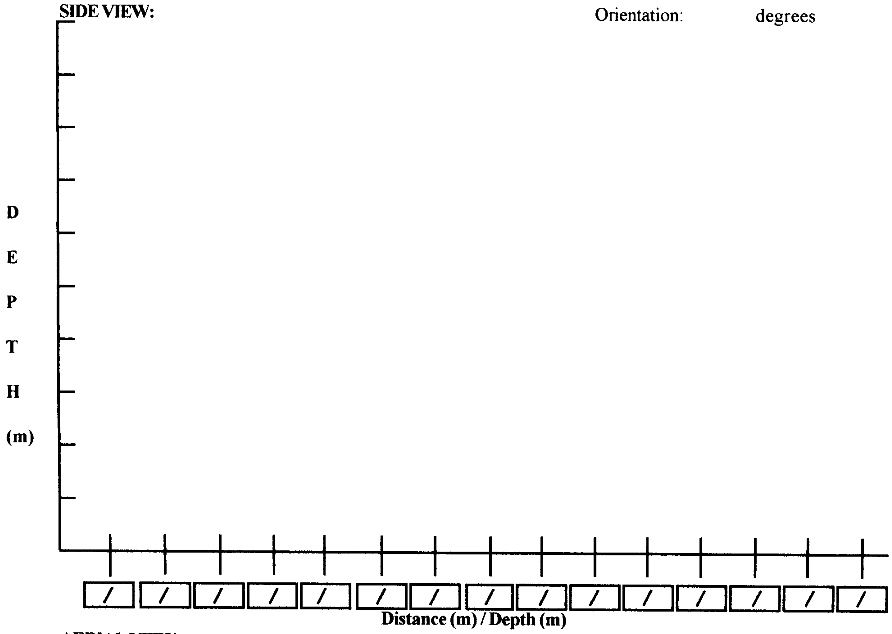
General Location ______________________________

Topography ______________________________

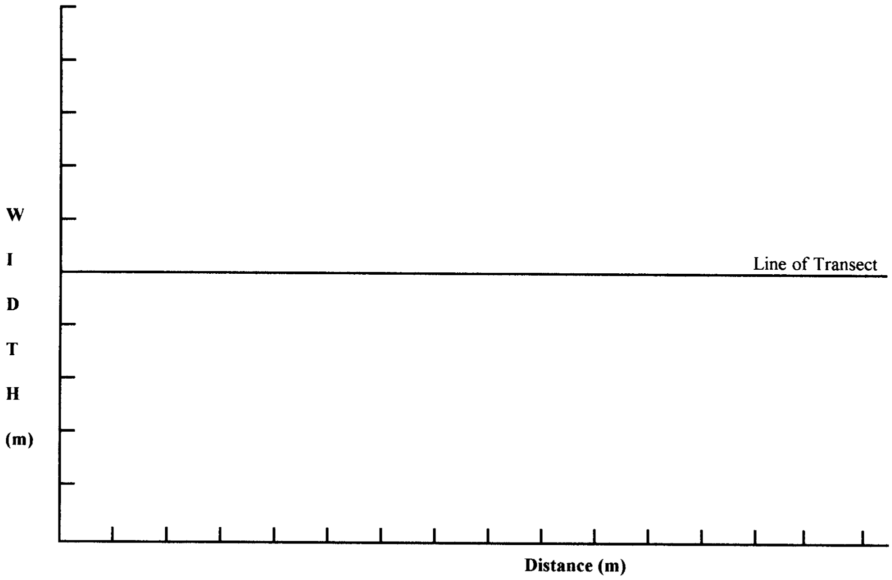
Main Habitats ______________________________

SITE PROFILE /PLAN DRAWING (Note depths, distances and habitats)

SIDE VIEW: Orientation: degrees



AERIAL VIEW:



BIOLOGICAL RECORDING FORM

Study: Transect No: Zone Code:

Habitat No: ______ of: ______ Date: / /

Database Code.

Percentage of dive: ____ % Start time: : End time: :

First: Last: No. dives/snorkels in Fiji

Recorder's name ____________ Phys ______ Depth limits: Min______ m

____________ Fish ______ Max______ m

____________ Coral ______ Underwater visibility______ m

____________ Algae ______ Cox______

GEOMORPHOLOGICAL CLASS - TICK ONE ONLY. Remember that if the geomorphology changes, you must start another habitat.

Backreef	☐	Shallow zone between the reef crest and lagoon or land. Usually hard substratum pavement.
Reef crest	☐	Shallowest and often emergent part of the reef, separating forereef from backreef / lagoon.
Spur and groove	☐	Spurs of hard corals / calcified green algae with sand / bedrock grooves.
Low spur and groove	☐	Spurs less than 5m high.
High spur and groove	☐	Spurs greater than 5m high.
Forereef	☐	Any area of reef with an incline of between 0 and 45°.
Escarpment	☐	Any area of the benthos whose angle of slope exceeds 45°.
Patch reef	☐	Coral formations in the lagoon which are surrounded by either seagrass, sand or algae.
Dense patch reef	☐	Areas of aggregated coral colonies (living or dead) which cover > 70% of the benthos.
Diffuse patch reef	☐	Areas of dispersed coral colonies where < 30% of the benthos is covered by coral colonies.
Lagoon floor	☐	The lagoon floor where the angle of slope does not exceed 45°.
Shallow lagoon floor	☐	Lagoon with a depth of < 12m.
Deep lagoon floor	☐	Lagoon with a depth of > 12m.

Italics indicate a sub-class of a main class and if there is any uncertainlty, the main class should be used.

SUBSTRATUM AND BIOLOGICAL COVER

Rating from 0-5 (figures need not add up to 5 total)

Bedrock	☐	Any exposed area of hard, bare substratum without visible coralline structures.
Dead corals	☐	Any area of hard bare substratum with visible corallite structure.
Rubble	☐	Any area of loose bedrock or hard substratum.
Sand	☐	Coarse sediment (diameter > 1mm). "Grainy" when disturbed.
Mud	☐	Fine sediment (diameter < 1mm). "Milky" when disturbed.

Hard corals	☐	
Soft corals	☐	
Sponges	☐	
Green algae	☐	Non-calcareous algae forming mats or turfs.
Brown fleshy algae	☐	e.g. *Lobophora, Padina, Sargassum, Turbinaria*.
Red/brown branching algae	☐	e.g. *Laurencia, Dictyota*.
Green calcified algae	☐	e.g. *Halimeda, Udotea*.
Red coralline algae	☐	e.g. Cement, crustose coralline.
Seagrass	☐	

Substratum types within the habitat: ____________

____

____

Other comments: ____________

SPECIES ABUNDANCE

NOTE THAT ALL CORAL AND FISH TARGET SPECIES MUST ALSO BE COUNTED IN THE APPROPRIATE FAMILY OR LIFEFORM

Rating	Meaning	Fish/Inverts
0	None	0
1	Rare	1-5
2	Occasional	6-20
3	Frequent	21-50
4	Abundant	51-250
5	Dominant	250+

MACRO-ALGAE

CYANO-BACTERIA: Blue-Green 1 ☐

CHLOROPHYTA: Green.

- Green filamentous 39 ☐
- *Chaetomorpha* sp. 15 ☐
- Marble - *Valonia* sp. 36 ☐
- *Bornetella* sp. 10 ☐
- Finger - *Neomeris* sp. 29 ☐
- Spongy - *Codium* sp. 18 ☐
- Grape - *Caulerpa* sp. 12 ☐
- **Calcified** - *Halimeda* sp. 24 ☐
- - *Tydemania* sp. 33 ☐

Further green species:

______ ☐
______ ☐
______ ☐
______ ☐

TOTAL GREEN ALGAE ☐

PHAEOPHYTA: Brown.

- *Ralfsia* sp. 51 ☐
- *Sphacelaria* sp. 54 ☐
- *Rosenvingea* sp. 58 ☐
- Flat-branched - *Dictyota* sp. 44 ☐
- Fan blade - *Padina* sp. 50 ☐
- Blade/Ruffle - *Lobophora* sp. 49 ☐
- *Hydroclathrus* sp. 48 ☐
- Pyramid - *Turbinaria* sp. 55 ☐
- Filamentous 42 ☐
- Bladder - *Sargassum* sp. 53 ☐

Further brown species:

______ ☐
______ ☐
______ ☐

TOTAL BROWN ALGAE ☐

RHODOPHYTA: Red.

- Wiry-branched 71 ☐
- *Gelidium* sp. 76 ☐
- *Gelidiella* sp. 74 ☐
- Fine branched - *Laurencia* sp. 85 ☐
- Calcified 70 ☐
- *Galaxaura* 73 ☐
- *Amphiroa* 63 ☐
- *Jania* / spikeweed 83 ☐
- Filamentous - *Ceramium* sp. 60 ☐
- Sheet - *Halymenia* sp. 80 ☐
- *Amansia* 62 ☐
- *Actinotrichia* 61 ☐

Further red species:

______ ☐
______ ☐
______ ☐

TOTAL RED ALGAE ☐

ANGIOSPERMOPHYTA:

Marine Plants.

- **Sea grass** 102 ☐
- Thalassia sp. 108 ☐
- Halophila sp. 105 ☐
- **Other:** ______ ☐
- **Mangroves** 114 ☐

TOTAL PLANTS (not including algae) ☐

TARGET INVERTEBRATES

PORIFERA: Sponges.

- Tube 126 ☐
- Barrel 146 ☐
- Elephant Ear 128 ☐
- Branching 143 ☐
- Encrusting 130 ☐
- Lumpy 145 ☐
- Rope 144 ☐
- Vase 125 ☐

CNIDARIA: Soft coral forms.

- Deadman's fingers 275 ☐
- Leather 277 ☐
- Tree 278 ☐
- Pulsing 295 ☐
- Sea fan 280 ☐
- Sea whip 281 ☐
- Bamboo 283 ☐
- Organ pipe 293 ☐
- Flower 294 ☐
- Black coral 303 ☐
- Anemone 306 ☐
- Zoanthid 315 ☐
- Medusa (jellyfish) 327 ☐
- Hydroid 333 ☐
- Corallimorph 320 ☐

ANNELIDA: Worms.

- Segmented worms 348 ☐
- Feather duster 349 ☐
- Christmas tree 350 ☐

ARTHROPODA: Crustacea.

- Shrimps 361 ☐
- Spiny Lobster 366 ☐
- Crab 381 ☐

MOLLUSCA:

- **Gastropods:** - Abalone 390 ☐
- - *Murex* sp. 394 ☐
- - Conch 398 ☐
- - Cowrie 402 ☐
- - Triton 406 ☐
- - Cone shell 408 ☐
- - *Drupella* sp. 419 ☐
- - Limpet 445 ☐
- - Topshell 404 ☐
- - Other 389 ☐
- **Bi-valves:** - Oyster 426 ☐
- - Clam 438 ☐
- - Other 425 ☐
- Chiton 442 ☐
- Nudibranch 448 ☐
- **Cephalopods**: - Cuttlefish 469 ☐
- - Squid 470 ☐
- - Octopus 468 ☐

ECHINODERMS	
Sea stars	
- Crown of thorns	472
- *Linkia laevigata* (Blue)	478
- *Nardoa* sp. (Brown)	479
- *Culcita novaeguineae*	474
- *Protoreaster nodosus*	482
- *Choriaster granulatus*	473
- Other	471
Brittle star	483
Feather star	489
Basket star	495
Sea urchin -short spine	502
-long spine	503
Sea cucumber- synaptid	515
- other	520
TUNICATE	529
BRYOZOAN	526
Further species:	
______	
______	
______	
______	
TOTAL INVERTEBRATES	
TARGET FISH	
Butterflyfish	540
(Big) Long-nosed	752
Klein's	651
Vagabond	541
Pyramid	750
Eastern triangle	783
Latticed	681
Redfin	760
Chevroned	677
Saddled	899
Threadfin	674
Teardrop	898
Orange-banded coralfish	923
Humphead bannerfish	669
Pennant bannerfish	939
Angelfish	544
Regal	663
Bicolour	673
Pearlscale	545
Emperor	756
Blue-girdled	937
Vermiculated	938
Surgeonfish	546
Convict	547
"Ringtail" sp.	548
Brushtail tang	638
Thompson's	747
Mimic	700
Unicorn sp.	550

Tunas / Mackerels	940
Narrow-banded king mackerel	558
Fusiliers	571
"Blue and yellow" sp.	929
Bluestreak	930
Damselfish	589
Chromis sp.	590
Black bar chromis	646
Blue devil	657
Threespot dascyllus	671
Humbug dascyllus	767
Reticulated dascyllus	771
Whitebelly damselfish	654
Staghorn damselfish	745
Black damselfish	759
Behn's damselfish	593
Honeyhead damselfish	594
Alexander's damselfish	764
Anemonefish sp.	591
Sergeant sp.	656
Wrasse	598
Diana's hogfish	931
Mesothorax hogfish	611
Humphead	600
Red-banded	932
Checkerboard	725
Twotone	768
Crescent	647
Sixbar	744
Jansen's	678
Cigar	685
Bird	610
Cleaner	605
Parrot fish	613
Bumphead	933
Goatfish	615
Half-and-half	648
Two-barred	666
Dash-and-dot	781
Multibarred	934
Blackstriped	616
Yellowfin	897
Triggerfish	624
Redtooth	786
Orangestriped	625
Clown	626
Blackbelly picassofish	927
Pinktail	782
Scthye	692
Halfmoon	796
Picasso	628
Moustache / Titan	623
Grouper	583
Flagtail	682
Peacock	935
Humpback	936

"Honeycomb" sp.	586
Lyretail	946
Soapfish	928
Anthias	642
Rabbitfish	579
Foxface	757
Virgate	630
Uspi	896
Spinecheek	581
Twoline	582
Pearly	659
Snapper	565
Two-spot	753
Checkered	665
Black-and-white	569
Bluelined	925
Spanish flag	679
Paddletail	564
Dartfish	774
Blackfin	695
Dottyback	900
Lined	686
OTHER MAJOR FAMILIES:	
Jack / Trevally	553
Sweetlips	577
Barracuda	560
Moorish Idol	551
Emperor	924
MISCELLANEOUS FAMILIES:	
Spadefish / Batfish	595
Cardinalfish	621
Squirrelfish / Soldierfish	619
Filefish	629
Lionfish	631
Scorpionfish / Stonefish	632
Lizardfish	643
Hawkfish	902
Sandperch	675
Porcupine / Puffer / Toby	634
Trunk / Box / Cowfish	640
Goby	749
Blenny	926
Sharksucker	787
Needlefish	562
Pipefish	911
Shrimpfish	790
Trumpetfish	664
Moray eel	637
FURTHER SPECIES:	
______	
______	
______	
______	
______	
______	
TOTAL FISH	

HARDCORAL

Life forms

DEAD CORAL	148
DEADCORALWITH ALGAE	149
ACROPORA:	
BRANCHING	150
ENCRUSTING	151
SUBMASSIVE	152
DIGITATE	153
TABULATE	154
NON-ACROPORA:	
BRANCHING	155
ENCRUSTING	156
FOLIOSE	157
MASSIVE	158
SUB-MASSIVE	159
MUSHROOM	160
FIRE *(Millepora)*	161
BLUE *(Heliopora)*	162
TOTAL CORAL LIFE FORMS	

Target life form, genera and species

Pocilloporadae	
Pocillopora: small	164
medium	165
large	166
Seriatopora hystrix	834
Stylophora pistillata	833
Stylophora mordax	803
Acroporidae	
Montipora foliosa	836
Montipora digitata	808
Bottlebrush *Acropora*	163
Poritidae	
Massive *Porites*	844
Porites cylindrica	845
Porites nigrescens	846
Porites rus	848
Goniopora / Alveopora	893
Agariciidae	
Pavona clavus	855
Pachyseris speciosa	859
Pachyseris rugosa	858
Fungiidae	
Ctenactis echinata	208
Herpolitha limax	248
Polyphyllia talpina	861
Upsidedown bowl	167
Oculinidae	
Galaxea	236
Pectiniidae	
Pectinia lactuca	865
Mycedium elephantotus	815
Mussidae	
Lobophyllia	269
Faviidae	
Favia	222
Favites	227
Diploastrea heliopora	215
Caryophylliidae	
Euphyllia	895
Plerogyra	874
Milleporidae	
Millepora platyphylla	827
Millepora intricata	826
Dendrophylliidae	
Tubastrea micrantha	877
Turbinaria reniformis	884

Miscellaneous

Brain:	- small	202
	- medium	273
	- large	253

Further species

TOTAL TARGET CORALS

NOTE THAT ALL CORAL AND FISH TARGET SPECIES MUST ALSO BE COUNTED IN THE APPROPRIATE FAMILY OR LIFEFORM

APPENDIX 2

Recording forms used for data collected during Reef Check surveys. Note that these are modified from the standard forms available at http://www.ReefCheck.org/

Site name and code	
Date	
Time of day that work started	
Time of day that work ended	
Longitude of Reef Check transect	
Latitude of Reef Check transect	
Orientation of Reef Check transect	N-S NE-SW E-W SE-NW
Distance of Reef Check transect from shore	_____ m
Distance of site from nearest river	_____ km
River mouth width	<10m 11-50m 51-100m 101-500m
Weather	sunny_____ cloudy_____ raining_____
Air temperature	___ degrees Celsius
Water temperature at surface	degrees Celsius
Water temperature at 3 m	___ degrees Celsius
Water temperature at 10 m	___ degrees Celsius
Water temperature at 20 m	___ degrees Celsius
Water temperature at 30 m	___ degrees Celsius
Distance to nearest population centre	_____ km
Approximate population size	_____ x 1000 people
Horizontal visibility in water	_____ m
Vertical visibility in water	_____ m
Why was this site selected?	
Is this site -	sheltered_____ or exposed_____
Any major coral damaging storms in past years?	yes no unknown
How do you rate this site overall in terms of anthropogenic impact?	none____ low____ moderate____ heavy__
What types of impact do you believe occur?	
Number of fishing boats within 500m	
Number of other boats within 500m	
Dynamite fishing	none____ low____ moderate____ heavy__
Poison fishing	none____ low____ moderate____ heavy__
Aquarium fish collection	none____ low____ moderate____ heavy__
Harvest of invertebrates for food	none____ low____ moderate____ heavy__
Harvest of invertebrates for curio sales	none____ low____ moderate____ heavy__
Tourist diving	none____ low____ moderate____ heavy__
Sewage pollution	none____ low____ moderate____ heavy__
Industrial pollution	none____ low____ moderate____ heavy__
Other forms of fishing? (Specify)	none____ low____ moderate____ heavy__
Other impacts? (Specify)	none____ low____ moderate____ heavy__
Is there any form of protection (statutory or other) at this site?	yes_____ no_____
If yes, what type of protection?	
Other comments	

Site name and code:
Depth: Time: Date:

Point Codes

ACB *Acropora* branching	**SC** Soft coral	**RKC** Recently killed coral
ACE *Acropora* encrusting	**SP** Sponge	**RC** Rock
ACS *Acropora* submassive	**ZO** Zoanthids	**SI** Silt/mud
ACD *Acropora* digitate	**AA** Algal assemblage	**RB** Rubble
ACT *Acropora* tabulate	**CA** Coralline algae	**SD** Sand
CB Non-*Acropora* branching	**HA** *Halimeda*	**OT** Other
CE Non-*Acropora* encrusting	**MA** Macroalgae	**WA** Water
CF Non-*Acropora* foliose	**TA** Turf algae	
CM Non-*Acropora* massive		
CS Non-*Acropora* submassive		
CMR Non-*Acropora* mushroom		
CHL *Heliopora*		
CME *Millepora*		
CTU *Tubipora*		

Code	**Sps**	**Code**	**Sps**	**Code**	**Sps**	**Code**	**Sps**
PS	Pocillopora small	**PN**	Porites nigrescens	**G**	Galaxea	**MII**	Millepora intricata
PM	Pocillopora medium	**PR**	Porites rus	**PLA**	Pectinia lactuca	**TM**	Tubastrea micrantha
PL	Pocillopora large	**GA**	Goniopora / Alveopora	**ME**	Mycedium elephantotus	**TR**	Turbinaria reniformis
SH	Seriatopora hystrix	**PCL**	Pavona clavus	**L**	Lobophyllia	**BS**	Brain small
S	Stylophora	**PAS**	Pachyseris speciosa	**FVA**	Favia	**BM**	Brain medium
MF	Montipora foliosa	**PAR**	Pachyseris rugosa	**FVT**	Favites	**BL**	Brain large
MD	Montipora digitata	**CEC**	Ctenactis echinata	**DH**	Diploastrea heliopora		
BA	Bottlebrush Acropora	**HL**	Herpolitha limax	**EU**	Euphyllia		
MP	Massive Porites	**PT**	Polyphyllia talpina	**PLE**	Plerogyra		
PC	Porites cylindrica	**UB**	Upsidedown bowl	**MIP**	Millepora platyphylla		

"Sps" is for coral only - if non-coral, leave blank

(For first segment, if start point is 0 m, last point is 19.5 m)

SEGMENT 1						SEGMENT 2						SEGMENT 3						SEGMENT 4					
0 - 19.5 m						25 - 44.5 m						50 - 69.5 m						75 - 94.5 m					
	Form	Sps		Form	Sps		Form	Sps		Form	Sps		Form	Sps		Form	Sps		Form	Sps		Form	Sps
1			21			41			61			81			101			121			141		
2			22			42			62			82			102			122			142		
3			23			43			63			83			103			123			143		
4			24			44			64			84			104			124			144		
5			25			45			65			85			105			125			145		
6			26			46			66			86			106			126			146		
7			27			47			67			87			107			127			147		
8			28			48			68			88			108			128			148		
9			29			49			69			89			109			129			149		
10			30			50			70			90			110			130			150		
11			31			51			71			91			111			131			151		
12			32			52			72			92			112			132			152		
13			33			53			73			93			113			133			153		
14			34			54			74			94			114			134			154		
15			35			55			75			95			115			135			155		
16			36			56			76			96			116			136			156		
17			37			57			77			97			117			137			157		
18			38			58			78			98			118			138			158		
19			39			59			79			99			119			139			159		
20			40			60			80			100			120			140			160		

MAKE CORAL CATEGORIES BOLD IF THEY ARE RECRUITS (I.E. < 5 CM DIAMETER)

TOTAL NUMBER OF RECRUITS (ALL LIFE FORMS COMBINED)

MAKE CORAL CATEGORIES ITALICS IF THEY ARE BLEACHED

TOTAL NUMBER OF BLEACHED CORALS (ALL LIFE FORMS COMBINED)

REEF CHECK 2001- Please fill in all Black outlined boxes

Site Name:
Depth:
Date: Time:

Indo-Pacific Belt Transect : Fish

Data recorded by:

	0-20m	25-45m	50-70m	75-100m
Butterfly fish (ALL SPS)				
Sweetlips (Haemulidae) (ALL SPS)				
Snapper (Lutjanidae) (ALL SPS)				
Two-spot				
Checkered				
Black-and-white				
"Bluelined"				
Paddletail				
Barramundi Cod (*Cromileptes*)				
Grouper >30cm (Give sizes in comments) (ALL SPS)				
Flagtail				
Peacock				
"Honeycomb"				
Lyretail				
Humphead wrasse				
Bumphead parrot				
Other Parrotfish (>20cm)				
Tuna / Mackerel				
Fusiliers				
Surgeonfish				
Rabbitfish				
Barracuda				
Jacks / Trevally				
Moray eel				

"ALL SPS" means that all individuals from that family should be counted in the box and additional target species are counted a second time on subsequent line e.g. a paddletail snapper is

counted both as a snapper AND as a paddletail snapper

Indo-Pacific Belt Transect : Invertebrates

Data recorded by:

	0-20m	25-45m	50-70m	75-100m
Banded coral shrimp (*Stenopus hispidus*)				
Diadema urchins				
Pencil urchin (*Heterocentrotus mammilatus*)				
Sea cucumber (edible only)				
Crown-of-thorns star (*Acanthaster*)				
Giant clam (*Tridacna*)				
Triton shell (*Charonia tritonis*)				
Drupella sp				
Squid				
Octopus				
Lobster				

For each segment, rate the following as: None=0, Low=1, Medium=2, High=3

Coral damage : Anchor				
Coral damage:Dynamite				
Coral damage : Other				
Trash : Fish nets				
Trash : Other				

Comments:				

Grouper sizes (cm)				
Bleaching (% of coral population)				
Bleach (% of colony)				
Suspected disease (type/%):				
Rare animals sighted (type/#):				
Other:				

APPENDIX 3.

Megafaunal Sightings by CCC staff and volunteers on surveys and recreational divesbetween April 2002 and April 2003

Month / Year	Site	Megafauna	Number
April 2002	Namotu	Nurse shark	1
		Spinner dolphins	60
		Grey Reef Shark	1
	Castaway Reef	Leopard Shark	2
		Turtle	2
May 2002	Castaway Reef	Green turtle	1
		Black tip reef shark	1
		White tip reef shark	1
	Ravenake	Eagle ray	1
		Blue spotted ribbon tail ray	1
	Supermarket	White tip reef sharks	2
	Pinnacle	Turtle	1
June 2002	Castaway Reef	Blue spotted ribbon tail ray	1
		White tip reef shark	7
		Turtle	1
		Spotted eagle ray	1
	Namotu	Grey reef shark	1
	Ravenake	White tip reef shark	1
July 2002	Ravenake	Spotted eagle ray	1
		Blue spotted ribbon tail ray	2
	Castaway Reef	Blue spotted rays	2
August 2002	M & M	Blue spotted ray	1
	Pinnacle	White tip reef shark	2
	Waidigi	Humpback whale	1
	Honeymoon	Spotted eagle rays	3
	Ed’s Diner	Leopard Shark	1
September 2002	Ravenake	Eagle ray	1
October 2002	Ed’s Diner	White tip reef shark	2
		Black tip reef shark	1
	Supermarket	White tip reef sharks	6
	Pinnacle	Eagle ray	1
	M & M	Shoal of juv barracuda	25
November 2002	Ravenake	White tip reef shark	1
		Barracuda	1
	Honeymoon	Turtle	1
		Ray	1
	Supermarket	White tip reef sharks	9
		Black tip reef sharks	8
		Grey reef sharks	14
		Humphead wrasse	1
	Namotu	Bumphead parrotfish	2
		Shoal adult barracuda	30
		Grey reef sharks	2
		Turtle	1

Month / Year	Site	Megafauna	Number
November 2002		Humphead wrasse	1
		Giant Moray	1
November 2002	Mana	Narrow-banded king mackerel (Walu)	1
	Ed's Diner	Trumpet fish (1.5m)	1
December 2002	Supermarket	Black tip reef shark	1
		White tip reef shark	2
		Turtle	1
	Mana	White tip reef shark	1
January 2003	Namotu	Spinner dolphins	9
	Chief's beach	Juv Black tip reef sharks	16
	Ravenake	Eagle rays	2
		White tip reef shark	1
	Charle's Patch	Olive Ridley Turtle	1
February 2003	Supermarket	Black tip reef shark	3
		White tip reef shark	1
March 2003	Pinnacle	Hawksbill Turtle	1
		Tiera Batfish	1
		White tip reef shark	1
	Supermarket	Grey reef shark	6
		White tip reef shark	4
		Black tip reef shark	2
		Barracuda	50+
	Ravenake	Black tip reef shark juv	1
		Eagle ray	1
		Cuttle fish	7
	Yalodrivi	Hawksbill turtle	1
		Common reef octopus	1
April 2003	Tavarua	Spinner dolphins	62
		White tip reef shark	3
		Blue spotted ray	1
	Ravenake	Black tip reef shark	2
		Travally	2
		Barracuda	1
		Sting ray	1
		Blue spotted sting ray	6
		White tip reef shark	1
	M & M	White tip reef shark	1
	Sunflower	Spiny lobster	1
		Humphead wrasse	1
		Octopus	1
	Ed's diner	Black tip reef shark	2
	Honeymoon	Eagle ray	2
		Giant travally	2
	Yalodrivi	Octopus	1
		Green turtle	1
		White tip reef shark	4
	Supermarket	White tip reef shark	2
		Grey reef shark	2
		Turtle	1
		Spinner dolphins	7