YASAWA ISLANDS CORAL REEF CONSERVATION PROJECT



- Prepared by -

James Comley, Director of Marine Science
Lene Tuveng, Project Scientist
Matthew Crabbe, Project Scientist
Peter Raines, Chairman

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Ministry of Tourism

Coral Cay Conservation Ltd.

13th Floor, The Tower
125 High Street, Colliers Wood
London, SW19 2JG, UK
Tel: +44 (0) 870-750-0668
Fax: +44 (0) 870-750-0667
Email: marine@coralcay.org
www.coralcay.org

CORAL CAY CONSERVATION Expeditions

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EXECUTIVE SUMMARY

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

- Following on from the work conducted by CCC in the Mamanuca Islands as part of the Fiji Coral Reef Conservation Project (FCRCP), CCC were approached early in 2003 to establish a presence in the Yasawa Islands. This relationship was formalised with the signing of an MOU in October 2003, which heralded the beginning of the Yasawa Islands Coral Reef Conservation Project (YICRCP).

- Fieldwork conducted in the YICRCP has been conducted using CCCs baseline technique that allows a level of information to be collected that is appropriate to management decisions makers and facilitates the use of remotely sensed imagery and Geographic Information Systems to represent the coral reef systems.

- This fieldwork data acquisition concentrated around Nacula and Tavewa Islands in the central Yasawa Island archipelago.

- Survey progress during the YICRCP has included 497 survey dives on 42 transects. The unique geomorphology of the reefs around Nacula Island in particular has dictated that much of the areas surveyed included the back reef and lagoonal patch reef areas.

- This data is analysed using extensive and exhaustive techniques.

- A habitat map outlining the zonation of the coral reef areas studies is presented and allows visualisation, quantification and analysis of the reef system.

- Results from the YICRCP indicated that whilst there were some locally attributable anthropogenic impacts, these were considerably lower in occurrence that observed in the less developed Mamanuca Islands. However, there are key signs in the data that impact is occurring and with continued and expanded development in the Yasawas, these impacts are likely to increase in both distribution and intensity.

- The field data indicates that the reef slopes and crests of the fringing reef systems around Nacula and Tavewa Island are of high ecological importance having diverse and strong ecosystem function in terms of both the benthic communities and fish assemblages found with them.

- Developed during previous years of work by CCC in the Mamanuca Islands, the technique of assigning Conservation Management Value Ratings to coral reef areas has been extended this year to produce a Geographic Information System density image of relative management importance. This technique is the culmination of the data analysis techniques employed and has lead to the making of a number of recommendations that relate to the continued management of the coral reefs of the central Yasawa Islands.

Recommendation 1- Whilst the signs of anthropogenic impact observed by CCC during the YICRCP were not of high frequency, impacts including litter were observed. This relates to impacts of continued development of the Yasawa Islands as a tourism industry focal point in Fiji.

Recommendation 2- To counteract the impacts of the developing tourism industry, proper management initiatives need to be taken to ensure that any development is done on a sustainable basis.

Recommendation 3- These management initiatives need to involve all levels of Governance and stakeholders; from central Government development initiatives to local community, Takina and Vanua plans.

Recommendation 4- Tourism development in the Yasawa Islands should proceed in a manner that is fair and equitable to all stakeholders; from local community members to international investors in the development of infrastructure and resorts. Only if this equitability can be realised will all parties in the development process receive due benefit.

Recommendation 5- To increase local stakeholder environmental awareness, a programme of education activities should be undertaken in a manner similar to that begun by CCC at the Ratu Meli Memorial School

Recommendation 6- Issues of customary tenure over the fisheries ground should be prevented from inhibiting the sustainable development of the Yasawa Islands. If the return of customary ownership is seen solely to be a mechanism for communities to enhance their economic earnings, this can often be at the detriment to marine conservation and sustainable development planning.

Recommendation 7- There should be a drive amongst the local communities in the Yasawa Islands to explore the opportunity for establishing a series of Marine Protected Areas to assist in the long-term protection of the coral reef resources of the archipelago.

Recommendation 8- The data presented in this report and, in particular, through the novel use of GIS techniques to allow the data to be accessible to all stakeholder levels can form a basis for activities related to Recommendation 7 above.

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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 have exacerbated these effects by acting synergistically to reduce reef health further. Such impacts represent substantial long- and short-term threats to the ecological balance and health of reef ecosystems which, if left unchecked, will ultimately lead to reduced income for coastal communities and other stakeholders relying on fishing and marine-based tourism.

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

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

2. PROJECT BACKGROUND

2.1 The coastal zone of Fiji

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

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

A recent study of nutrient levels along the Coral Coast of Viti Levu (Mosley and Aalbersberg, 2002) found that levels for nitrate and phosphate exceeded thresholds considered harmful to coral reef ecosystems. Furthermore nutrient levels were highest at sites located near hotels, other populated coastal locations and in rivers.

In addition to coastal development, fishing in Fiji, which occurs at both traditional subsistence and commercial scales, has significantly reduced the populations of many species. Although data are scarce, even traditional techniques, such as hand-lines, fish traps and gill nets, in combination with commercial catches have led to over-fishing of many reef areas. For example, a study by Jennings and Polunin (1996) found low abundances of certain highly targeted fish species, such as groupers and emperors. Over-fishing of prized invertebrate species, such as *Tridacna* clams and sea cucumbers, has also been reported close to urban areas and is thought to have increased since the introduction of SCUBA apparatus and escalating demands of foreign markets (Vuki *et al*., 2000). Fiji is the world's second largest exporter of live reef products for the aquarium trade (Wilkinson, 2002) with a well-established industry that has been operating for over 16 years exporting coral reef fishes and curio coral (Lovell, 2001).

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

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2.2 The Yasawa Islands

The Yasawa Islands (figures 1 and 2) have recently been the focus of rapid development of the tourism industry in Fiji. Since the Yasawas Flyer transfer boat operated by South Sea Cruises begun operation into the Yasawa Islands, the main limitation of access to the Yasawas has been removed and development has progressed apace. The Yasawas tourism industry is based on both locally managed and owned 'alternative' traveller destinations and high-class resort based accommodation including the Yasawas Resort and Turtle Island.

Geographically, the Yasawa Islands stretch as far south as the northern most extent of the Mamanuca Islands with the first Island in the archipelago being Waya Island. The Yasawas then extend in a Northeast direction for approximately 88km to the northern tip of the most northerly Island- Yasawa Island. In between Waya and Yasawa Island lie the main Islands of Naviti, Nanuya and Nacula.

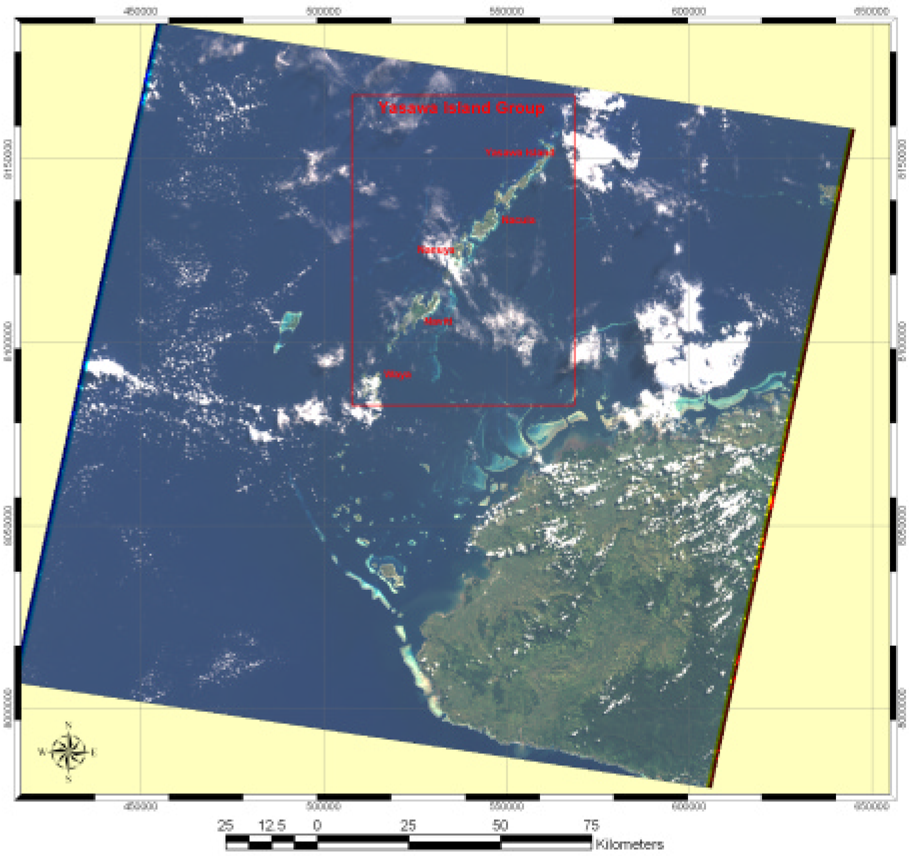

Figure 1. The Fiji islands, showing the Yasawa Islands relative to mainland Viti Levu. Image source- Landsat 7 ETM+ image acquired on 18.05.2001 (image courtesy of Global Land Coverage Facility and U.S. Geological Survey).

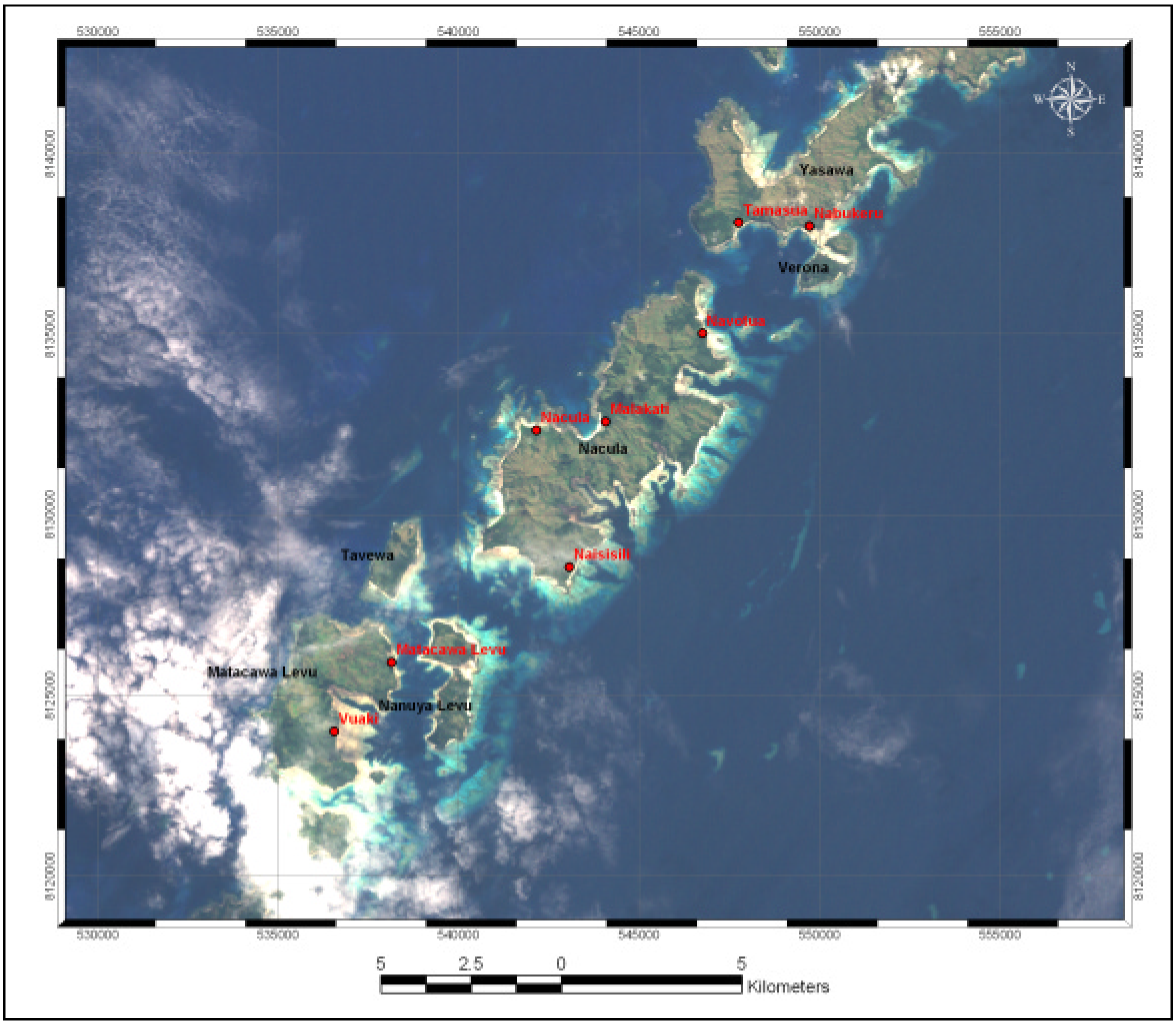

Figure 2. Major islands and villages within the central Yasawa Islands

2.2.1 Traditional Ownership Boundaries in the Project Area.

The coral reef resources of Fiji are split into a number (512) of discreet areas each of which is owned by a community group of indigenous Fijian people. These areas are termed iqoliqoli and are typically owned by a Mataqali or family unit or a group of the community termed the Vanua. The boundaries of these iqoliqoli areas in the project area of the YICRCP are shown in figure 3

The entire project area of the YICRCP encompassing both Nacula and Tavewa Islands fall into the largest iqoliqoli in the Yasawa Islands that covers 4181 km^2 and extends to the south as far as Matcawa Levu and as far north as the northern most point of the Yasawa Islands at the north tip of Yasawa Island.

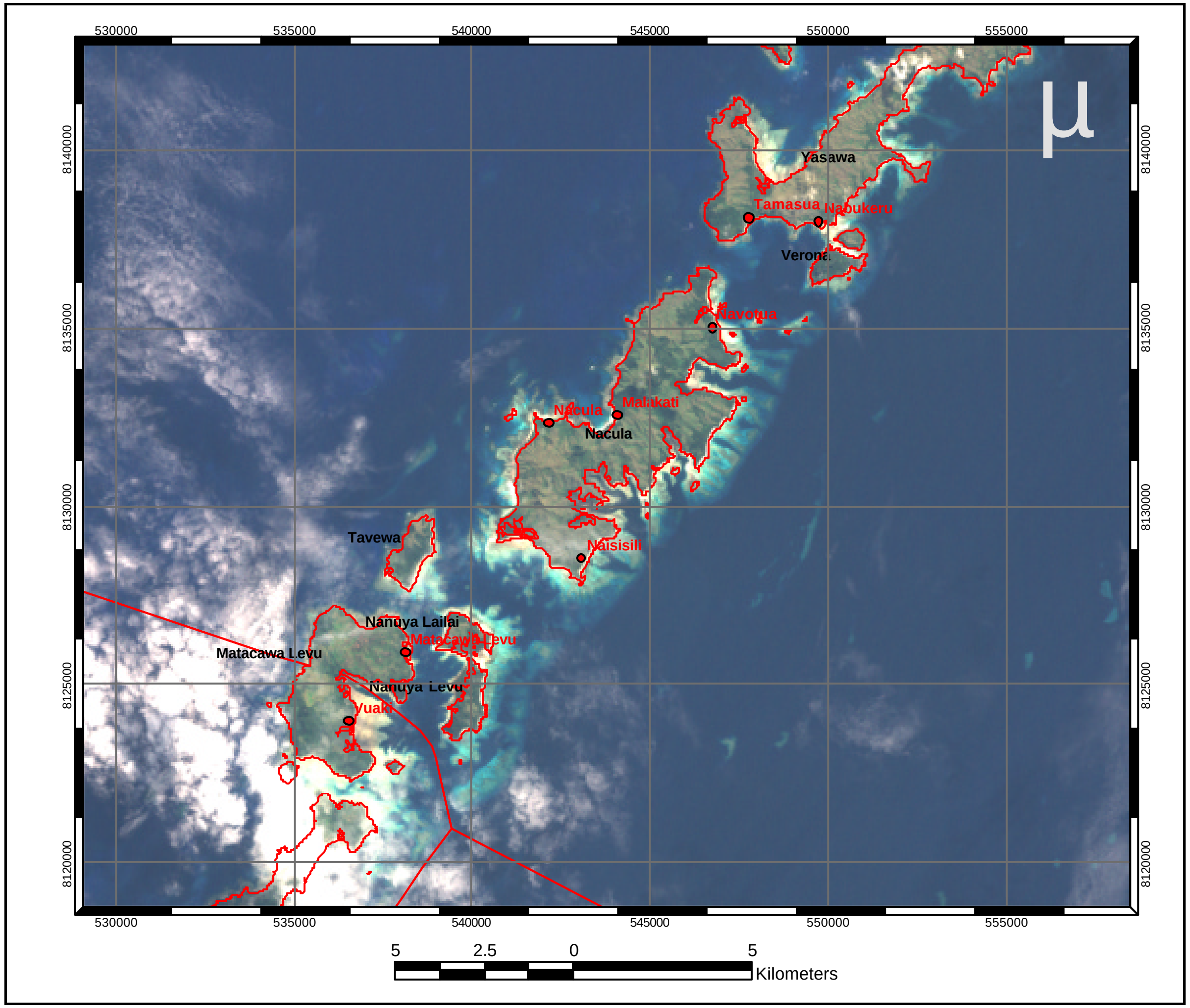

Figure 3. Traditional fishery grounds (iqoliqoli) in the central Yasawa Islands

This report documents the results and conclusions of the marine surveying programme of the Yasawa Island Coral Reef Conservation Project and offers recommendations for both conservation initiatives and future work in the project area in the coming year.

2.3 Aims and Objectives

The establishment of the Yasawa Island Coral Reef Conservation Project had the aims of undertaking a series of baseline surveys on and around Nacula Island towards an understanding of the condition of the coral reef resources in the area.

In addition to this survey component of the work, a programme of education and capacity building was also undertaken involving the major stakeholder groups in the Yasawas including tourist operators, school children and local communities.

2.3.1 Project Activities and Timetable

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

Data Acquisition and Management (Table 1)

1. Systematic surveys of all reefs around Nacula and Tavewa Islands from CCCs base of operations on Nacula Island employing survey divers trained by CCCs *Skills Development Programme* Table 2)
2. Assess the environmental impacts and physical oceanography of the coastal areas on the local coral reefs of Nacula and Tavewa Island. Again, this will be carried out using divers that have been trained during the *CCC Skills Development Programme* Table 2)

Counterpart Training and Conservation Awareness Programmes (Table 1)

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. In the case of the Yasawa Islands project, this training was conducted from CCCs main base of operations in the Mamanuca Islands
2. Establish a schools curriculum for conservation education by participating and joining Ratu Meli Memorial School in the Nacula area with presentations, classes and interactive practical classes on the local marine environment.

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 Yasawa Islands.

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 *Yasawa Islands Coral Reef Conservation Project March 2004- May 2005*.

ACTIVITY - Marine	**2004**										**2005**					**ASSUMPTION**
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	
Data Acquisition and Management																
Development of a comprehensive classification scheme for the reefs around Nacula and Tavewa Islands	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	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)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Counterpart Training, Capacity Building and Environmental Education																
Counterpart Training (to be conducted at CCCs main base of operations in the Mamanuca Islands)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Appropriate individuals are identified
Report production	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Reporting to Ministry of Tourism
Schools visits	•	•	•								•	•	•			Acceptance of local schools to facilitate visits by CCC staff.
Report Production					•											

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2.3.2 Geographic Information Systems

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

3. METHODS

3.1 Survey strategy

Since the area encompassed by the YICRCP is large and occupies the reef systems around both Nacula and Tavewa Islands, the survey strategy was designed to sample a representative portion of the main geomorphologic areas of the reef systems.

The Concept Of 'Survey Sites'

During the YICRCP, 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 shown in figure 4. 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 seven survey sectors were designated for potential surveying during the YICRCP (figure 4). Baseline transects were completed throughout all months of the YICRCP.

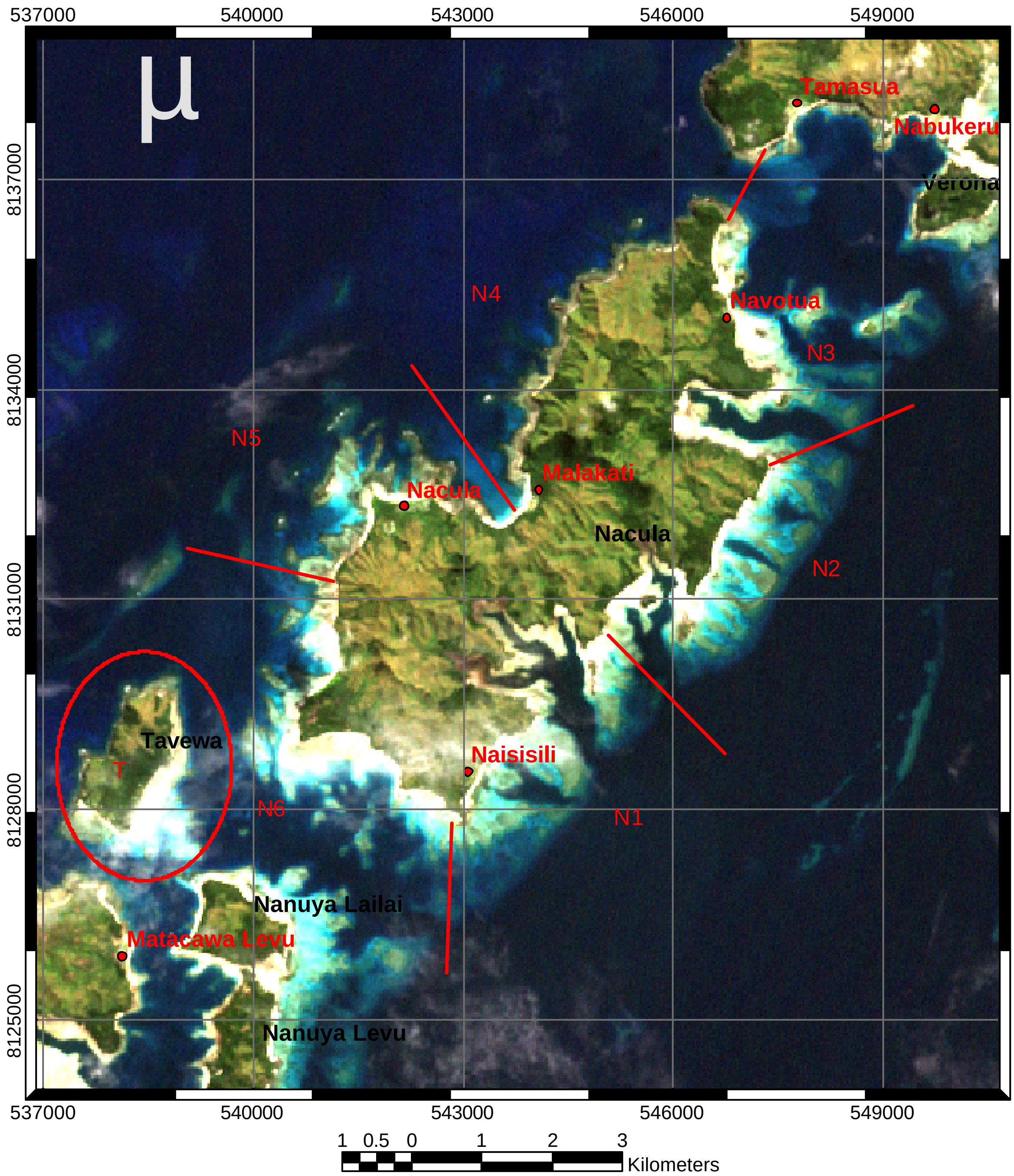

Figure 4. Location of the different 'Survey Sectors' around Nacula and Tavewa Islands. Seven survey sectors are highlighted in red (N1-N6 and T).

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 YICRCP, CCC used an intensive two-week training programme, which is outlined in table 2. 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 2. CCC Skills Development Programme timetable for CCC volunteers and local counter-parts during the YICRCP

	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 2(continued). CCC Skills Development Programme.

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

3.3 Baseline transect technique

The YICRCP 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 5. 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.

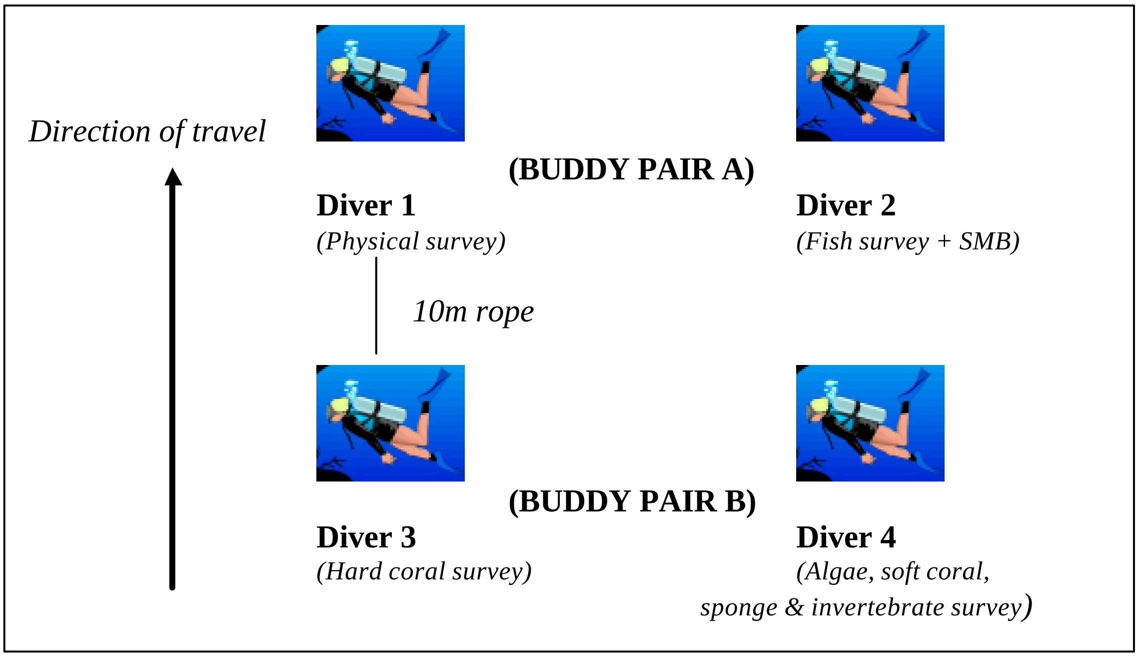

Figure 5. Schematic diagram of a baseline survey dive team showing the positions and data gathering responsibilities of all four divers. Details of the role of each diver are given in the text.

Each species, life form or substratum category within each ten meter sub-transect encountered was assigned an abundance rating from the ordinal scale shown in table 3.

Table 3. 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 6). 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.

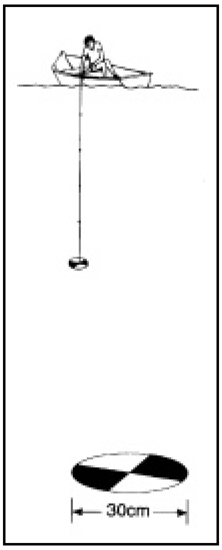

Figure 6. The use of a secchi disc to assesses vertical water clarity. The secchi disc is lowered into the water until the black and white quarters are no longer distinguishable. The length of rope from the surveyor to the disc is then recorded. *Source*: English *et al.* (1997).

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 Data analysis

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

3.5.1 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 survey sectors as appropriate.

3.5.2 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).

3.5.3 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.

3.6 Habitat Mapping

A Landsat 7 ETM+ satellite image produced by the U.S. Geological Survey (USGS) was purchased for use in the FCRCP. Landsat 7 carries the Enhanced Thematic Mapper plus (ETM+) sensor in support of research and applications activities. Further details are available from the USGS website[1]. The image was acquired on 18th May 2001.

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

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

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

The final stage in the pre-processing of the Landsat image prior to classification was to perform a water column correction technique with the aim to remove the effect that the overlying water column has on the spectral composition of the light reflected by the coral reef. The purpose behind the employment of this technique is that frequently the effect of the water column on the attenuation of light from a coral reef target is far greater than the

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

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

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

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

3.7 Conservation Management Ratings and Geographic Information System

In order to examine the relative health, diversity and status of the coral reef areas in the central Yasawa Islands, an innovative method of calculation has been devised. The theoretical basis behind the conservation management rating system is that areas of coral reef around which Marine Protected Areas should be established to maximise their benefit should be as biodiverse, productive and representative of all habitats. This technique combines many of these variables based upon the classification of coral reef areas that have been surveyed and subsequently classified into a habitat.

Once all survey records had been assigned to one of a discreet number of benthic classes, further analysis based on these subsets of data was performed. The total number of species and Shannon-Weiner diversity indices have been calculated on both the benthic community as well as on the fish communities that were recorded by CCC divers at the site of each Survey Record. Finally, values of average hard coral cover from the detailed habitat descriptions for each habitat were also extracted. Average values for each of these biological indicators of reef health were then calculated across the entire data set.

To quantify the spatial distribution of areas of reef, each Survey Record was assigned a rating from one to five. A score of zero on this rating scale equates to the Survey Record belonging to a habitat or benthic class where none of the five univariate reef health indicator variables were above average across all the Survey Records analysed. By contrast, a Survey Record with a score of five belongs to a benthic class where all five variables were above the average value calculated.

Each transect surveyed during the CCC Baseline technique is comprised of a composite of more than one Survey Record, each of which may belong to different benthic classes and therefore have differing degrees of reef health. By splitting each transect into its constituent parts, and weighting the composition of each transect according to the length surveyed, it was possible to construct an overall reef health statistic for that survey transect ranging from 0-5. To facilitate easy interpretation of these values, the following scale was used; where transects scored an overall rating >4.5 they were classified as of high management potential, from 3.5-4.5 as moderate management potential and finally below 3.5 of low management potential. With each of these transects being spatially locatable data sets, a map to show the relative management potential of each transect surveyed thus far has been constructed.

The resulting map illustrates point data sources but does not allow the overall interpretation of conservation value of areas surrounding these transect points. To allow this, a unique mapping procedure was performed. The first stage in this methodology was to produce a density grid over the survey area that illustrates the density of the both transects and also the relative management value of these transects. It was realised however that areas of high density could be as a result of higher survey effort in a reef area and not as a result of high management potential rating. To overcome this, another density grid of survey effort was created, the units of which, although arbitrary, represent the number of transects per reef unit area. Finally, by performing a calculation on the raster layers in a Geographic Information System to divide the density grid of management value combined with survey effort and the grid of survey effort alone, the output density grid is weighted for survey effort and represents only the density of management value.

This output image was contained in a Geographic Information System that allows users to query and delineate areas of high conservation and management value, to calculate the geographic area comprising these sites and to add, for example, buffer zones of a set distance around each of these sites of interest.

The production of this map is the culmination of the work conducted by CCC in the YICRCP. It has huge potential of use for all stakeholders; allowing a degree of flexibility in the identification of key sites of biodiversity in the central Yasawa Island region.

3.8 Environmental Awareness and Community work

3.8.1 Environmental Awareness Teaching at Local Schools

In the early stages of the YICRCP an environmental education programme was implemented at Ratu Meli Memorial School on Nacula Island. A ten-week programme was developed to coincide with the term time and was directed at class 8 students. The course focused on introducing reef ecology and biology concepts to highlight the fragile nature of the reef systems and the need for management, thereby increasing the environmental awareness of the children. Concepts were promoted through worksheet exercises, word games, drama, art, group debates, and physical exercises such as litter surveys. 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. The curriculum taught at the school is shown in table 4.

Table 4. Marine Environment Programme schedule for Ratu Meli Memorial School

WEEK	ACTIVITY SCHEDULE
1	**Introduction to MES, CCC and Reef Check.** Teach Reef Check survey technique, survey the proposed tabu area Collate data from surveys, discuss implications of data
2	**What is the coastal zone?** Description of the coastal zone Forests, mangroves, seagrass beds; their importance to humans and to other ecosystems Brainstorming session: types of trees found in Fijian upland forests
3	**Coral reefs as part of the coastal zone** Description of coral reefs, where they are found globally and why What corals need to grow, what corals eat Structure of a coral polyp Common types of reefs
4	**Importance of reefs and coastal zone interaction** Why coral reefs are important to humans and to other ecosystems How the four communities of the coastal zone are interlinked
5	**Threats to the coastal zone** Threats facing forests, mangroves, seagrass beds, and reefs Brainstorming session: natural and anthropogenic threats to reefs
6	**Animals on the reef** Introduction to 10 animals found on the reef: coral polyp, lobster, octopus, sponge, sea urchin, crown of thorns, sea cucumber, parrotfish, triton trumpet shell and giant clam. Activities: various activities based around these animals
7	**Food webs** How energy is transferred through a coral reef ecosystem Symbiotic relationships on the reef Activity: construct a coral reef food web, what happens if certain elements are removed
8	**Human impacts on coral reefs – litter** How long litter persists in the environment Brainstorming session: why litter might be bad for the reef Litter survey: collection of litter on the beach, followed by discussion of what was collected Suggestions on how to minimise littering The theory of composting Activity: making and tending a compost heap
9	**Human impacts continued – fishing** Good and bad fishing practices Minimum catch sizes for important food fishes Activity: fish questionnaire – impacts of fishing
10	**Human impacts continued – sediment, sewage, tourism, villages** Causes and effects of reef sedimentation, effects of sewage disposal, tourism and village communities on the reef Brainstorming sessions: how tourism-related activities might harm the reef, what activities within a village community may harm the reef

Table 4 (cont). Marine Environment Programme schedule for Namamanuca Primary School

WEEK	ACTIVITY SCHEDULE
11	**Skits on threats and benefits to reefs** Acting out 10 brief skits on threats to and benefits of reefs: fishing for the family, fishing for income, tourists enjoying the reef, reef protecting the village, variety of marine life, overfishing, land pollution, sewage, pollution, working together for a better future
12	**What are Marine Protected Areas?** The difference between a Marine Protected Area (MPA) and a tabu area What is an MPA, why set one up Advantages of MPAs

4. RESULTS

In this report, analysis has been conducted at two levels; data on anthropogenic impact and oceanographic observations as well as fish and invertebrate population studies is analysed at the level of analysis sectors identified in figure 4. This data has then been combined to examine the benthic classes or habitats throughout the whole study area, upon which calculations of biodiversity, habitat cover and conservation value have been conducted towards the identification of areas of high biodiversity and ecosystem and therefore management importance. All data analysis techniques lead to the contents of the discussion. The analysis of the data is schematically presented in figure 7.

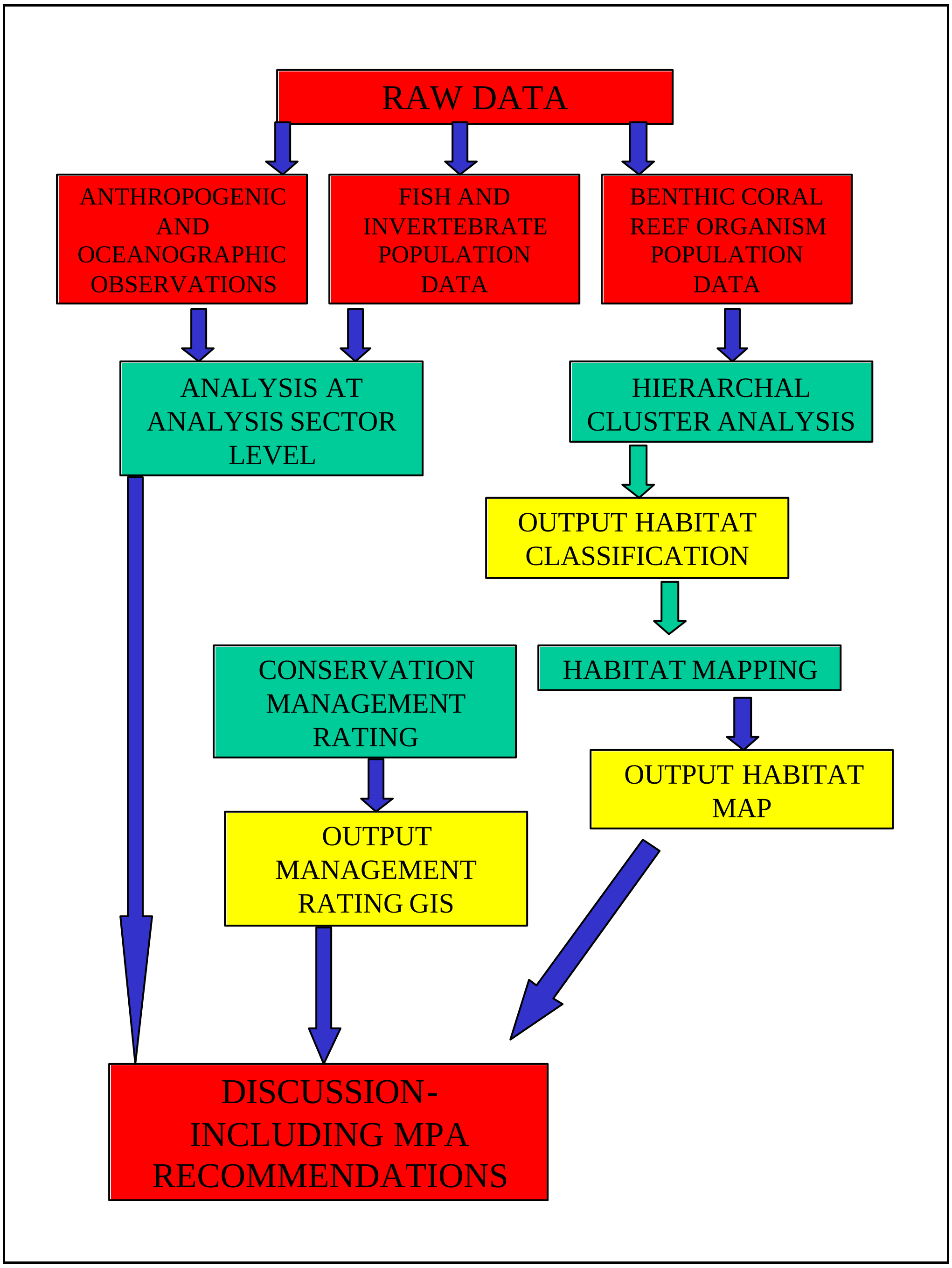

Figure 7. Schematic representation of data analysis techniques employed in this report.

4.1 Survey Progress

Of the seven survey sectors included in the Yasawa Island Coral Reef Conservation Project, all have been surveyed. The quantity of surveys done in each varies dependent on the timeframe in which the project was conducted.

In the YICRCP, a total of 497 survey dives were conducted on 42 transects. With four survey divers per team, this equates to approximately 1000 man-hours of surveys. Additionally, CCC survey teams made 33,300 observations on abundance of target species during this period.

Figure 8 shows the spatial distribution of these transects indicating the start points of each transect from which surveys were undertaken towards the shore or shallow water.

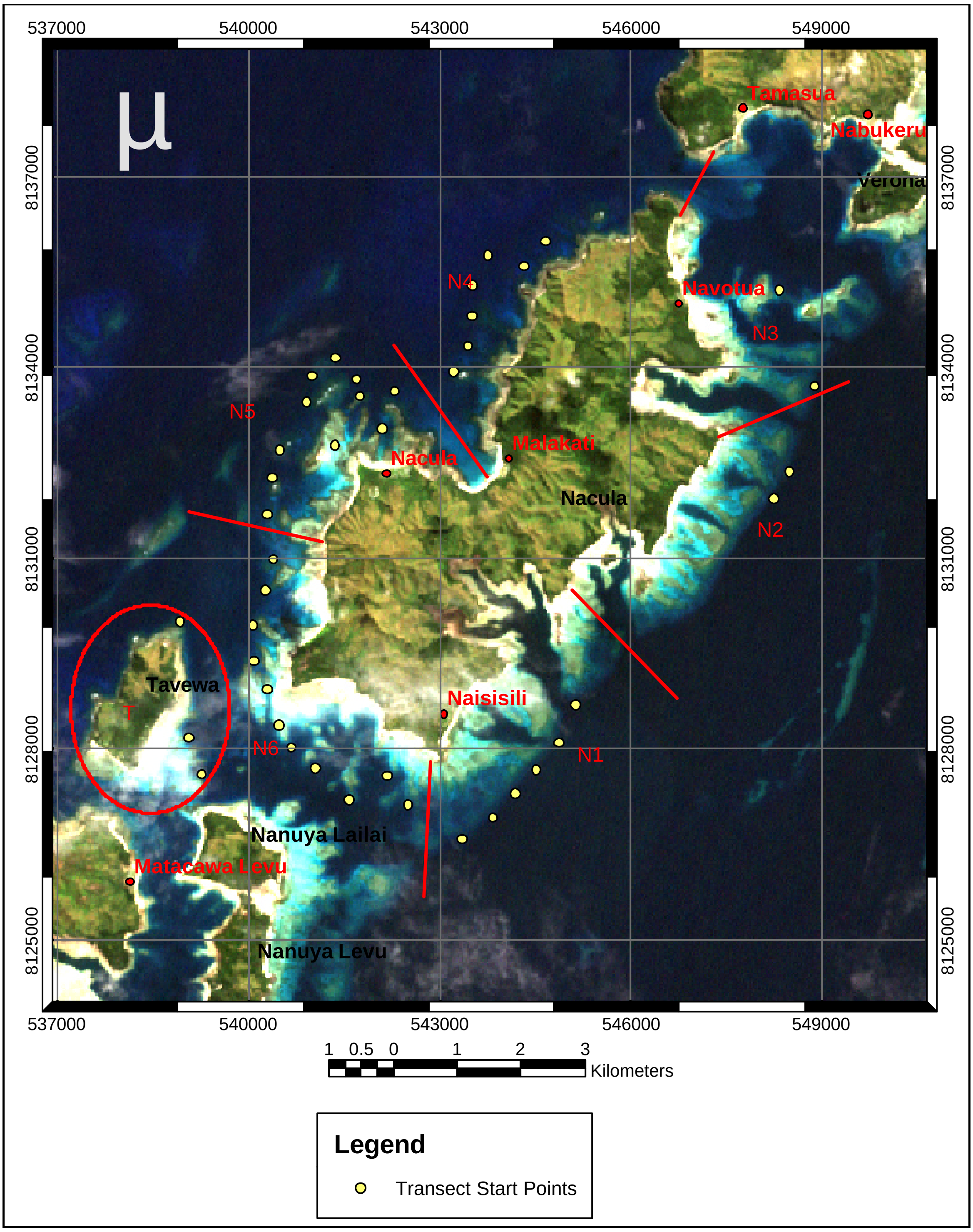

Figure 8. Start points of Baseline survey Transects conducted by CCC during the YICRCP.

4.2 Oceanographic, climate and anthropogenic impact data.

4.2.1 Water Temperature

Water Temperatures recorded during the YICRCP have been summarised in figure 9. Average surface temperatures for the study area measured 28.1 ^{o}C (standard deviation 1.3 ^{o}C; n = 862). Water temperatures collected by survey teams at the maximum survey depths were summarised in 5m depth classes (0.1-5 m, 5.1-10 m, 10.1-15 m, 15.1-20 m, 20.1-25 m, 25.1-30 m). The lowest mean temperatures occurred both in the surface waters and also in the depth range of 20-25 meters (28.1and 27.5 ^{o}C). Highest temperatures were recorded in the shallow depth range (0-5, 5-10 and 10-15m) with average temperatures of 28.6, 28.5 and 28.5 ^{o}C respectively.

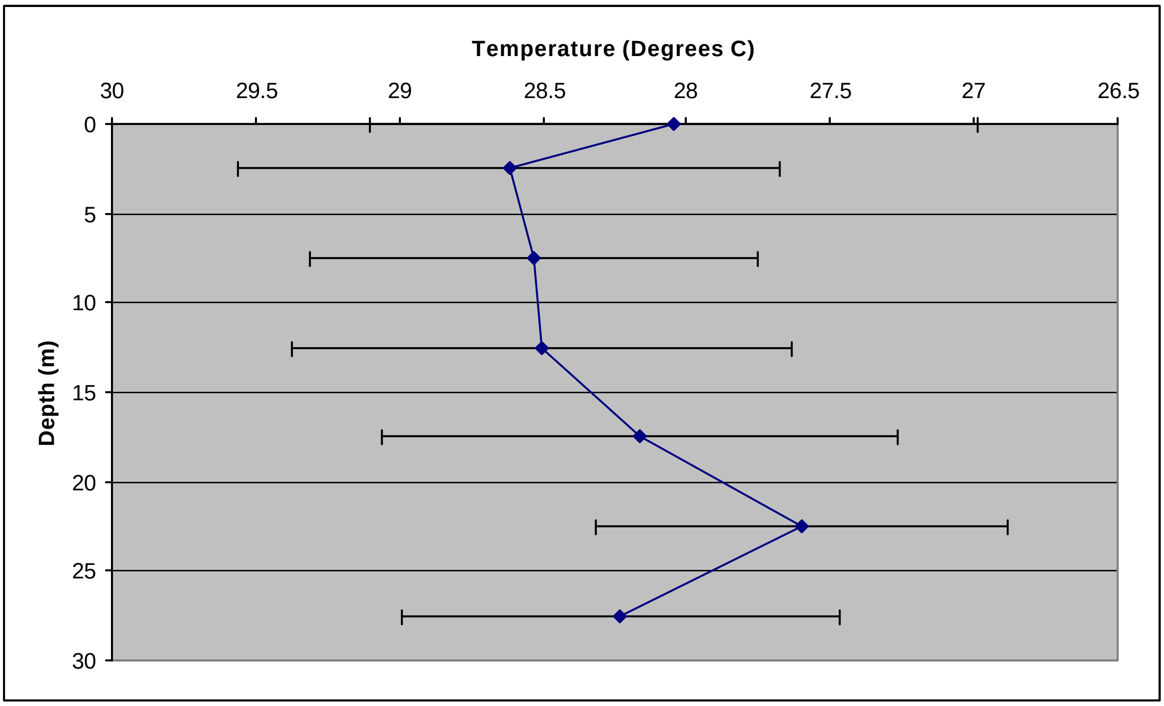

Figure 9. Mean water temperatures for all surveys in the project area in 5m depth classes throughout the water column. Bars represent standard deviation. Sample sizes: Surface Water = 502, 0.1-5 m = 123, 5.1-10 m = 88, 10.1-15 = 93, 15.1-20 m =67, 20.1-25 m = 80, 25.1-30 m = 26.

4.2.2 Water Salinity

Salinity measurements collected by survey teams during the YICRCP show little variation in salinity between the nine analysis sectors. Further analysis of the data revealed a degree of variation in salinity with depth, as shown in figure 10. Salinity measurements taken vertically through the water column are summarised in 5 m depth 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). Salinity values are given as Practical Salinity Units (PSU) that are equivalent to parts per thousand (‰) of sodium chloride. Between 0 m and 30 m, average salinity fluctuated between 31‰ and 32.5‰. The highest variation in salinity levels was found between 5-10 and 10-15 meters as represented by the wide standard variation bars on the graph. Overall, there is a general decreasing trend in salinity levels with increasing depth with the lowest value of 31‰ recorded in the 25-20 meter depth range.

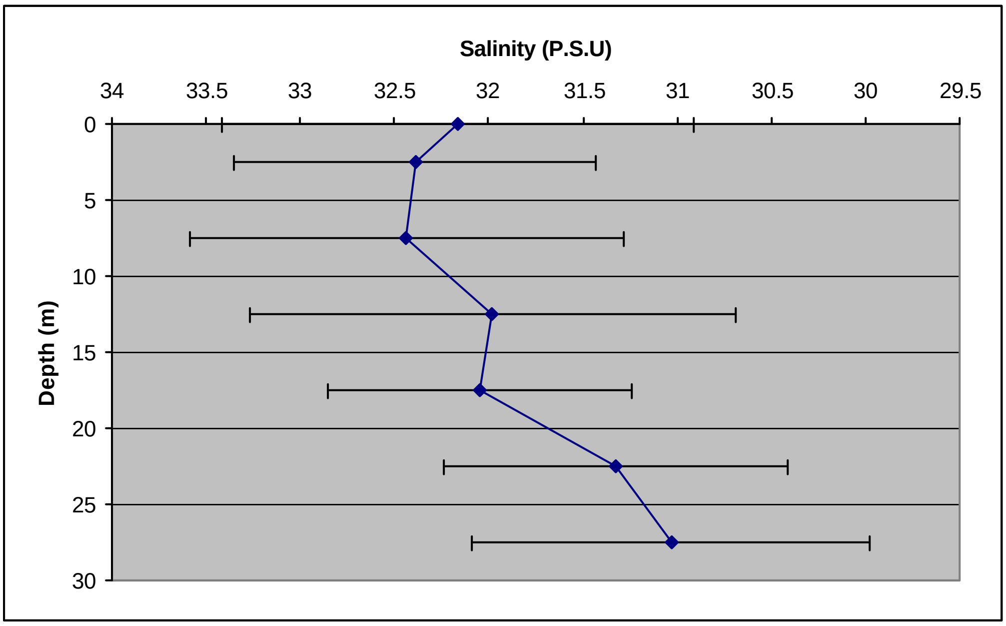

Figure 10. Mean water salinity for all surveys in the project area in 5m depth classes throughout the water column. Bars represent standard deviations. Sample sizes: Surface Water = 500, 0.1-5 m = 124, 5.1-10 m = 88, 10.1-15 = 95, 15.1-20 m = 67, 20.1-25 m = 80, 25.1-30 m = 26.

4.2.3 Water visibility

A summary of inverse secchi disc readings of vertical underwater visibility is shown in figure 11. Visibility varied between analysis sectors from 7.4 in survey sector N2 to more than 9 m in sector N5.

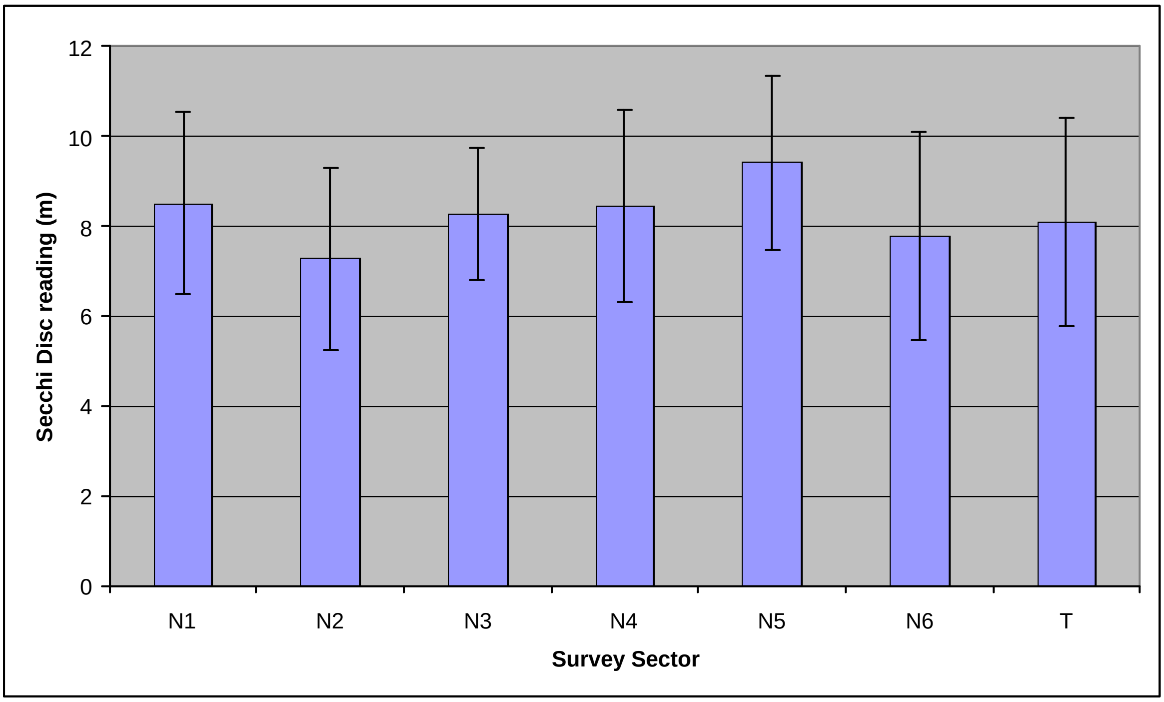

Figure 11. Mean Secchi Disc recordings of vertical water visibility in metres. Bars represent standard deviation for each analysis sector. Sample sizes: N1= 85, N2 = 25, N3 = 18, N4 =78, N5 = 176, N6 = 97, T = 9.

4.2.6 Surface Impacts

Impacts seen by CCC divers on the surface of the sea during the YICRCP are summarised in figure 12. In the figure, the occurrence of impacts are shown as a percentage of the transects conducted in each survey sector during which the impact was observed. The most commonly observed impact across all sectors was floating mats of unattached algae. Comprising these mats, the most commonly observed species were members of the Genera *Gracillaria and Sargassum.* In addition to these macroalgae, occasionally observed were slicks of microalgae. The second most commonly observed surface impact was the presence of litter which was seen in 22% of all transects conducted in survey sector N2. There was however a large degree of variation in the occurrence of litter, with it not being recorded in sector N4 and only seen very occasionally in sector N5. From the occurrence of litter, there appears to be a pattern in recordings between east-facing coasts of Nacula where litter was found and the west-facing coast where litter was largely absent. Nets were seen floating on the surface around Tavewa Island though was only recorded in one of the surveys undertaken.

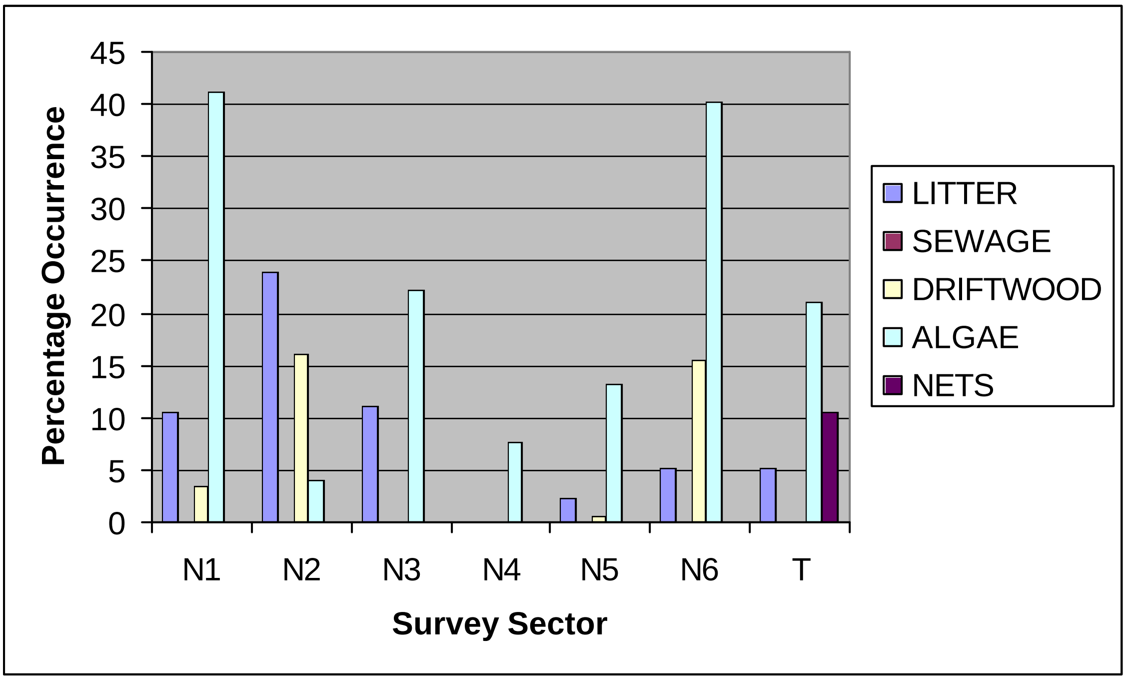

Figure 12. Frequency of observation of surface impacts recorded during the YICRCP.

4.2.7 Sub-surface Impacts

Impacts seen by CCC divers under the surface of the sea during the YICRCP are summarised in figure 13. In the figure, the occurrence of impacts are shown as a percentage of the survey dives conducted in each survey sector during which the impact was observed. Coral damage was seen in all survey sectors and was particularly commonly observed in the survey sectors around the southwest and south of Nacula Island (N5 and N6). Coral bleaching was seen as one of the more common under-water impacts and in N2 and N6 was the second most commonly observed impact having been seen on 20 and 15.5% of all survey dives conducted in these areas. Sedimentation of live hard coral was observed to be very common in the southern-most survey sector on Nacula Island with observations being made of this impact on 26% of all survey dives conducted in this area. Finally, the occurrence of litter was most commonly observed around Tavewa Island with litter being seen on 16% of all survey dives conducted there.

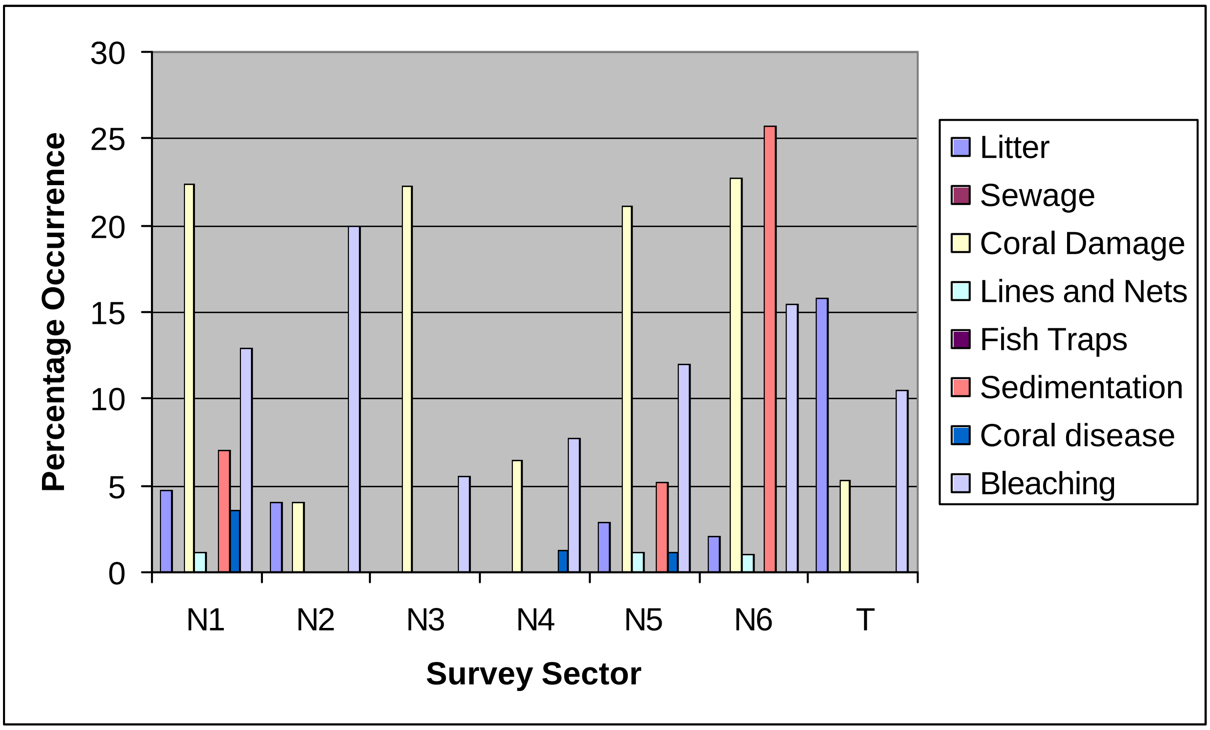

Figure 13. Frequency of observation of sub-surface impacts recorded during the YICRCP.

4.2.9 Aesthetic and Biological Impressions

A summary of both the biological and aesthetic values of the coral reefs surveyed in the YICRCP are given in figures 14 and 15 respectively. Whilst aesthetic and biological impressions of survey divers are subjective, they do allow a crude-scale assessment of the coral reef conditions prevalent in each survey sector to be made.

The only survey sector in which survey dives were rated by surveyors as excellent were conducted in survey sector N3 at the northern tip of Nacula Island. However, also within this survey sector, there were a high proportion of survey dives that were adjudged to be poor in aesthetic value (50%). This indicates that the reefs surveyed in this area may be of patchy and heterogeneous value in terms of their aesthetic value. Across all of the survey sectors, sector N1 had perhaps the best overall observed aesthetic value for whilst there were no excellent impressions recorded, it did receive a high number of very good, good and average ratings with proportionally few poor ratings. This survey sector is located at the southeast tip of Nacula Island. Finally, sector N6 had perhaps the lowest overall rating of aesthetic value, with no excellent ratings, very few very goods and over 57% of all survey dives conducted in the area being rated of poor aesthetic value.

In terms of the ratings made of the relative biological values of each survey sector, sector N3 is the only sector that has a substantial amount of excellent rated observations. Sector N2 is the sector with overall observed lowest biological value with 80% of observations being recorded as average 10% as poor and only 10% rating good or above. Overall, the survey dives conducted around Tavewa Island had the best biological impression, with 30% of survey dives being rated as having very good biological value, a further 35% as being either good or average and only 35% being of poor biological value.

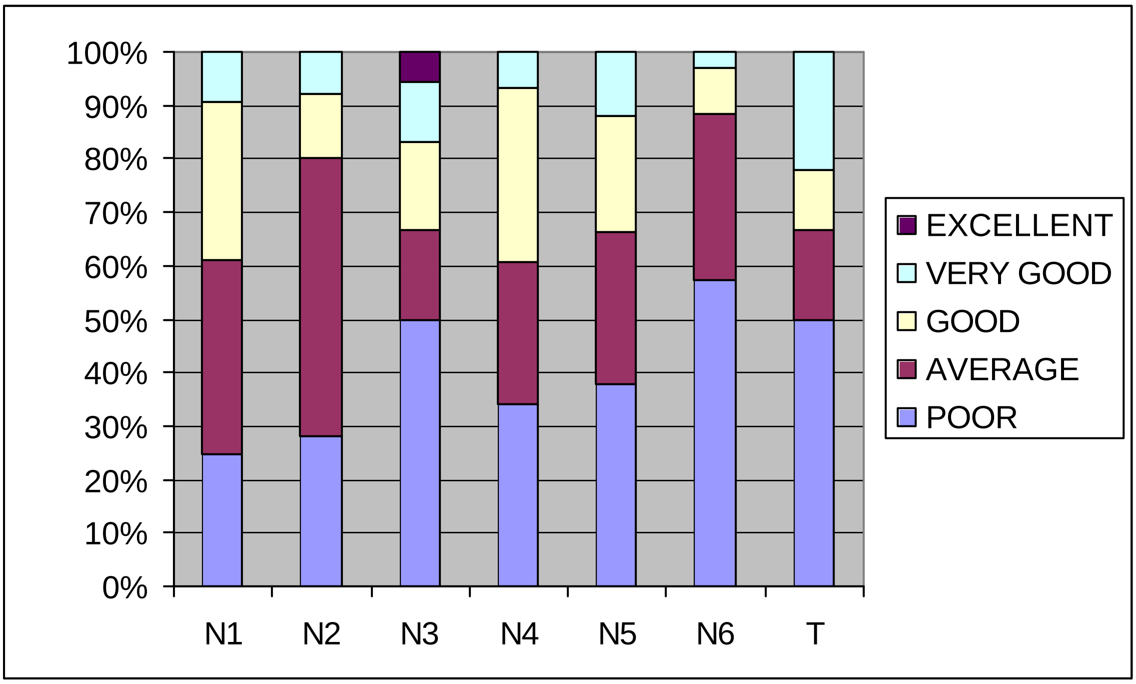

Figure 14. Summary of aesthetic ratings in each analysis area. Ratings assigned from a scale 0-5 where 0 is poor and 5 is excellent. Sample sizes: N1= 85, N2 = 25, N3 = 18, N4 =78, N5 = 176, N6 = 97, T = 9.

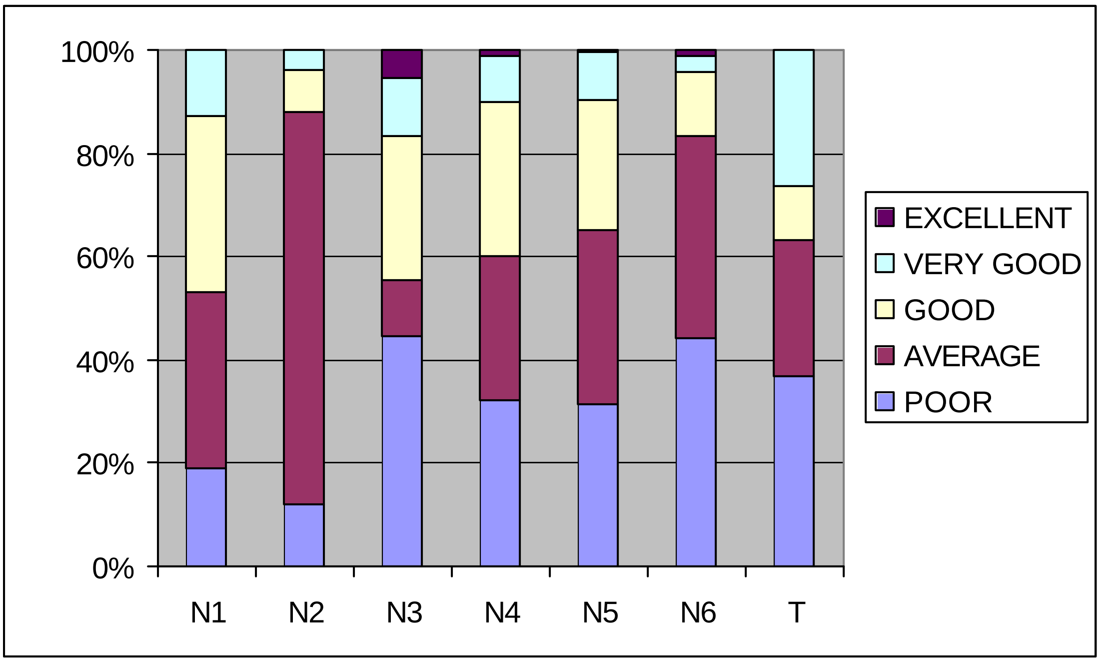

Figure 15. Summary of biological ratings in each analysis area. Ratings assigned from a scale 0-5 where 0 is poor and 5 is excellent. Sample sizes: N1= 85, N2 = 25, N3 = 18, N4 =78, N5 = 176, N6 = 97, T = 9.

4.3 Multivariate analysis and benthic habitat definitions

A total of eight discreet Benthic Classes or habitat types have been identified using the procedure of agglomerative hierarchal clustering using the data collected in the Yasawa Island Coral Reef Conservation Project

The dendrogram produced from the process of hierarchal cluster analysis is shown as figure 16.

The habitat types are quantitatively described below in table 5. A breakdown of the main biological and substratum classes that characterise each of these benthic habitats is given.

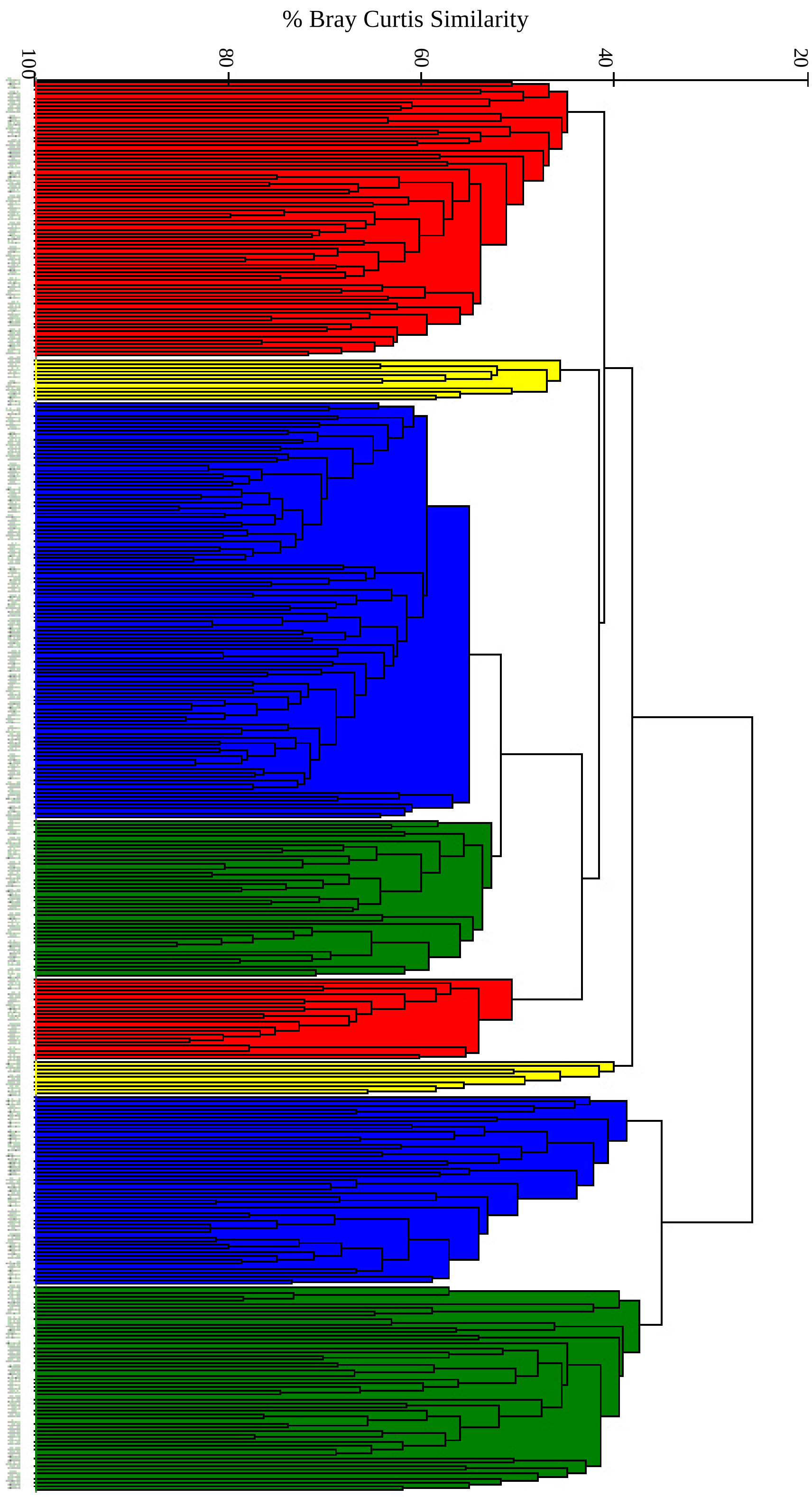

Figure 16. Dendrogram produced from cluster analysis of CCC baseline survey data collected in the YICRCP. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%).

Table 5. Quantitative description of the eight benthic classes defined from the data collected during the YICRCP. 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	Sponges	Algae / Seagrass
1 – Shallow sand and bedrock substrate with moderate hard and soft coral coverage with calcified green algae dominated assemblage	155	5.6	Sand (2.0), Bedrock (1.9), Dead Coral w Algae (1.6), Rubble (1.0)	Total Hard Coral (1.8), *Favites sp* (0.7), *Acropora* tabulate (0.7) and branching (0.7)	Total Soft Coral (1.4)	Total Sponge (1.0)	*Green Calcified (1.5),* Halimeda sp *(1.4), Cyanobacteria (1.0), Green Filamentous (0.9)*
2 – Shallow benthos comprised of dead coral and sand, with *Acropora* dominated coral community	19	6.3	Dead Coral w Algae (2.2), Sand (2.1), Rubble (1.2)	Total Hard Coral (1.9), *Acropora* digitate (0.9), branching (0.9) and submassive (0.8)	Total Soft Coral (0.8)	Total Sponge (0.6)	Halimeda sp *(1.3), Cyanobacteria (1.0), Green Filamentous (0.9)*
3 – Bedrock, dead coral with algal overgrowth and sand substrate, with high live hard/soft coral and algal coverage	198	10.3	Bedrock (2.0), Dead Coral w Algae (1.7), Sand (1.7), Rubble (0.9)	Total Hard Coral (2.0). Fungiidae (1.1), *Montipora sp* (1.1), *Pocillopora sp* (1.1), *Acropora carduus* (1.1)	Total Soft Coral (1.4)	Total Sponge (1.1)	*Green Calcified (1.6),* Halimeda sp *(1.5), Cyanobacteria (1.0), Green Filamentous (0.9)*
4 – Sand substrate, mixed with bedrock and dead coral with algal overgrowth, and moderate hard coral and algal coverage	81	11.0	Sand (2.4), Bedrock (1.6), Dead Coral w Algae (1.5), Rubble (1.2)	Total Hard Coral (1.7). Non-*Acropora* (1.1), *Acropora* tabulate (1.0) and branching (0.9)	Total Soft Coral (1.3)	Total Sponge (1.1)	*Green Calcified (1.5),* Halimeda sp *(1.4), Cyanobacteria (1.0), Green Filamentous (0.8)*
5 – Non-*Acropora* dominated coral community, with complex algal, soft coral and sponge assemblages	36	12.0	Bedrock (1.75), Dead Coral w Algae (1.7), Sand (1.6)	Total Hard Coral (2.3). *Favia stelligera* (1.3), *Fungia valida* (1.2), *Galaxea fascicularis* (1.1), *Favites sp* (1.1)	Total Soft Coral (1.6)	Total Sponge (1.3)	*Green Calcified (1.8),* Halimeda sp *(1.7), Cyanobacteria (1.0), Red Coralline (0.8)*
6 – Shallow bedrock-dominated benthos with mixed *Acropora* and non-*Acropora* coral community	20	5.6	Bedrock (2.8), Sand (1.7), Dead Coral w Algae (1.5), Rubble (0.9)	Total Hard Coral (1.4). Non-*Acropora* massive (0.9), *Acropora* branching (0.7), *Favites sp* (0.7)	Total Soft Coral (0.8)	Total Sponge (0.8)	*Green Calcified (1.2),* Halimeda sp *(1.1), Green Filamentous (1.0), Red Coralline (1.0)*

Table 5 cont. Quantitative description of the eight benthic classes defined from the data collected during the YICRCP. 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	Sponges	Algae / Seagrass
7 – Deep sand substrate with cyanobacterial overgrowth, but generally low biological cover	125	14.1	Sand (4.3)	Total Hard Coral (0.3). *Acropora* digitate (0.1)	Total Soft Coral (0.2)	Total Sponge (0.4)	*Cyanobacteria (1.4), Green Calcified (1.1),* Halimeda sp *(1.0), Green Filamentous (0.8)*
8 – Sand dominated benthos, with high calcified green algae cover	118	11.6	Sand (3.6), Bedrock (1.0), Dead Coral w Algae (1.0), Rubble (0.8)	Total Hard Coral (0.9). *Acropora* branching (0.5)	Total Soft Coral (0.8)	Total Sponge (0.8)	*Green Calcified (1.6),* Halimeda sp *(1.5), Green Filamentous (1.0)*

4.4 Biodiversity and Ecosystem Function of Benthic Habitat Classes

A number of univariate statistics can be used to represent the biodiversity, ecosystem function and productivity of the benthic habitat classes described from the data. The statistics presented here include the mean cover of live hard coral on the 0-5 DAFOR abundance rating, the total number of species of benthic organisms found and Marglef and $\log_e$ Shannon-Weiner diversity indices. The calculated values are presented in table 6.

Table 6. Univariate biodiversity and ecosystem function statistics calculated for each benthic habitat class described from data collected during the YICRCP. Benthic Classes highlighted in bold text indicate high biodiversity classes.

Habitat	Live hard coral cover	Total species	Marglef diversity index	Log_e Shannon-Weiner diversity
1	**1.8**	**167**	**46.55**	**4.41**
2	**1.9**	**142**	**41.02**	**4.52**
3	2.0	147	39.51	4.08
4	1.7	161	46.90	4.16
5	**2.3**	**110**	**28.24**	**4.27**
6	1.4	114	34.39	4.31
7	0.3	139	53.73	4.20
8	0.9	151	52.71	4.28

The three most diverse habitats classes described include habitats 1, 2 and 5. All of these three habitats have high live hard coral cover, with habitats 1 and 2 being found associated with the upper areas of the reef slope. Habitat 5 by contrast is a mid- to low-reef slope habitat on bedrock that supports a diverse community of both hard and soft corals.

4.5 Reef Fish Populations

Fish population data collected during baseline surveys in the YICRCP 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.

4.5.1 Fish Family and Selected Species Abundance

The ten most abundant reef fish categories found throughout the survey area are depicted in table 7 in terms of mean abundance for all baseline surveys seen in YICRCP. Damselfish (Pomacentrids) were the most abundant reef fish family found during surveys conducted throughout the project area, followed by the Wrasse family (Labridae) and then the Surgeonfish family (Acanthuridae) though it is shown in the next section that the distribution of Surgeonfish is highly heterogeneous.

Table 7. Mean abundances of the ten most commonly observed fish families throughout all survey areas conducted in the YICRCP as recorded during baseline surveys. Mean abundances correspond to the semi quantitative 0-5 DAFOR scale.

Reef Fish Family		Mean Abundance
Damselfish	Pomacentrids	2.33
Wrasse	Labrids	1.56
Surgeonfish	Acanthurids	0.84
Butterfly	Chaetodontids	0.73
Goby	Gobidae	0.61
Blenny	Blennidae	0.56
Chromis	Pomacentrids	0.52
Goatfish	Mullids	0.49
Fusilier	Caesionidae	0.45
Angelfish	Pomacanthidae	0.40

Figures 17 and 18 respectively illustrate the mean abundance recorded for the most and less commonly observed fish family across each of the survey sectors in the YICRCP. The data in figure 17 illustrates that Damselfish were seen ubiquitously throughout the survey sectors, with little variation from the mean abundance of 2.33 seen in the whole survey area. By contrast, Surgeonfish whilst being the third most commonly observed fish family across all surveys conducted have extremely heterogeneous distribution with a mean abundance of over 1 on the semi-quantitative DAFOR scale in sector N4 and an abundance of less that 0.5 in sector N2. Likewise, Gobies and Butterfly fish have patchy distributions despite being the third and fourth most commonly observed fish families across all survey sectors.

Amongst the less frequently observed fish families shown in figure xxx, the most striking feature is the abundance of Fusiliers seen in sector N3 where members of this family were recorded with a mean abundance 1.3, yet were seen with a mean abundance of only 0.18 around Tavewa Island.

Kruskal-Wallis analysis of mean abundance between survey sectors indicates that of the fish families, Blennies, Surgeonfish and Damselfish were seen with abundances across survey sectors that were significantly different. In the case of the Surgeonfish this is likely because of the very high abundance observed in sector N3 compared to relatively lower abundances across all other survey sectors. By contrast, both the Blennies and Damselfish were seen with varying abundances across all survey sectors. These results likely relate to the feeding mechanisms and behaviour of each of these families. Surgeonfish and Damselfish are algal grazers and therefore can be expected to be closely associated with geographic areas in which there is high macroalgal cover. The most commonly observed species of Blennies live in burrows they have constructed in soft sediment areas and therefore were their recordings were restricted largely to lagoon and lower reef slope areas where sand and rubble predominates.

There were no other significant differences in the distribution and abundance of fish families between survey sectors.

Table 8. Results of Kruskal-Wallis test comparing the abundance of major fish families between survey sectors. Degrees of freedom=8 for all tests. Results shown in bold indicate significance.

Fish Family	Kruskal-Wallis statistic (H)	P-value (adjusted for ties)
Blenny	11.48	0.009*
Surgeonfish	20.92	0.001*
Damselfish	12.14	0.033*
Butterflyfish	4.25	0.236
Angelfish	4.58	0.334
Fusilier	5.10	0.403
Goby	2.70	0.609
Wrasse	3.43	0.634
Goatfish	1.59	0.810
Chromis	1.53	0.821

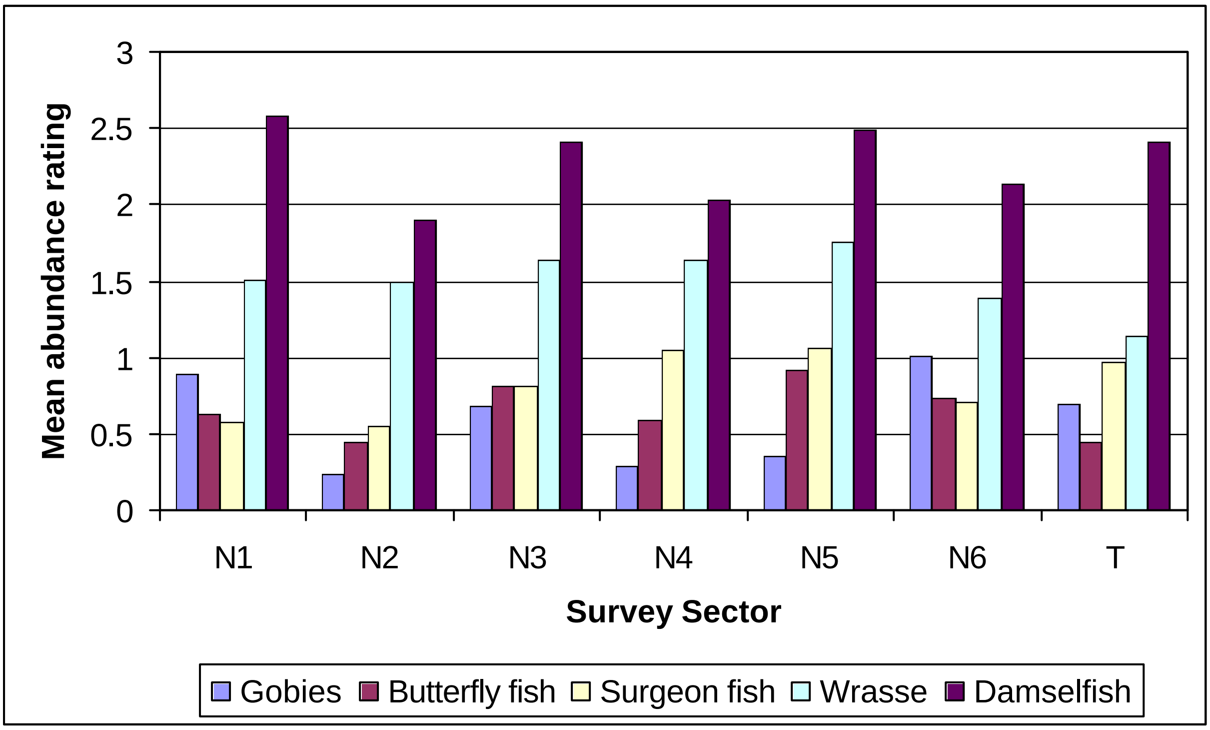

Figure 17. Mean abundance of commonly observed fish families by Survey Sector. Mean abundance refers to the values recorded on the 0-5 DAFOR semi quantitative abundance scale.

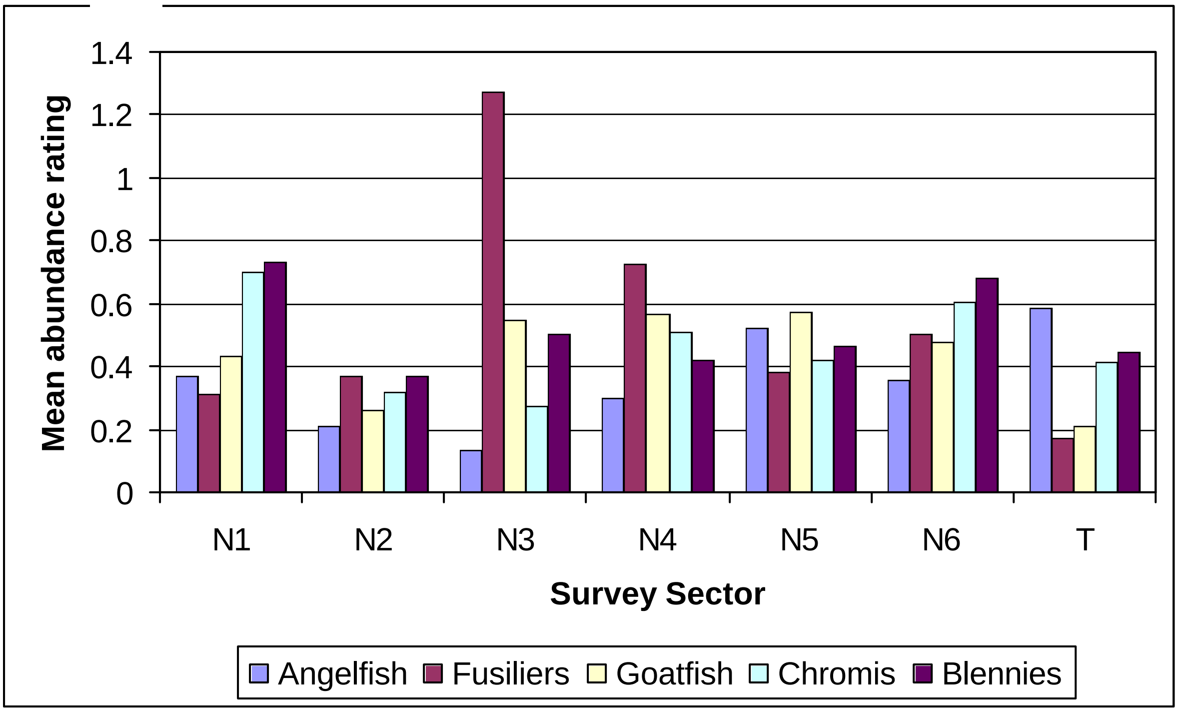

Figure 18. Mean abundance of less commonly observed fish families by Survey Sector. Mean abundance refers to the values recorded on the 0-5 DAFOR semi quantitative abundance scale.

4.5.2 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.

4.5.3 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 table 10.

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= 0.41, P-value= <0.01).

The fish assemblages associated with habitat 7 are statistically different from all assemblages found associated with other habitats. A comparison of biodiversity indices for the benthic identified in the YICRCP region clearly shows that BC 7 (deep sand substrate) is the least rich habitat in terms of biodiversity of reef fish (table 9) with the fish assemblage associated with this habitat having the lowest overall diversity as measured by the Shannon-Weiner diversity index. By contrast, the fish found associated with habitats 3, 4 and 5 are similar to each other and according to the univariate biodiversity statistics of these assemblages (table 9), are all high biodiversity assemblages. This indicates that protection of geographic representative of these habitats would also ensure protection of a biodiverse coral reef fish assemblage.

Table 9 Univariate biodiversity indices calculated for fish assemblages associated with each habitat defined from data collected in the YICRCP. The four most biodiverse habitats in terms of the fish assemblages associated with them are shown in bold.

Benthic Class	Species Number	Marglef Richness (d)	Pielous Eveness (J')	Log_e Shannon-Weiner (H')
1	**130**	**40.0**	**0.84**	**4.07**
2	81	24.8	0.87	3.83
3	**139**	**42.7**	**0.82**	**4.03**
4	**110**	**37.0**	**0.84**	**3.95**
5	**103**	**29.7**	**0.87**	**4.01**
6	75	25.4	0.86	3.71
7	82	42.1	0.82	3.60
8	101	41.2	0.82	3.80

Table 10. Results of pairwise analysis on the fish assemblages found associated with each habitat defined during analysis of data collected during the YICRCP. Number in normal font represents R-statistic; figure in bold represents P-value. P-values marked with an asterisk indicate significant results. Note that 6 samples had to be removed, as they contained a zero abundance of fish.

BENTHIC CLASS	1	2	3	4	5	6	7
2	0.02 **0.564**						
3	0.018, **0.053**	0.02, **0.411**					
4	0.04, **0.045***	0.04 **0.705**	0.01, **0.121**				
5	0.06 **0.918**	0.02 **0.360**	0.02, **0.686**	0.04 **0.874**			
6	0.14 **0.041***	0.00 **0.412**	0.20, **0.005***	0.08, **0.121**	0.13 **0.02**		
7	0.56, **>0.001***	0.22, **>0.001***	0.67, **>0.001***	0.38, **>0.001***	0.30, **>0.001***	0.16, **0.011***	
8	0.26, **>0.001***	0.05, **0.767**	0.38, **>0.001***	0.06, **0.002***	0.01, **0.417**	0.05, **0.776**	0.13, **>0.001***

4.6 Invertebrate Populations

The mean abundance ratings for the ten most commonly observed invertebrate taxa over the YICRCP for all analysis sectors combined are depicted in table 11. The first thing of note is that all ratings were below a value of 1. This is on average an exceptionally low value when compared to work conducted using the same methodology in both Fiji at other CCC sites globally.

The most commonly observed taxa were the tunicates that were observed ubiquitously in all survey dives. Featherstars, the second most commonly observed taxa were seen with a patchy distribution occurring in certain instances with relatively high abundance. The *Diadema sp.* long spined sea urchins were seen in relatively high abundance in areas dominated by rubble substrate. Very few Giant Clams and Crown of Thorns Seastars were observed (0.013 and 0.012 mean abundance across all survey sectors respectively)

Table 11. Mean abundances of the ten most commonly observed invertebrate groups recorded throughout all survey areas during the YICRCP. Mean abundances correspond to the semi quantitative 0-5 DAFOR scale.

Invertebrate Group	Mean Abundance
Tunicates	0.76
Featherstar	0.70
Long spine sea urchin	0.46
Gastropod	0.46
Annelids	0.42
Zoanthids	0.28
Seastar	0.28
Short spine sea urchin	0.26
Bivalve	0.26
Synaptid sea cucumber	0.24

Of the most commonly observed invertebrate taxa (figure 19), tunicates were seen with a fairly ubiquitous distribution though differences are evident between survey sectors N1 and N6 versus sectors N4 and in the surveys done around Tavewa Island where the average abundance of tunicates in the first two was over 1 on the DAFOR scale yet was below 0.5 in the latter survey areas. Notably, crustaceans were absent from the surveys done around Tavewa Island yet were present in surveys done in all of the other survey sectors. Finally, cephalopods including octopus, squid and cuttlefish were present in surveys done around one survey sector- sector N3.

Within the echinoderms (figure 20), sea urchins were observed ubiquitously in all survey sectors, with the greatest abundance being in the surveys done around Tavewa Island. There are some observable differences in sea cucumber population distributions where they were observed with a mean abundance of 0.21 in all survey sectors except for in N4 and N5 where the mean abundance was below 0.05.

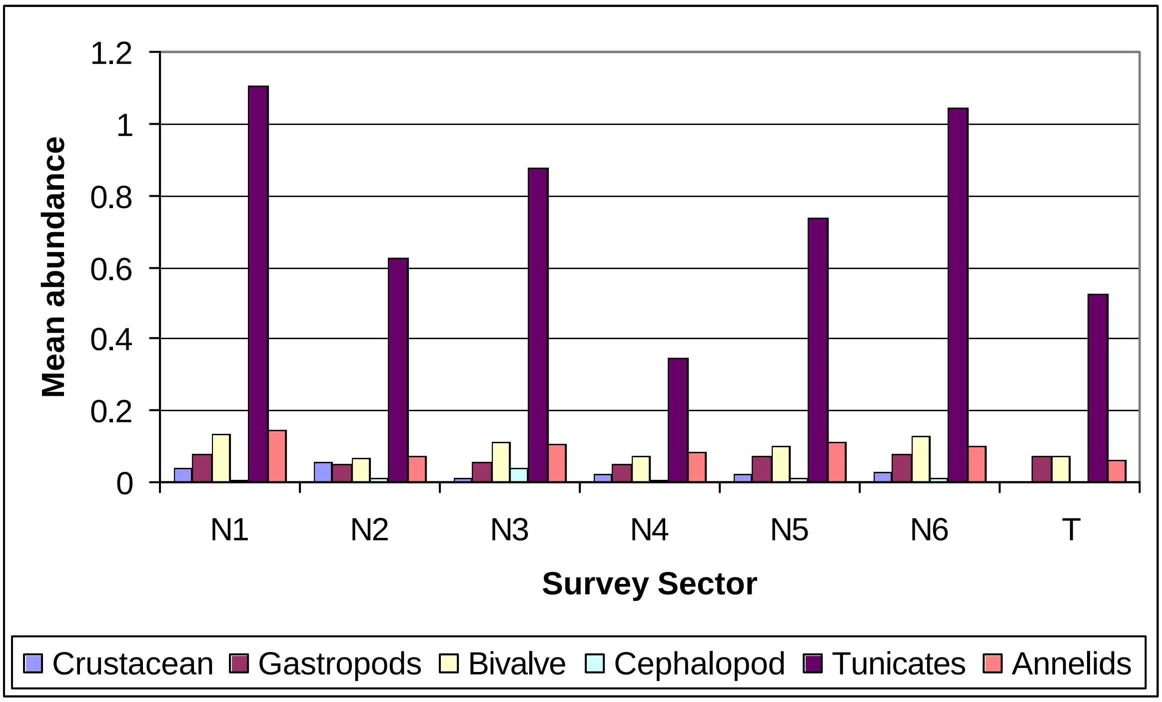

Figure 19. Mean abundance ratings for the major invertebrate groups recorded by survey sector. Mean abundance refers to the values recorded on the 0-5 DAFOR semi quantitative abundance scale.

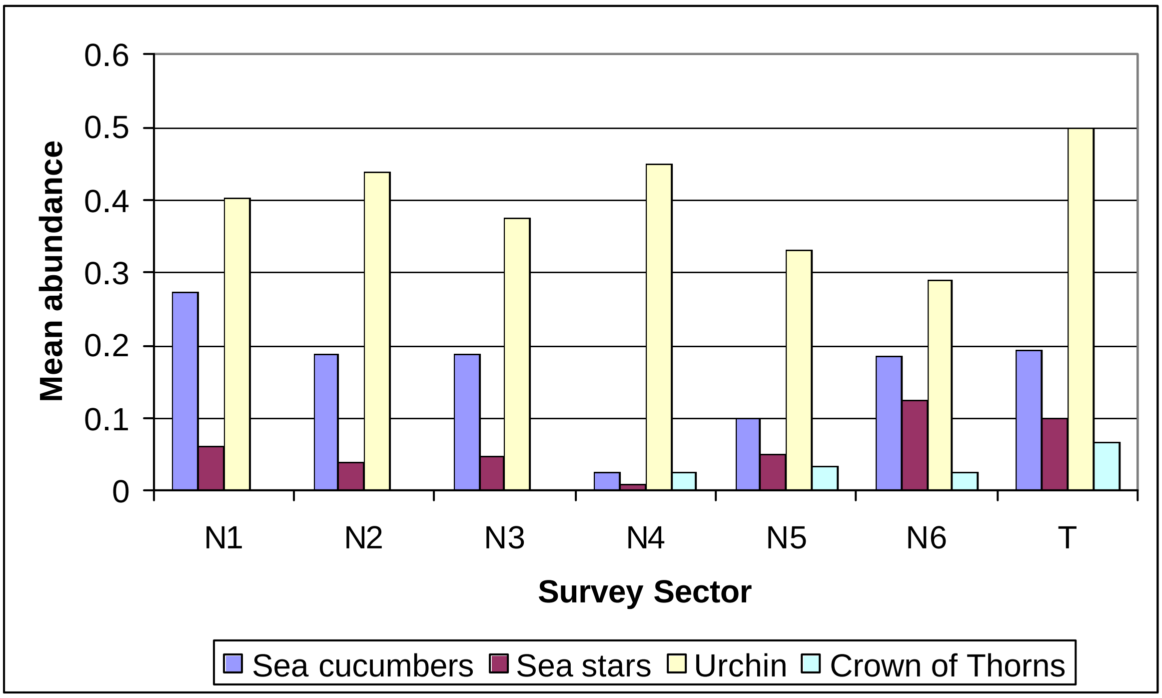

Figure 20. Mean abundance ratings for Echinoderms recorded by survey sector. Mean abundance refers to the values recorded on the 0-5 DAFOR semi quantitative abundance scale.

4.7 Habitat Mapping

Figure 21 depicts the habitat map produced by combining both field collected data acquired by CCC during the YICRCP and an external data source; in this case a Landsat 7 ETM+ image.

The classes identified in the habitat map correspond to those classified from the field collected data by hierarchal cluster analysis and presented in table 5. For purposes of clarity, the habitat labels on the map legend have been simplified from those given in the text of this report.

A summary of the spatial statistics of each habitat classified in the image is given in table 12.

Table 12. Spatial statistics of the eight habitat types identified through the combination of field collected data and remotely sensed satellite imagery to produce the habitat map of the central Yasawa Island (figure 21)

Habitat	Area (km^2)	Percentage of total area of all benthic classes
Habitat 1- Shallow lagoonal sand and patchy bedrock with some live hard coral	8.75	21.4
Habitat 2- Shallow lagoonal dead coral with algae and sand	8.06	19.7
Habitat 3- Lower reef slope sand substrate and algal overgrowth	6.37	15.6
Habitat 4- Mixed bedrock and live hard coral reef slope	3.86	9.4
Habitat 5- Reef slope mixed hard coral community	2.37	5.8
Habitat 6- Shallow lagoonal bedrock with low live hard coral cover	3.42	8.4
Habitat 7- Deep sand and blue green algae	4.22	10.3
Habitat 8- Sand and green calcified algae	3.83	9.4
Total all Benthic classes	40.88	100.0
Unclassified	128.81	

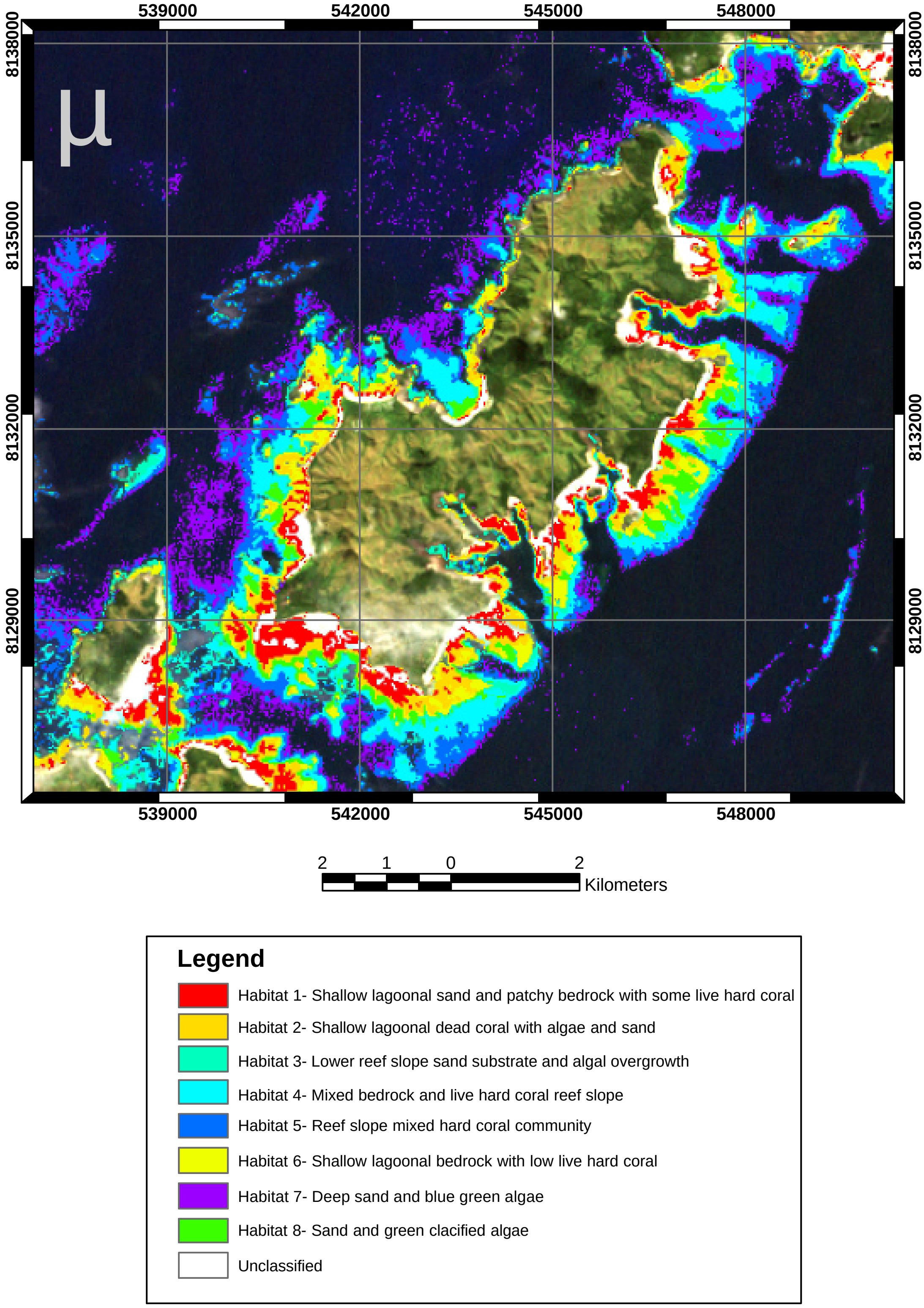

Figure 21. Habitat map of Nacula and Tavewa Islands produced by combining field data collected in the YICRCP and remotely sensed satellite imagery.

4.8 Conservation Management Rating and Geographic Information System

The univariate biodiversity and ecosystem productivity statistics used in the calculation of all fifteen habitats identified by cluster analysis are shown in table 13.

Table 13. Univariate biodiversity and ecosystem function statistics calculated for each of the eight habitats defined by multivariate analysis. These values formed the basis of the calculation of Conservation Management Ratings for each Baseline transect conducted in during the YICRCP.

Habitat	Benthic community			Fish community	
	Live hard coral cover	Total species	Log_e Shannon-Weiner diversity	Total species	Log_e Shannon-Weiner diversity
1	1.8	167	4.41	130	4.07
2	1.9	142	4.52	81	3.83
3	2.0	147	4.08	139	4.03
4	1.7	161	4.16	110	3.95
5	2.3	110	4.27	103	4.01
6	1.4	114	4.31	75	3.71
7	0.3	139	4.20	82	3.60
8	0.9	151	4.28	101	3.80

Using these values as a basis, the output Conservation Management Rating density grid is overlaid onto the satellite image in figure 22.

When interpreting the image, it is important to note that unclassified areas of reef do not have low value, but instead have not yet been surveyed and therefore cannot be included in the classification system.

A number of areas rated of higher Conservation Management Value have been identified in the image. Perhaps the largest of these areas is lies on the channels bisecting the reef just to the north of Naisisili village on the east coast of Nacula Island. In this area, there are a number of key points of high management importance including at the tip of the reef structure that protrudes in an easterly direction immediately in front of Naisisili village. On the west side of Nacula Island there are some isolated patches where the coral reef was found to be of high management value. Further interpretation of the map suggests that these sites of high conservation importance are to be found slightly offshore from the Island, most notably in front of Nacula village. Around Tavewa Island, the northern tip of the island was found to support high conservation importance coral reef communities as illustrated by the green area in the GIS output.

By contrast, sites of low management value can be found extending close into shore in front of Naisisili village around the headland to the south and then in a westerly direction along the southern shore of Nacula Island. There is also an apparent discrepancy in coral reef conservation importance between the northern point of Tavewa Island, which as discussed is of relatively high conservation management value and the southern reefs around the Island which are illustrated as being of low diversity and ecosystem health in the map.

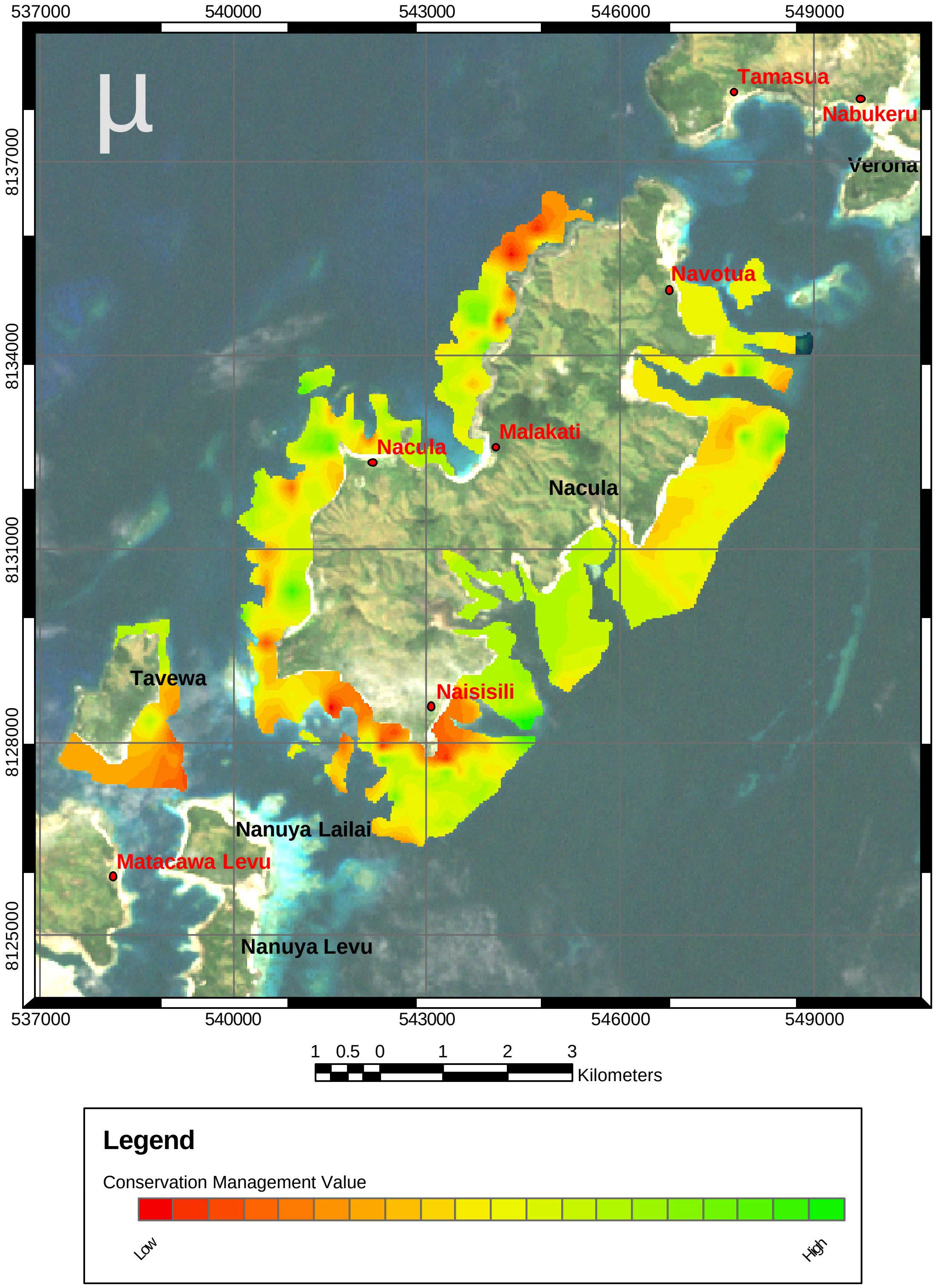

Figure 22. Conservation Management Rating contours as calculated from data collected by CCC during the YICRCP. Contours have been overlaid onto a Landsat 7ETM+ image acquired on 11th April, 2001.

5. DISCUSSION

5.1 Training

The training programme used during the YICRCP 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 Environmental Awareness and Community Work

Establishing the schools programme at the Ratu Meli Memorial School was an important part of the environmental awareness work undertaken during the YICRCP. Targeting education initiatives at this age range of community members ensures that in years to come there is a lasting understanding of the issues behind the need to conserve natural resources such as coral reefs.

Due to time and human resource constraints however, the other planned community capacity building work components that characterises the projects of CCC in Fiji were not adequately developed during the YICRCP. If further work ever were to be undertaken in the Yasawas, it is of key importance that community capacity building and education work take a higher priority.

5.3 Survey progress

Much of the coral reef area around both Nacula and Tavewa has been surveyed during the YICRCP. However, the density of these surveys in places is quite low. A total of forty-two transects have been undertaken in this study which represents on average one transect per 700 meters of the coastline which supports coral reef development (calculated from the Geographic Information System to be 38km). Ideally and with given a longer timeframe this spatial resolution would be increased with transects being conducted every 400 meters.

Whilst the number of transects surveyed is quite low, the length of each transect is very long. Typically transects took an average of 12 dives to complete from the 30 meter isobath to the shallow reef crest though in certain instances, this number was far higher with two transects needing nearly 30 dives to be complete.

This relates largely to the topography of the coral reefs in the project area. Most reefs were found to slope steeply up to approximately six meters where they reached the ill-defined reef crest and then continued as patch reefs into the expansive lagoon areas found around both Nacula and Tavewa Islands. The necessity to survey these patch reefs is however very high as in certain areas, these patch reefs supported excellent coral reef development and a healthy, biodiverse ecosystem.

The use of an additional data set that has been remotely sensed- in this instance- satellite imagery does however provide a valuable technique to extrapolate the field collected data into areas that have not been directly surveyed during the field data collection phase. In this manner, despite the areas that have been surveyed being distributed quite widely, the satellite image derived habitat map covers a continuous area around both Nacula and Tavewa Island reefs.

5.4 Oceanographic observations

Perhaps surprisingly, both the water temperature and salinity data in profile through the water column that is presented in this report does not appear to indicate that there is stratification through the water column. It is commonly observed in tropical coral reef ecosystems that the upper shallow portion of the water column that is exposed to large quantities of incoming solar irradiance heats up, forming a less dense lens of high salinity and temperature water over the underlying cooler, lower salinity main body of water. The fact that this stratification was not observed in the data collected indicates that there is a good degree of vertical mixing in the water column. In turn, the oceanographic and topographic characteristics of the small patchy Islands of the Yasawas that are bisected by channels between the Islands would precipitate this high degree of tidal induced water column mixing.

Water temperature monitoring is an essential part of an early warning system for the likely occurrence of bleaching as seen in the Mamanucas Islands in 2000-2001 which lie to the south of the Yasawas. Whilst the causes of bleaching are slowly becoming understood, treating the likely cause, global warming, using localised management of reef resources is not practical. Indeed during the time of the YICRP a bleaching event occurred in the Yasawa Islands. This event was first reported by personnel from the University of the South Pacific and subsequently CCC became aware of the event first hand. The initial bleaching event involved soft corals and non-scleractinian corals with anemones, *Sinularia sp.* and *Sarcophyton sp.* worse affected. Soon however, these non-scleractinian corals were accompanied by bleaching observed on reef building corals. The taxa worse affected were those that make greatest use of the symbiotic algae they contain including members of the *Acropora*, *Seriatopora*, *Pocillopora* and *Stylophora* genera. Overall, bleaching occurred in up to 50% of the colonies of these genera examined however little or no mortality was observed by CCC survey divers.

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 inverse secchi disc recordings representative of water turbidity are comparable to those recorded in earlier survey work conducted by CCC in the year one report of the FCRCP (Comley *et al.*, 2003). Additionally, there was insignificant variation in the water turbidity between survey areas representing different geographic regions around both Nacula and Tavewa Island. This again supports the discussion point made earlier about their being good tidal mixing around the Yasawa Island in that the water body surrounding the Islands is likely to be homogenous.

By far the most commonly observed surface impact in all survey areas in the YICRCP were large floating mats of unattached macroalgae, most commonly of the genus *Sargassum sp.* and *Gracillaria sp*. Both of these genera have the ability to rapidly increase in biomass given conditions of increased nutrient levels present in the environment. These observations do indicate therefore that nutrient levels in the Mamanucas may be artificially elevated, perhaps as a result of sewage discharge from development on the islands (Mosely *et al.*, 2002). There is however considerable local indigenous knowledge (pers comms- Ratu Sakiusa Tunitoto, 2005) that these peaks in algal biomass are linked more to prevalent oceanographic and climatic conditions and, having been observed prior to development in the Islands, may not be linked to increased nutrient input upsetting the coral/algal ratio.

An additional sign of development on the Yasawa Islands observed by CCC survey divers was the presence of litter both on the surface and at depth on the seabed. There is however a disparity between the peak occurrence of litter at surface and at depth and, in turn this perhaps relates to the source of the litter. By far the most commonly observed occurrences of litter on the surface were recorded around the east side of Nacula Island where the village of Naisisili and many of the resort developments are based. However, by contrast the most commonly observed occurrences of sub-surface litter were recorded both to the north and south of this area. This likely relates to the oceanographic and current regime of the area with litter being deposited into the marine environment around the centres of development and then being carried, becoming negatively buoyant and sinking to the seabed in neighbouring areas.

The use of an albeit subjective measure of both biological and aesthetic value by divers has been demonstrated in this report to be a valuable tool. The areas of highest biological and aesthetic value recorded were in survey sectors N1, N4 and T- to the southeast and northwest of Nacula Island and around Tavewa Island. When subsequent analysis was then done on the management value of these areas, this did indeed indicate that these three key sites were those of high diversity, ecosystem health and function.

5.5 Multivariate Analysis and Benthic Habitat Definitions

Using the data collected by CCC survey divers engaged in the YICRCP, through multivariate analysis techniques, it has been possible to identify eight statistically discreet key shallow benthic communities. However, as previously mentioned in the discussion section of survey progress, many of the surveys conducted encountered large back reef and lagoonal patch reef and consequently much of the survey data were restricted to these areas. Accordingly, in terms of the benthic habitat definitions, the classification scheme is heavily biased towards the habitats that occur in these specialised environments. It would be anticipated that with additional survey data, it would be possible to identify additional outer reef slope habitats. However, it is worthy of note that many of these reef slope areas are homogenous with variation in coral reef geomorphology occurring only between east (leeward) and west (windward) side of Nacula Island.

5.6 Reef Fish Populations

By far the most commonly observed fish family in the YICRCP were the Damselfish. Damselfish are restricted in distribution and are highly correlated with the presence of macroalgae in coral reef ecosystems though are ubiquitously and abundantly encountered in regions fulfilling these ecological criteria. By contrast the schooling behaviour of Surgeonfish and Fusiliers means that these families are encountered rarely, but that when a school is encountered in all probability it is likely to be composed of many individuals.

Wrasse are commercially and artisanally fished in Fiji though were observed to be the second most abundant fish family in the Yasawas. This contradicts with the work done by CCC in the Mamanuca Islands (Comley *et al.*, 2004) using the same experimental design and survey technique where wrasse were rarely found. This disparity may have two explanations. Firstly, the prevalence of surveys in this study conducted in the lagoonal area may have caused a bias in the abundance of juvenile wrasse. The lagoon environment is an important nursery area for juvenile wrasse and they can often be seen in these areas. However, this is likely not the only explanation-in this study, adult wrasse were also seen with a proportionately higher abundance than in the Mamanucas. This most likely signifies that there is a lower fishing pressure on the coral reef communities of the Yasawa Islands than there is in the Mamanucas.

Fishing pressure on coral reefs can have significantly deleterious effects. Coral reefs are characteristically found and are actually dependent on seawater that is very low in nutrient levels; elevated nutrient levels favours macroalgal growth as discussed in the previous section. However, coral reefs are an extremely productive ecosystem; it is through close recycling of nutrients within the ecosystem that this can be accomplished with coral reefs having one of the lowest net losses of nutrients to surrounding areas. By removing fish biomass through fishing pressure, the loss of nutrients from the ecosystem is highly accentuated, thereby threatening the health of ecosystem. An additional impact of fishing is the change in trophic or feeding interactions in the ecosystem. If algal grazing fish families are subjected to a targeted fishing regime, then it has documented that macroalgae communities may evolve to replace the coral reef community.

The most biodiverse fish populations in the Yasawas were found associated with habitats that had high proportions of live hard coral (Benthic Classes 1, 3, 4 and 5). This supports the theory that these three reef habitats are biodiverse not just in terms of the benthic communities they contain, but also in terms of the fish assemblages found associated with them. Interestingly, these fish assemblages are not just biodiverse; the results of the pairwise multivariate analysis procedure performed on the data indicates that these assemblages are found specifically associated with the habitat in which they area found. This has important management implications in that by protecting areas found to be comprised of these four habitats, one is also protecting the unique associated fish assemblages. Additionally, from the habitat map produced of the area (figure 21) habitats 3, 4 and 5 are found in deeper water on the fringing reef slope. This indicates that these areas are responsible for the development of biodiverse and healthy fish assemblages and that the remaining lagoonal habitats tend to be more depurate in terms of fish biomass and diversity.

5.7 Habitat Mapping

The habitat map produced for this report allows the spatial coverage habitats that comprise the coral reefs around Nacula and Tavewa Islands to be evaluated.

Many studies have been undertaken to assess the relative merits of different remote sensing data sources; excellent reviews are provided in Green *et al.*, 2000. These studies acknowledge two key factors that determine the useful application of remote sensors to coral reef habitat mapping; spectral and spatial resolution. Spectral resolution refers to both the number of bands in the electromagnetic spectrum that are imaged as well as the location of these bands in the spectrum. Spatial resolution by contrast refers to the size of individual picture elements on the ground. Landsat 7ETM+ imagery is accepted as being perhaps the best widely available and economically viable source of data. It has suitable spectral resolution with seven bands; three of which have application in coral reef remote sensing. The major disadvantage with Landsat as a data source for this genre of study is that it has very low spatial resolution with the smallest discernable features on the ground measuring 30 x 30 meters. The ideal sensor platform for coral reef mapping surveys are the multispectral airborne scanners. However, in most instances the costs associated with the acquisition of this type of data is so high and can rarely be justified when mapping at the generic habitat level necessary for management purposes.

5.8 Conservation Management Rating and Geographic Information System

The Conservation Management Rating methodology developed for this report is a culmination of many of the other advanced analysis techniques used. Based on the habitats defined from the data set by multivariate cluster analysis, the technique allows all of the data to be compared in a simple manner. Using univariate reef diversity and function statistics then allows each of these habitats to be assessed for management importance.

This method of analysis was developed during and included in the year one report of CCCs work in the Mamanuca Islands (Comley *et al.* 2003); however, at this stage, it only allowed for the assessment of discreet points representative of start locations of CCC Baseline transects. By developing a system of density gradients in this report, the Conservation Management Ratings scheme is now able to clearly identify areas of high management importance. It is these areas that have been recommended for the establishment of Marine Protected Areas.

However, one of the main advantages of the presenting the analysed data in this format is that it is graphical and therefore easily to interpret by all stakeholders. It is hoped therefore that the GIS presented in this report can form an important part of the integrated decision framework involving all stakeholders in the conservation of the coral reef ecosystems around Nacula and Tavewa Islands.

Once created, a GIS can be developed both in complexity and function. Many parameters including not just information on biological and ecological patterns can be stored as spatial data in the GIS. What has been achieved thus far therefore is the creation of a basic system, but one that is capable of storing an increasing quantity of data from different data sets.

6. RECOMMENDATIONS

The following section presents a number of recommendations that have been made from the data collected in the Yasawa Islands Coral Reef Conservation Project as well as a number of issues that relate more directly to the threats posed to the reefs in the project area.

Recommendation 1- Whilst the signs of anthropogenic impact observed by CCC during the YICRCP were not of high frequency, impacts including litter were observed. This relates to impacts of continued development of the Yasawa Islands as a tourism industry focal point in Fiji.

Recommendation 2- To counteract the impacts of the developing tourism industry, proper management initiatives need to be taken to ensure that any development is done on a sustainable basis.

Recommendation 3- These management initiatives need to involve all levels of Governance and stakeholders; from central Government development initiatives to local community, Takina and Vanua plans.

Recommendation 4- Tourism development in the Yasawa Islands should proceed in a manner that is fair and equitable to all stakeholders; from local community members to international investors in the development of infrastructure and resorts. Only if this equitability can be realised will all parties in the development process receive due benefit.

Recommendation 5- To increase local stakeholder environmental awareness, a programme of education activities should be undertaken in a manner similar to that begun by CCC at the Ratu Meli Memorial School

Recommendation 6- Issues of customary tenure over the fisheries ground should be prevented from inhibiting the sustainable development of the Yasawa Islands. If the return of customary ownership is seen solely to be a mechanism for communities to enhance their economic earnings, this can often be at the detriment to marine conservation and sustainable development planning.

Recommendation 7- There should be a drive amongst the local communities in the Yasawa Islands to explore the opportunity for establishing a series of Marine Protected Areas to assist in the long-term protection of the coral reef resources of the archipelago.

Recommendation 8- The data presented in this report and, in particular, through the novel use of GIS techniques to allow the data to be accessible to all stakeholder levels can form a basis for activities related to Recommendation 7 above.

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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.					

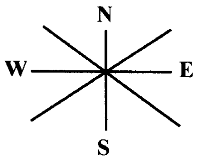
END:

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

CURRENT STRENGTH

none
weak
medium
strong

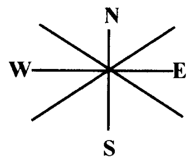
CURRENT DIRECTION (towards)



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

D E P T H (m)

Distance (m) / Depth (m)

AERIAL VIEW:

W I D T H (m)

Line of Transect

Distance (m)

BIOLOGICAL RECORDING FORM

Study: Transcect No: Zone Code:

Habitat No: ________ of ______ Date: ____________

Database Code:

Percentage of Dive: ________ % Start time:____________ End time: __________

	First:	Last:	No. dives/snorkels in Fji		Depth Limits:		
Recorder's Name	______________________	Phys	____________		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 grooes.
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 45º
Escarpment	☐	Any area of benthos whose angle of slope exceeds 45º
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 the slope does not exceed 45º
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 uncertainty, 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 coraline structures
Dead Coral with Algae	☐	Any area of hard bare substratum with visible coralite structure covered in algae
Dead Corals	☐	Any area of hard bare substratum with visible coralite structure
Rubble	☐	Any area of oose 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-calcerous algae forming mats or turfs
Brown fleshy algae	☐	e.g. Lobophora, Padina, Sargassum, Turbinaria
Red/brown branching algae	☐	e.g. Dictyota, Galaxaura, Amphiroa, Jania
Green calcified algae	☐	e.g. Halimeda, Tydemania
Red coralline algae	☐	e.g. Cement, crustose coralline
Seagrass	☐	

Substratum types within the habitat: (e.g. sand / bedrock) ______________________________

____

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Other comments : ______________________________

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SPECIES ABUNDANCE

N.B. ALL CORAL AND FISH TARGET SPECIES MUST ALSO BE COUNTED IN THE APPRORIATE 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
Ventricaria sp.	3
Bornetella sp.	10
Neomeris sp. (Finger)	29
Caulerpa sp. (Grape)	12
Calcified: - Halimeda sp.	24
- Tydemania sp.	33
Codium sp. (Spongy)	18

Further Green Species:

TOTAL GREEN ALGAE

Phaeophyta: Brown

Dictyota sp. (Flat-Branched)	44
Padina sp. (Fan Blade)	50
Lobophora sp. (Blade/Ruffle)	49
Hydroclathrus sp.	48
Turbinaria sp. (Pyramid)	55
Filamentous	42
Sargassum sp. (Bladder)	53

Further Brown Species:

TOTAL BROWN ALGAE

Rhodophyta: Red

Calcified	70
Galaxaura	73
Amphiroa	63
Jania / Spikeweed	83
Filamentous - *Ceramium* sp.	60
Sheet - *Halymenia* sp.	80

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

Anthropoda : *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 Cucumbe	Synaptid	515
	Other	520

Tunicate	529
Bryozoan	526

FURTHER SPECIES:

TOTAL INVERTEBRATES

HARD CORAL

Life Forms

DEAD CORAL	148
DEAD CORAL WITH 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 forms, genera and species

Pocilloporadae

Pocillopora:	Small	164
	Medium	165
	Large	166
Seriatopora hystrix		834
Stylophora pistillata		833
Stylophora mordax		803

Acroporidae

Bottlebrush *Acropora*	163
Montipora foliose spp.	167

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
Echinopora lamellosa	218

Caryophylliidae

Euphyllia	895
Plerogyra	874

Milleporidae

Millepora platyphylla	827
Millepora intricata	826

Dendrophylliidae

Tubastrea micrantha	877
Turbinaria reniformis	884

Merulinidae

Hydnophora sp.	247
Merulina scabricula	895

Miscellaneous

Brain:	Small	202
	Medium	273
	Large	253

FURTHER SPECIES

TOTAL TARGET CORALS

N.B. ALL CORAL AND FISH TARGET SPECIES MUST ALSO BE COUNTED IN THE APPROPRIATE FAMILY OR LIFEFORM

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
Humphead Bannerfish	669
Pennant Bannerfish	939
Longfin Bannerfish	588
Masked Bannerfish	587

Angelfish	544
Regal	663
Bicolour	673
Emperor	756
Blue-girdled	937
Dusky	561
Semicircle	576
Lemonpeel	563

Surgeonfish	546
Convict	547
"Ringtail" sp.	548
Brushtail tang	638
"Bristletooth" sp.	959
Sailfin Tang	961
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
Blue-Green Chromis	596
Black Bar Chromis	646
Threespot *dascyllus*	671
Humbug *dascyllus*	767
Reticulated *dascyllus*	771
Talbot's demoiselle	612
Whitebelly	654
Staghorn	745
Blue Devil	657
Black	759
Lemon	713
Golden	740
"Seargent" sp.	656
"Anemone fish" sp.	871

Wrasse	598
Diana's hogfish	931
Mesothorax hogfish	611
Humhead	600
Red-banded	932
Checkerboard	725
Twotone	768
Crescent	647
Sixbar	744
Jansen's	678
Cigar	685
Bird	610
Cleaner	605
Rockmover	949
Slingjaw	620
Black-Edged Thicklip	770

Goatfish	615
Half-and-half	648
Two-barred	666
Dash-and-dot	781
Multibarred	934
Blackstriped	616
Yelowfin	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
Saddleback Coral	578
Leopard Coral	580
Soapfish	928
Anthias	642

Parrot Fish	613
Bumphead	933
Bicolour Parrot juv.	614

Spinecheek	581
Twoline	582

Snapper	565
Two-spot	753
Twinspot	956
Black-and-white	569
Bluelined	925
Five-lined	957
Paddletail	564

Rabbitfish	579
Foxface	757
Pencil-streaked	958
Uspi	896

Dartfish	774
Blackfin	695

Cardinalfish	621
Pyjama	917
Blackstriped	717

Toby	636
Spotted	794

Puffer	635
Blackspotted	652

Blenny	926
Yellowtail Poisonfang	705
Bicolour	687

Goby	749
Sphynx	954
Brownbarred	955

OTHER MAJOR FAMILIES

Jack / Trevally	553
Sweetlips	577
Barracuda	560
Moorish Idol	551
Emperor	924

MISCELLANEOUS FAMILIES

Spadefish / Batfish	595
Dottyback	900
Porcupine	634
Trunk / Box / Cowfish	640
Squirrelfish / Soldierfish	619
Filefish	629
Lionfish	631
Scorpionfish / Stonefish	632
Lizardfish	643
Hawkfish	902
Sandperch	675
Sharksucker	787
Needlefish	562
Pipefish	911
Shrimp fish	790
Trumpetfish	664
Moray Eel	637

FURTHER SPECIES

TOTAL FISH