FIJI – CASTAWAY ISLAND PROGRESS REPORT –

BASELINE SURVEY DATA MARCH-MAY 2002

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- by -

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ACKNOWLEDGEMENTS

EXECUTIVE SUMMARY

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

?? Stakeholders in the Mamanuca Islands are aware of the value of conserving coral reefs and in late 2001 invited Coral Cay Conservation (CCC) to assist in the implementation of a three year project entitled *'Fiji Reef Conservation Project (FRCP)*. This followed the success of an initial three month pilot project; the Mamanuca Coral Reef Conservation Project – Fiji 2001 (MCRCP).

?? Fieldwork during the initial phase (March – May 2002) of the FRCP focused on gathering data from a wide range of habitat types around Castaway (Oalito) Island using the CCC baseline transect technique.

?? The data collected for Castaway Island showed a number of detrimental anthropogenic influences to be present. Perhaps the most obvious of these impacts was the mass coral bleaching event which occurred in early 2000.

?? A preliminary breakdown of seven defined habitats in four survey sectors around Castaway Island was produced from 85 baseline survey dives.

?? The western and northern sectors possess more hard substrata (bedrock, live and dead hard coral) than the remaining two sectors (south and east), which are dominated by more sand-based habitat types.

?? The hard coral lifeform 'dead coral with algae' was most prevalent in all four sectors of Castaway island. The mass coral bleaching event in 2000 may have contributed significantly to the dominance of this lifeform for hard coral substrata.

?? There was little difference in the abundance and diversity of marine life (all records combined) between the four sectors, although Castaway south had a slight edge (but was not statistically significant).

?? Diver ratings on CCC surveys marked out the western sector as the highest for aesthetic and biological value. This sector also possesses the highest abundance of a number of hard coral lifeforms and reef fish families.

?? The support by local stakeholders for mitigating measures around Castaway Island represents a clear desire to address the threats to reef health and work towards sustainable use. Reducing the threats to reef health and establishing one or more marine reserves on the island could address this goal.

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

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. Similarly, the countries' coral reef ecosystems are being adversely affected by a range of anthropogenic activities including over-fishing, destructive fishing, sedimentation, eutrophication and pollution, which has resulted in extensive loss of coral reefs and inducement of coral diseases. Recent coral bleaching events and storm damage has exacerbated these effects by acting synergistically to reduce reef health further. Such impacts represent substantial long- and short-term threats to the ecological balance and health of reef ecosystems which, if left unchecked, will ultimately lead to reduced income for coastal communities and other stakeholders relying on fishing and marine-based tourism.

Effective coastal zone management, including conservation of coral reefs requires a holistic and multi-sectorial approach which is often a highly technical and costly process and one that many developing countries cannot afford. With appropriate training of non-scientifically trained, self-financing volunteer divers it is possible 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). This technique has been pioneered and successfully applied by Coral Cay Conservation (CCC), a British not-for-profit organisation.

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

The Mamanuca Islands in western Fiji (Figure 1) have been the focus of tourism development in Fiji for many years and the industry is very much aware of the value of conserving the coral reefs and fostering sustainable development.
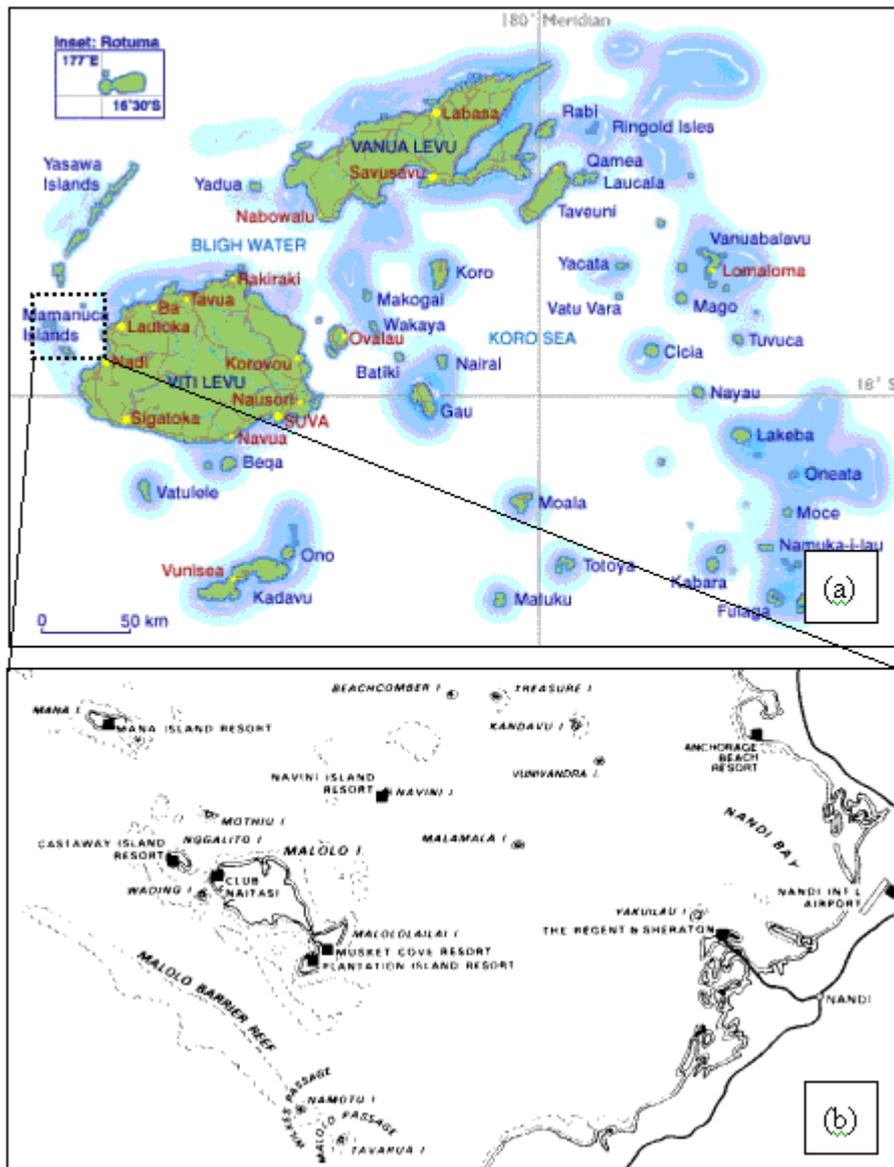
Figure 1. (a) The Fiji islands, showing the project area (dashed line) for the MCRCP. *Source*: Fiji Visitors Bureau. (b) Major islands with the Mamanucas.

In December 2001 the Honourable Minister Konisi Tabu Yabaki (then Minister of Tourism, Culture, Heritage and Civil Aviation) and Professor David Bellamy OBE (President, CCC) signed a *Memorandum of Agreement* for the initiation of the *Fiji Reef Conservation Project*, an extensive three-year project which will include surveys of coral reefs and adjacent forest systems throughout Fiji, plus conservation education and training programmes.

The marine survey programme started baseline surveys using the *CCC Standard Survey Technique* on the island of Castaway (Qalito Island) in March 2002. This work has been carried out in close collaboration with The Mamanucas Hoteliers Association, the Ministry for Tourism, Transport and Aviation and the Fiji Visitors Bureau.

This report is a summary of the survey work undertaken between March and May 2002 from the CCC field base at Castaway Island. CCC was initially present in the Mamanucas between June-September 2001 for the pilot phase project entitled the *Mamanuca Coral Reef Conservation Project – Fiji 2001*(see Harborne *et al*., 2001).

Systematic surveys are being carried out by CCC volunteers in and around the Mamanuca Islands in order to designate potential marine protected areas within discrete sections of the islands. Although the pilot phase final report mentioned above gave comprehensive information from a variety of study areas within the island group, it remains unclear on a scale of 100's of metres, which sections of the coast, in particular geomorphological zones, are in better ecological health than others. The baseline survey work highlighted in this document gives comprehensive information on the scale of tens of metres. This resolution makes it possible to accurately assign areas of high coral species richness and cover, and following this, investigate motile organism dispersal. The definition of these biologically rich areas from the data collected enables the next part of the process; the proposal of potential marine protected areas for the Mamanucas Island group and in this case, Castaway Island..

2.   SITE LOCATION

Castaway Island lies at the western most point of the 'Malolo Group' of volcanic islands, to the south west of Nadi. It is inhabited by Castaway Island resort on the western part of the island, with the CCC field station based on the eastern tip of the island facing Malolo Island (Fig. 2).

Figure 2.   Position of Castaway Island within the Malolo Island group in the Mamanucas, and the location of transects around the island.

Surveys were carried out in all areas of Castaway Island and split into four different sectors of the coastline (north, south, east and west). The table below designates the transects that were completed in each sector.

Table 1.   Transects within each island sector (refer also to Fig. 1).

Sector	Representative transects
North	1704, 1705, 1706, 1715
South	1710, 1711, 1712, 1713, 1714
East	1701, 1702, 1703
West	1707, 1708, 1709

1.   **2.**

Plates 1 and 2.   Fringing reef adjacent to Castaway Island.

Plate 1.   Fringing reef in front of the CCC expedition field base at Ravanyaki.

Plate 2.   South-facing view from the top of Castaway Island showing the fringing coral reef at the bottom of the picture and the expansive inner barrier and outer barrier reefs that shelter the island from southerly swell.

Plate 3. Castaway Island (a view looking at the eastern shore of the island), with the inner Malolo barrier reef in the foreground.

3. METHODS

3.1 Volunteer Training

Efficient and effective training is a vital component of any volunteer programme in order to allow participants to quickly gain the required identification and survey skills that allow them to collect accurate and useful data. During long-term projects, CCC uses an intensive two-week training programme (*The CCC Skills Development Programme*) that has been constantly refined since 1990. The programme is 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 lectures during this two week programme is to give volunteers the ability to discern the specific identification characteristics and relevant biological attributes of the species which they will encounter during their diving surveys. The training programme is co-ordinated by the Project Scientist (PS) and Science Officer (SO) and involves two lectures and two dives each day along with de-briefings and evening audio-visual presentations. Volunteers are 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 is a series of testing procedures to ensure that each volunteer has reached a minimum acceptable standard.

A timetable for science training week is provided in Table 2. Within the day to day planning of the project there will also be opportunities for local counterparts to join and participate in science training week and subsequent survey work.

3.2 The Concept Of 'Survey Sites'

During the project CCC volunteers collect data from a series of 'survey sites' each being a cross section of reef less than one kilometre long. Surveys at each site generate a standardised data set that will facilitate characterisation of each area and also allow powerful comparisons at a range of spatial scales. For example comparisons can be made between sites in the same sector, different sectors, different islands or across the wider biogeographical region. Sites are 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 is based on a combination of existing data, local information (e.g. dive resorts), local biologists and initial assessments (e.g. diving or snorkelling reconnaissance trips).

The standard *CCC Reef Survey Technique* was used on transects to provide general data on each habitat type present. The exact number of transects at each site can vary depending on the topography of the reef (e.g. fewer transects at those sites with a wide or deep reef profile) but usually numbers between 15 and 50 depending on the scale and size of each survey site.

Table 2. Proposed *CCC Skills Development Programme* timetable for CCC volunteers and local counter-parts.

	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** ⌐ GPS & 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

CCC Skills Development Programme (continued)

	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**	**Departures** ⌐ Skills Development Programme **Start Conservation weeks**
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	
EVE		**Lecture 20** ⌐ Marine reserves **retakes of ID skills if required**	**Lecture 21** ⌐ mangrove ecology **retakes of ID skills if required**	

3.3   CCC Reef survey Technique

CCC's standard baseline transect survey technique utilises a series of plot-less transects perpendicular to the reef, starting from the 28 metre contour and terminating at the reef crest or in very shallow water. The start depth of 28 metres sometimes varies as a function of underwater visibility, currents and the speed at which surveys are carried out. CCC's techniques have been shown to generate precise and consistent data appropriate for baseline mapping. Benthic and fish surveys are generally focused on life forms or families along with a pre-selected number of target species that are abundant, easily identifiable and either ecologically or commercially important. Life forms of stony corals are recorded as described by English *et al.* (1997) and selected corals are identified to species level. Fish are generally identified to family level but in addition, the presence and abundance of a number of important target species are recorded. Sponges and octocorals are recorded in various life form categories. Seaweeds are classified into three groups (green, red and brown algae) and identified to a range of taxonomic levels such as life form, genera or species. During the course of each survey, certain oceanographic data (e.g. salinity, temperature, vertical turbidity, current strength and direction and wind strength and direction) and observations on obvious anthropogenic impacts and activities (e.g. presence and activity of boats) are also recorded at depth by the divers and from the surface support vessel.

Since most transects require two or more dives to complete, transect surveys are usually divided up into sections (or 'sub-transects') with surveys of each sub-transect being carried out by a team of four trained divers divided into two buddy pairs (A and B) as shown in Figure 3. At the start point of each sub-transect, Buddy Pair B remains stationary with Diver 3 holding one end of a 10 m length of polypropylene line. The other end of the line is held by Diver 1. Buddy Pair A then swim away from Buddy Pair B, navigating up or along the reef slope in a pre-determined direction until the 10 metre line connecting Diver 1 and 3 becomes taught. Buddy Pair A then remains stationary whilst Buddy Pair B swim towards them. This process is repeated until the end of the planned dive profile, when a surface marker buoy (SMB) carried by Diver 2 is deployed to mark the end of that sub-transect. The SMB acts as the start point for the next survey team and this process is repeated until the entire transect is completed. The positions of the SMB at the start and end of each dive is fixed using a Global Positioning System (GPS).
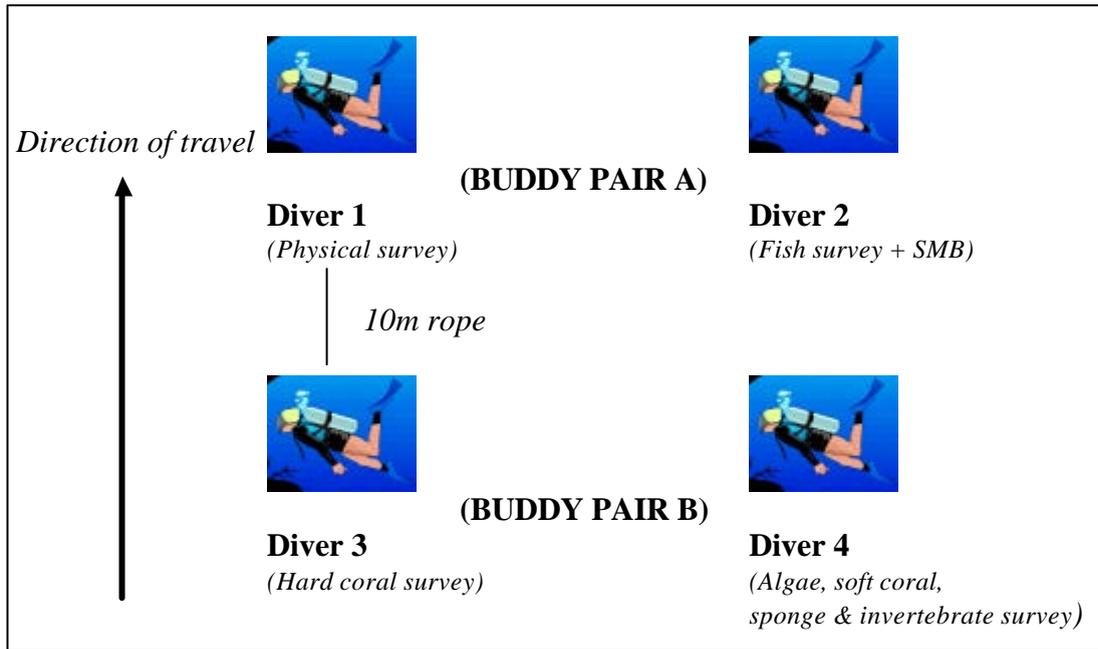
Figure 3.   Schematic diagram of a baseline survey dive team showing the positions and data gathering responsibilities of all four divers. Details of the role of each diver are given in the text.

Plate 4.

CCC volunteers surveying a baseline transect.

Diver 1 is responsible for leading the dive, taking a depth reading at the end of each 10 metre interval and documenting signs of anthropogenic impact such as broken coral or fishing nets. Diver 1 assesses the current direction and strength and takes a temperature reading at the start of the sub-transect along with a water sample for subsequent salinity measurements. Diver 1 also describes the substratum along the sub-transect by recording the presence of five substrata categories (dead coral, bedrock, rubble, sand and mud). Diver 3 surveys 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.

During the course of each sub-transect survey, divers may traverse two or more apparently discrete habitat types, based upon obvious gross geomorphological or biological differences (e.g. dense coral reef, sand or rubble; Figure 4). The data gathered by each diver from each habitat type are recorded separately for subsequent analysis.
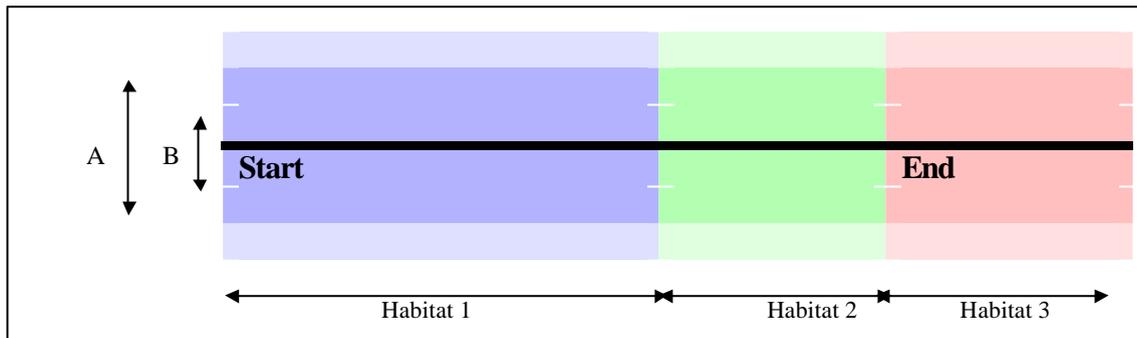

Figure 4.   Schematic diagram (aerial aspect) of an example of a reef area mapped by divers during a sub-transect survey. Solid line represents imaginary sub-transect line. Dashed lines and shaded areas represent areas surveyed (A = 5m wide swathe surveyed by Divers 1, 2 and 4; B = 2 m wide swathe surveyed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

Each species, life form or substratum category within each habitat type encountered is assigned an abundance rating from the ordinal scale shown in Table 3. Data collected from each sub-transect survey are transferred to recording forms, prior to incorporation into CCC's GIS-compatible database.

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+

3.4   Data analysis

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 (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 gemorphological class and benthic class to produce a habitat label follows the format described by Mumby and Harborne (1999).

4   RESULTS

4.1   Oceanography, climate and anthropogenic/physical impacts

Surface Impacts

Surface impacts around Castaway Island were predominantly floating macroalgae and to a lesser extent, either litter or driftwood. Driftwood was highest in the western sector whilst algal impacts were the lowest here. No nets or sewage impacts were observed around Castaway.
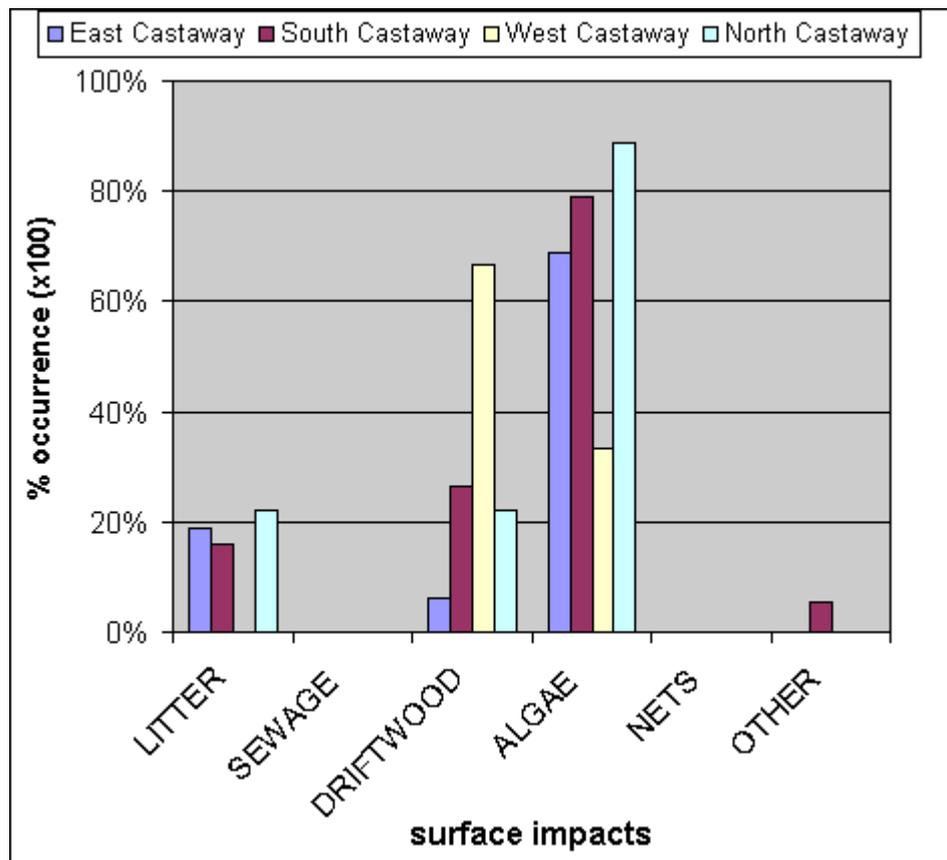

Figure 5   Surface impacts around Castaway Island.

The Y-axis (% occurrence) relates to the percentage of dives where a particular surface impact was observed in each sector.

Benthic impacts

Litter was the most prevalent benthic impact on the coral reefs of Castaway Island (Figure 6). Sewage and coral damage were recorded most often in the western sector of the island whilst bleached coral was most prevalent in the North Castaway sector. Sedimentation was also having an impact on benthic organisms in both the northern and eastern sectors of the island.
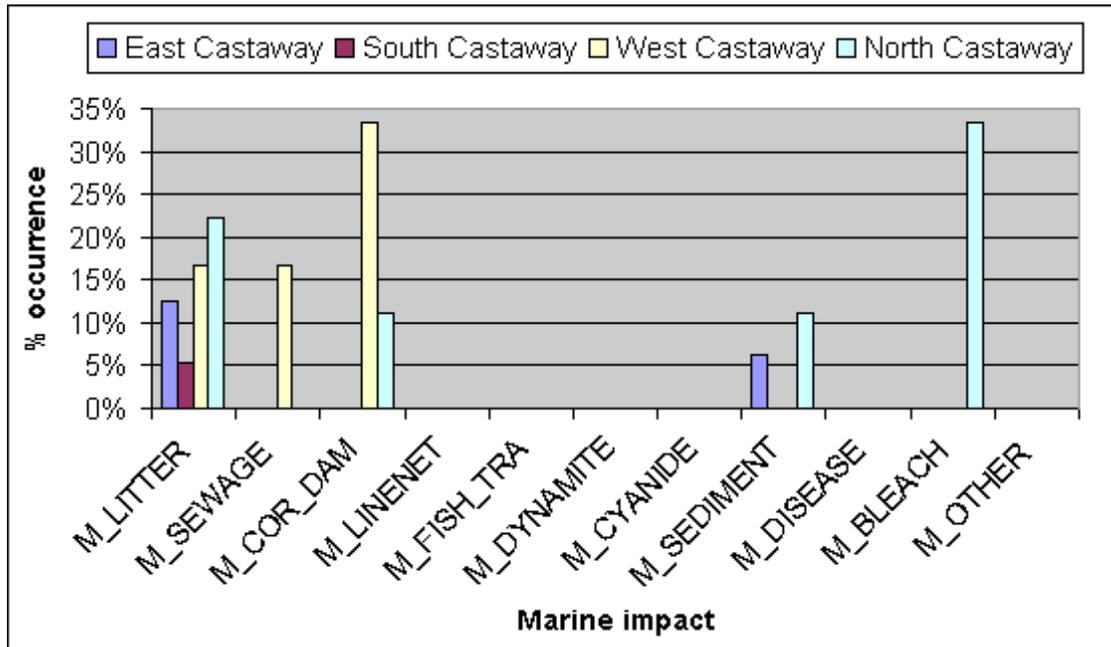

Figure 6.   Benthic impacts observed on CCC baseline survey dives around Castaway Island.

Diver Ratings

Subjective ratings of the quality of diving around Castaway Island resulted in fairly mediocre results for both biological and aesthetic ratings of dive sites (Figure 7). This indicates that the majority of dives were regarded as poor to average by the volunteer divers. However, the biological rating of the western sector of Castaway Island was clearly higher than the other sectors.
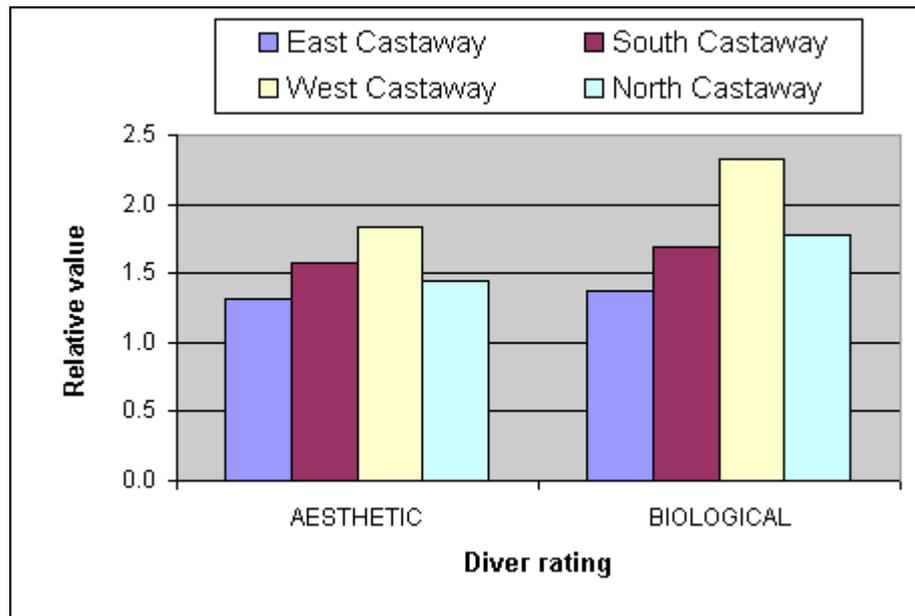

Figure 7.   Biological and aesthetic ratings of the different sectors of the island by survey divers, where: 1 = poor, 5 = excellent.

Boat Activity

Boat activity was mainly observed off the west coast of Castaway Island during surveys (Figure 8) and can be attributed to location of the hotel complex in this sector. Fewest boats were recorded in North Castaway.
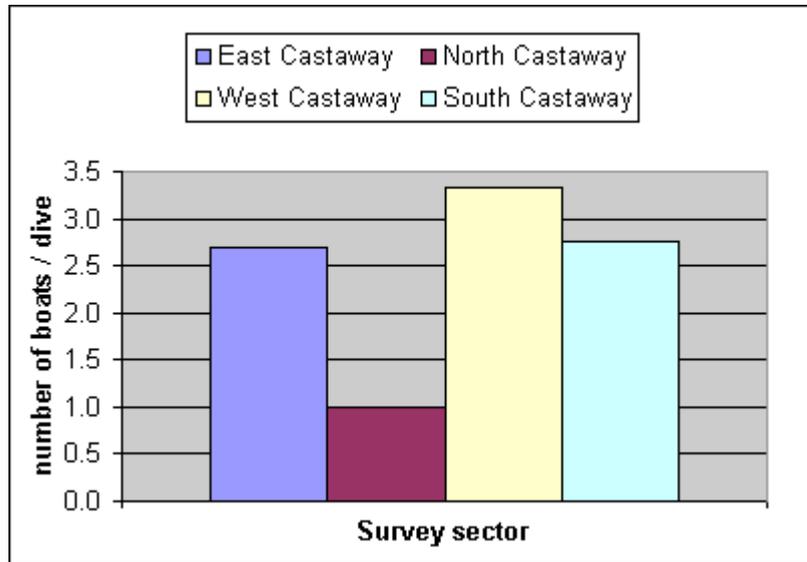

Figure 8.   Mean number of boats observed in different sectors of Castaway Island during survey dives.

Of the total number of vessels observed (Figure 9) a large number of both commercial and pleasure boats were recorded on the eastern part of Castaway Island. Fishing appears to be most prevalent in the western sector. Fishing boats were often recorded nearer to the northern-western tip of the island.
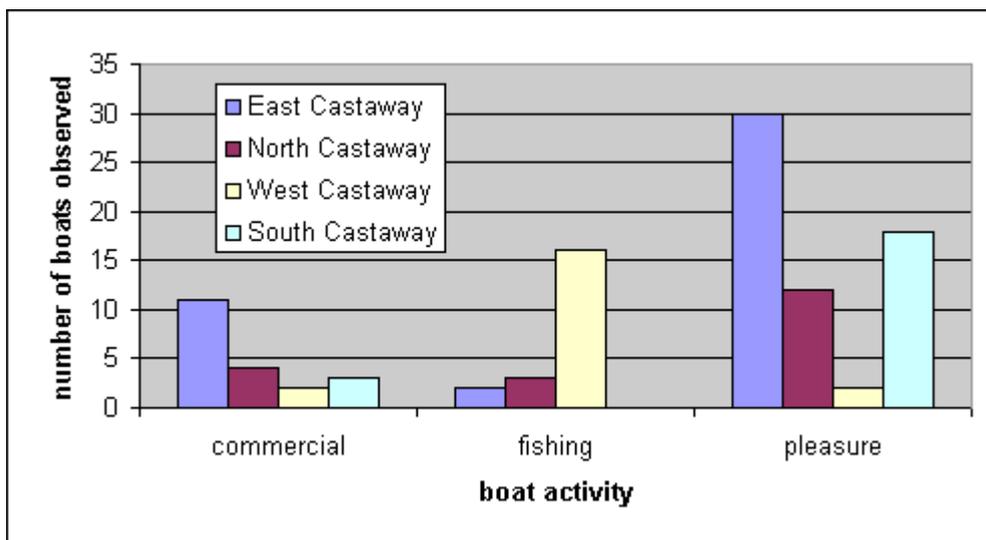

Figure 9.   Type of boat activity around Castaway Island during survey dives.

Oceanographic data

Measurements of vertical visibility through the water column (Figure 10) revealed that the greatest water clarity was recorded on the west and northern sides of the island (with measurements of 15.17 and 13.4 metres respectively). The lowest vertical visibility was recorded at the southern coast of the island with a reading of 9 metres.
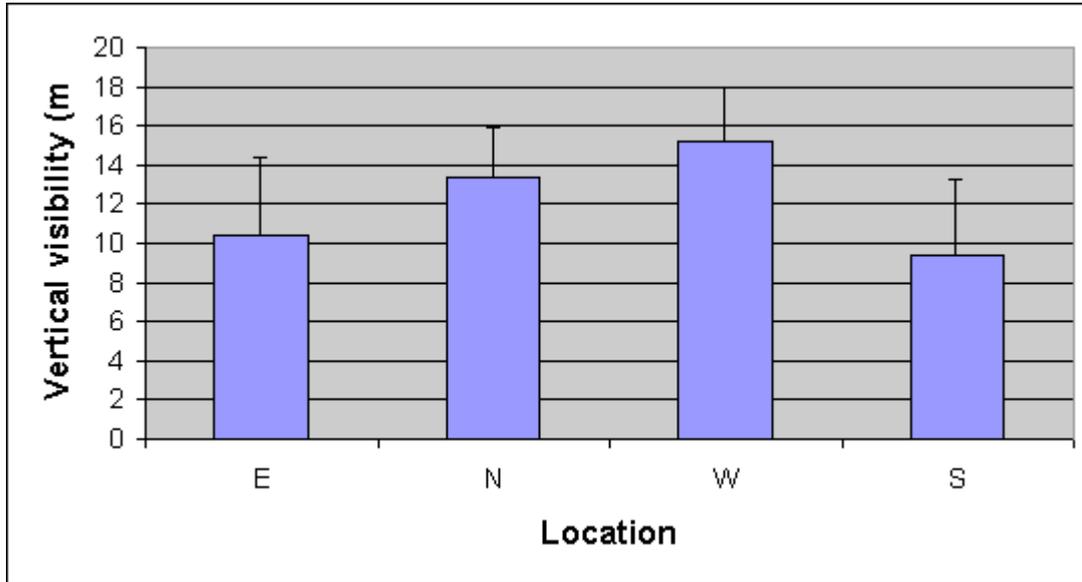

Figure 10.   Vertical secchi disc readings (metres) in survey sectors of Castaway Island (mean values + S.D.)
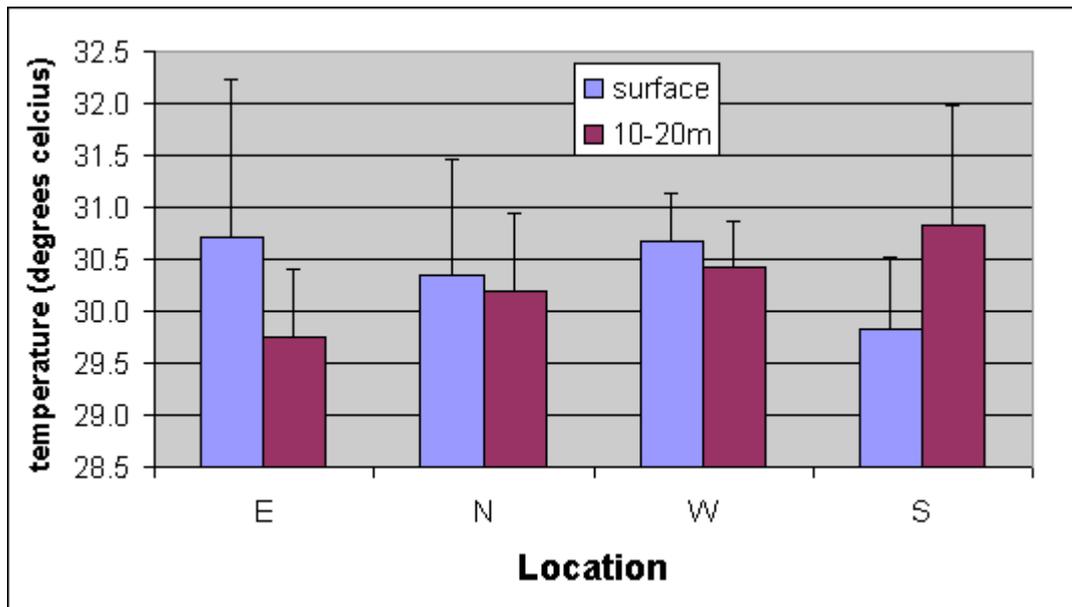

Figure 11.   Surface and underwater temperature measurements at different locations around Castaway Island.

Wind direction and strength

Wind 'rose' diagrams provide information on the strength and direction of the winds around Castaway Island. Most recordings of wind showed low wind speeds (around 1 on the Beaufort scale) from easterly and westerly directions (Fig. 12-15).
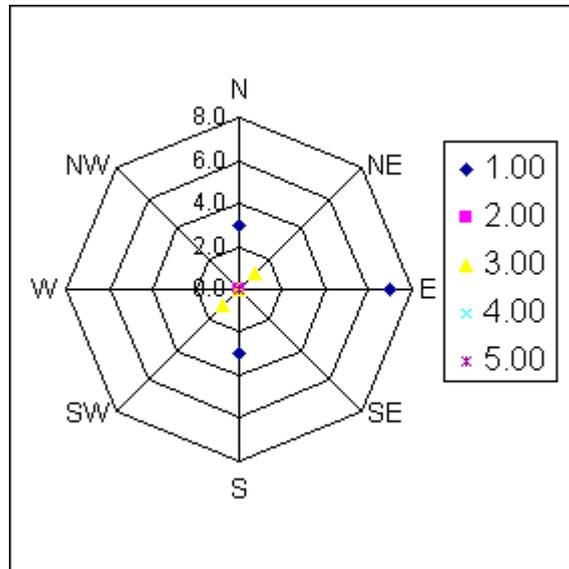

Figure 12.   Wind direction and strength at east Castaway Island.

Note: The rings on the rose indicate number of records whilst the legend indicates wind strength using the Beaufort scale.
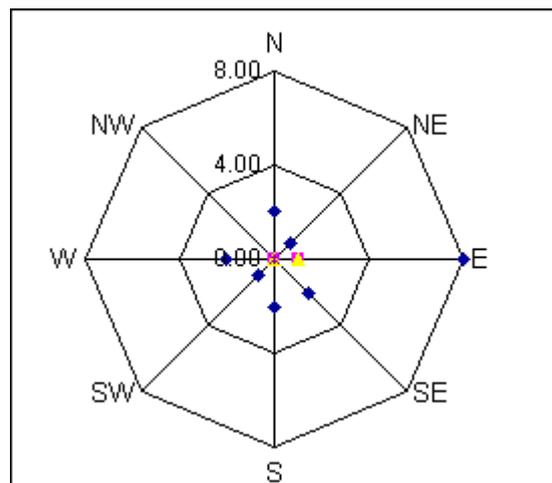

Figure 13.   Wind direction and strength at north Castaway Island.
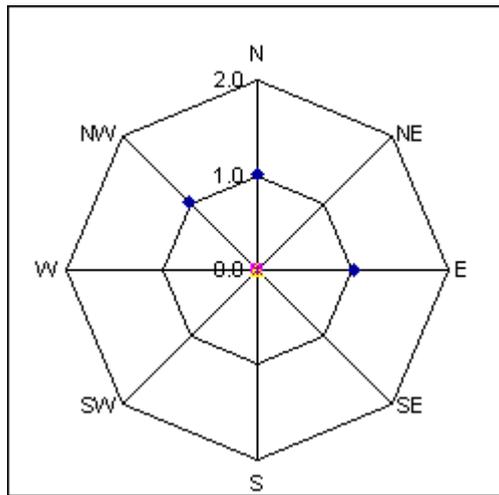
Figure 14.   Wind direction and strength at west Castaway Island.
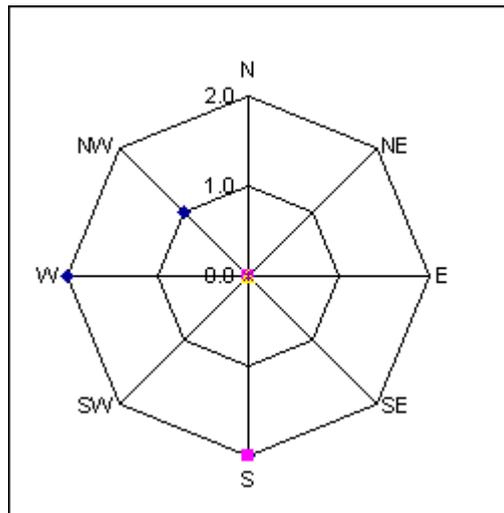
Figure 15.   Wind direction and strength at south Castaway Island.

Current direction and strength

Current diagrams for the four survey sectors are depicted by Figures 16 – 19. The rings on each diagram indicate the number of records whilst the legend indicates current strength in knots. The diagrams indicate that generally weak current were recorded around Castaway Island

Figure 16.   Current strength and direction records in east Castaway Island sector.

Figure 17.   Current strength and direction on the northern coast of Castaway Island

Figure 18.   Current strength and direction in the western sector of Castaway Island.

Figure 19.   Current strength and direction in the southern sector of Castaway Island.
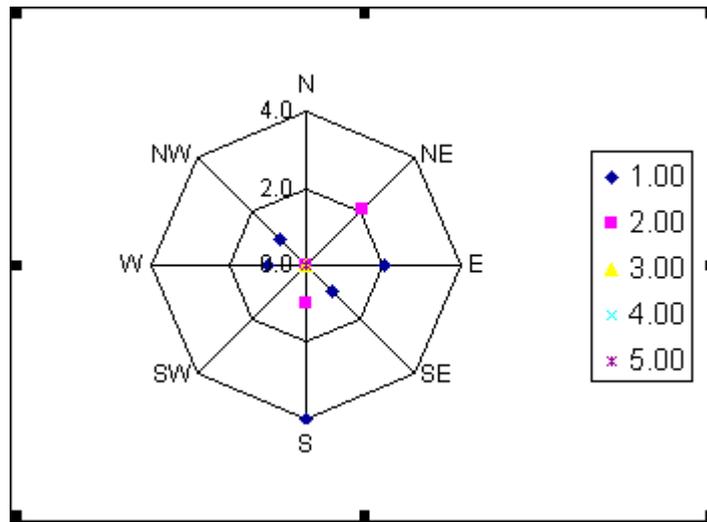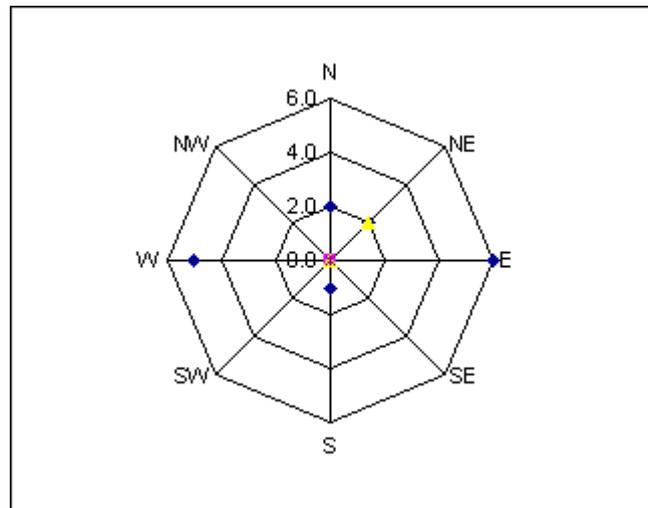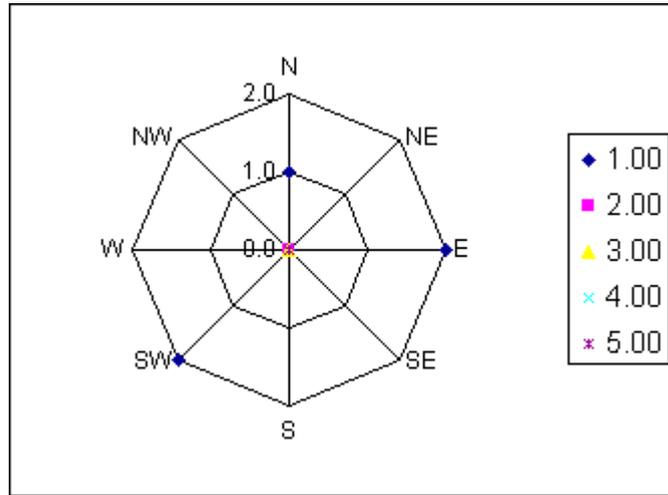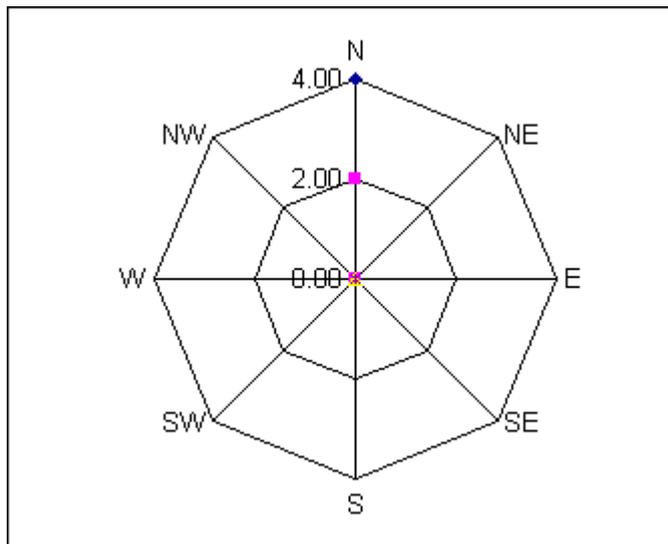
4.2   Benthic data

Classification of the 111 substrata and biological variables was derived by conducting a cluster analysis on the replicate survey samples after an initial SIMPER analysis on the data (see Fig. 20).

From the 80 survey dives carried out on Castaway Island, the following benthic classes were derived:

BC 1: Sand, sparse algae and seagrass.

BC 2: Sand with dense algae and seagrass.

BC 3: Dead coral and sand with filamentous and macroalgae.

BC 4: Sand with mixed algae and sponge and sparse coral heads.

BC 5: Bedrock and sand with scattered sponge, algae and patchy coral.

BC 6: Hard coral, bedrock and rubble with scattered massive and branching corals.

BC 7: Bedrock with sponge, live and dead coral.

Details of the main constituents of the seven defined habitats of Castaway Island are outlined in Table 5. The order of abundance of habitats from most abundant (seen on most dives) to least abundant was as follows: 3>4=1>7=5>6=2. Overall, sand dominated habitats (BC 1, 3 and 4) were recorded most often on transects whilst two habitats, BC 2 and BC 6, were recorded the least.

A pictorial representation of the relative frequency of occurrence of the different habitat types within each sector of Castaway Island can be seen in Figure 21. The pie charts have been created by calculating the proportion of dives that occurred in each defined habitat. Figure 21 indicates that the benthic classes dominated by live coral (classes 5, 6 and 7) were recorded more often in the northern and western sections of Castaway Island, 41 and 42 % respectively. Conversely the eastern and southern sectors were dominated by softer substrata such as mud and sand with seagrass or macroalgae. In these two sectors hard coral dominated habitats were recorded on only 12.5 % (south) and 26 % (west) of dives. In terms of the total number of defined habitats recorded in each sector, all seven benthic classes were found in the Castaway North whilst the eastern sector only contained five. The remaining sectors were intermediate with six benthic classes. The northern and western sectors also contained a more even mix of habitats whilst the remaining two 'quarters' were dominated by one or two habitats.
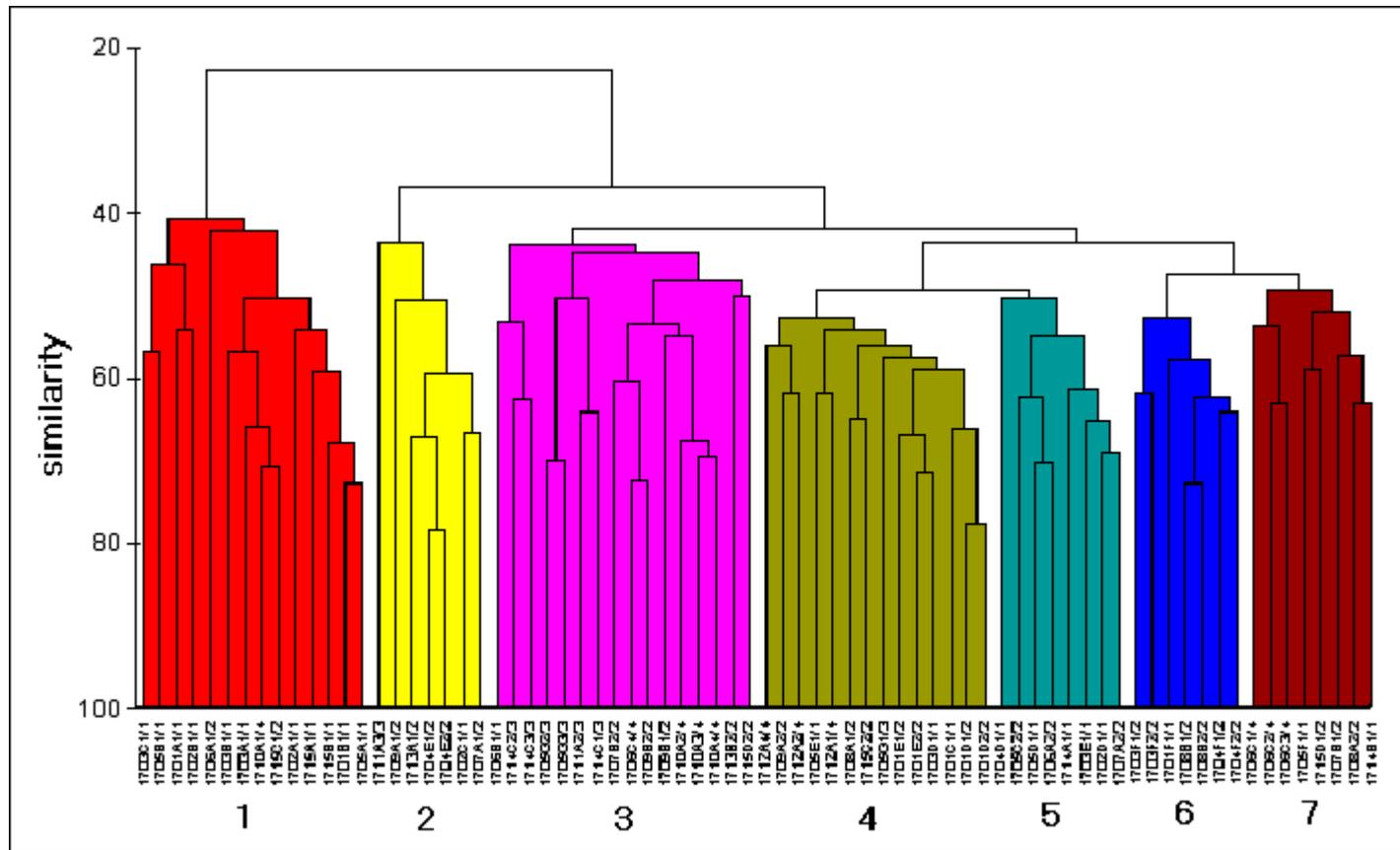
Figure 20.   Dendrogram of the relative similarities of dives carried out in all sectors (N,S,E,W) of Castaway Island for benthic categories (variables). The number of species/families and life forms that were included in the analysis of benthic habitats was 111. Different colours represent different 'clusters' of definable habitats. SIMPER analysis was used to pull out species that were found to be major components of these 'clusters'.

Table 5.   Major characteristics of the seven benthic classes (as designated by SIMPER analysis on community data) along the coastline of Castaway (Qalito) Island, Fiji.

Note: Figures in parentheses indicate the median abundance (semi-quantitative scale) of each benthic category and its contribution to defining the overall benthic class. Images depict typical habitats described by the benthic classes.

BENTHIC CLASS	NO. DIVE SURVEYSL	SUBSTRATUM (AV. ABUND.)	HARD CORALS (AV. ABUND.)	OCTOCORALS (AV. ABUND.)	SPONGES (AV. ABUND.)	ALGAE/ SEAGRASS (AV. ABUND.)	IMAGE
1 Sand, sparse algae and seagrass	14 (19%)	Sand (5)	None	None	All species (0.79)	All species (1.07); *Schizothrix* sp. (1.29); Seagrass (0.57); *Halimeda* sp. (0.71)	
2 Sand with dense algae and seagrass	7 (9%)	Sand (3.71)	All species (0.86)	None	All species (1.29); Lumpy (1.14)	*Halimeda* sp. (2.43); Coralline algae (2.14); seagrass (1.86); *Padina* sp. (1.71); *Halophilia* sp. (2.00)	

Table 5 (continued)

BENTHIC CLASS	NO. SURVEYS	SUBSTRATUM	HARD CORALS	OCTOCORALS	SPONGES	ALGAE/ SEAGRASS	IMAGE
3 Dead coral and sand with filamentous and macroalgae	**16 (22%)**	Dead coral (3.13); sand (2.75)	All species (1.75); *Acropora*: branching (1.31); massive *Porites* (1.00)	None	All sponges (0.88); Lumpy sponge (0.63)	Dead coral with filamentous algae (3.13)l; *Sargassum* sp. (3.13); *Padina* sp. (2.13); all species (2.06); fleshy brown algae (2.06); green calcareous algae (1.44); *Halimeda* sp. (1.38)	
4 Sand with mixed algae and sponge and sparse coral heads	**14 (19%)**	Sand (3.50); Bedrock (1.71); Rock (0.93)	*Porites* massive (1.57); All species (1.50); Non-*Acropora* massive (1.29); NonAcropora encrusting (1.07); Non-*Acropora* branching (0.86); *Favites* sp. (0.86); *Acropora* branching (0.86)	All species (1.36); *Xenid* sp. (0.71)	All species (2.14); Lumpy (2.00); Encrusting (1.07); Branching (0.93) *Lobophyllia* sp. (0.57)	*Tydemania* sp. (2.57); Dead coral with flimentous algae (2.21); All species (1.29)	No picture available
5 Bedrock and sand with scattered sponge, algae and patchy coral	**8 (11%)**	Bedrock (2.88); Sand (2.77); Rock (1.88); Rubble (1.25)	All species (2.25); *Favites* sp. (2.00); Non-*Acropora* encrusting (1.88); Non-*Acropora* mushroom (1.38); Non-*Acropora* massive (1.63); *Porites* massive (1.63); *Favia* sp. (1.25); *Acropora* branching (1.25); *Galaxea* (0.88)	All species (2.50); *Cirrhipathes anguina* (2.25); *lobophyllia* sp. (1.00); Pulsing (1.13); *Xenid* sp. (1.00)	All species (3.13); Lumpy (2.75); Encrusting (1.88); Branching (1.63); Leathery (1.38); Rope (1.00)	Dead coral with filamentous algae (2.57); green coralline algae (2.75); *Halimeda* sp. (2.75); *Tydemania* sp. (2.38); red coralline algae (2.88); *Schizothrix* sp. (1.63)	

Table 5 (continued)

| BENTHIC CLASS	NO. SURVEYS	SUBSTRATUM	HARD CORALS	OCTOCORALS	SPONGES	ALGAE/ SEAGRASS	IMAGE
6 Hard coral, bedrock and rubble with scattered massive and branching corals	7 (9%)	Bedrock (2.57); Rubble (2.00); Sand (1.57)	all species (2.71); non-*Acropora* submassive (1.71); *Acropora* branching (1.86); *Porites* massive (1.43); Non-*Acropora* encrusting (1.43); *Acropora* table (1.43); *Pocillopora* small (1.29); Non-*Acropora* massive (1.14); *Diploastrea heliopora* (1.29); Bottlebrush *Acropora* (1.71)	All species (1.29); Deadmans fingers (0.86);	All species (0.86); Plate (0.86); Leathery (1.00)	Dead coral with filamentous algae (2.71); *Padina* sp. (2.29); *Schizothrix* sp. (2.29); green coralline algae (1.00); filamentous algae (1.29)	
7 Bedrock with sponge, live and dead coral	8 (11%)	Bedrock (2.75); Sand (1.75); Rubble (1.50)	All species (2.13); *Porites* massive (1,63); Non-*Acropora* massive (1.38); Non-*Acropora* branching (1.50); *Acropora* branching (1.13); *Porites rus* (1.50); Non-*Acropora* sub-massive (1.25); Non-*Acropora* encrusting (1.13); *Diploastrea heliopora* (1.13); Non-*Acropora* mushroom (0.88); *Favites* sp. (0.88)	All species (1.38); Deadmans fingers (1.13); *Cirrhipathes anguina* (0.88);	Lumpy (1.88); All species (1.63); Leathery (1.00); Encrusting (0.88)	Dead coral with filamentous algae (2.13); brown fleshy algae (1.75); *Padina* (1.50)	
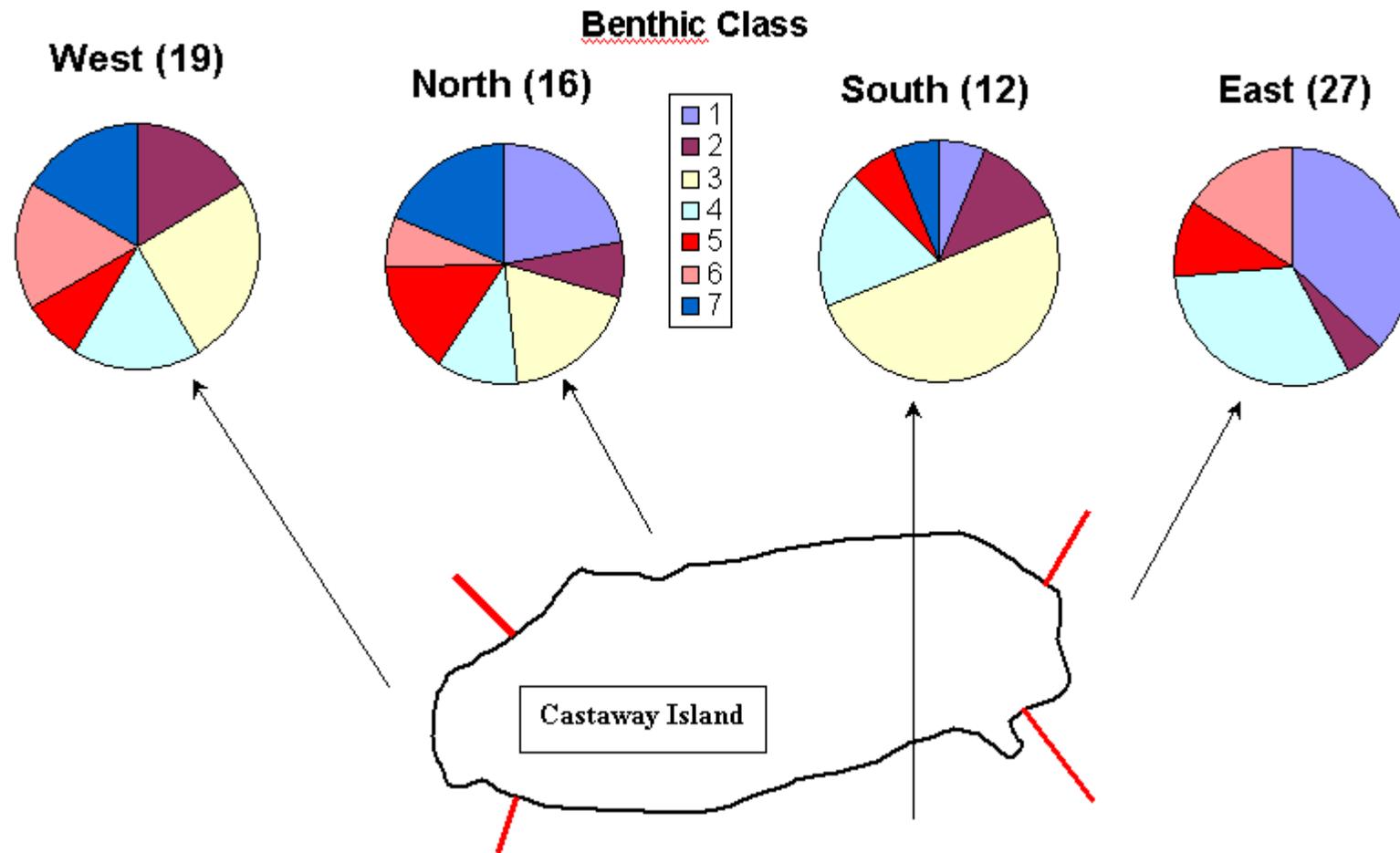
Figure 21.   Relative percentages of the seven defined habitats in the four survey sectors around Castaway Island based on the number of dives completed for each benthic class. Figures in parentheses indicate total number of survey dives in each sector.

Indices of species diversity and abundance, derived from PRIMER analysis, were rather similar between all sectors of Castaway Island (Table 6). Slightly higher mean values were recorded for the southern sector, although differences were not statistically significant. Values for the eastern sector were consistently the lowest.

Table 6.   Indices of species diversity and abundance for all benthic classes combined in each survey sector around Castaway Island; mean values with standard deviation in parentheses.

Location	Total species records	Total species abundance	Margalef (species abundance)	Pielous eveness	Shannon-Weiner Index
East	26.21 (15.42)	46.26 (28.25)	6.37 (3.18)	0.94 (0.04)	2.86 (0.89)
North	29.93 (12.99)	49.15 (21.72)	7.30 (2.83)	0.95 (0.03)	3.10 (0.74)
West	29.93 (12.99)	49.15 (21.72)	7.30 (2.83)	0.95 (0.03)	3.10 (0.74)
South	31.83 (10.36)	54.33 (15.52)	7.67 (2.18)	0.97 (0.01)	3.29 (0.37)

4.3 Coral Lifeform abundance

'Dead coral with algae' was the most abundant hard coral lifeform in all sectors around Castaway Island (Figure 23). The most abundant live hard coral lifeforms were branching *Acropora* species, and massive, branching and encrusting non-*Acropora* corals. Of these lifeforms branching *Acropora* and both encrusting and branching non-*Acropora* lifeforms were more abundant in the southern and western sectors of the island. A further five lifeforms were most abundant in the western sector.

Figure 23.   Median abundance of living and dead coral lifeforms in four survey sectors around Castaway Island.
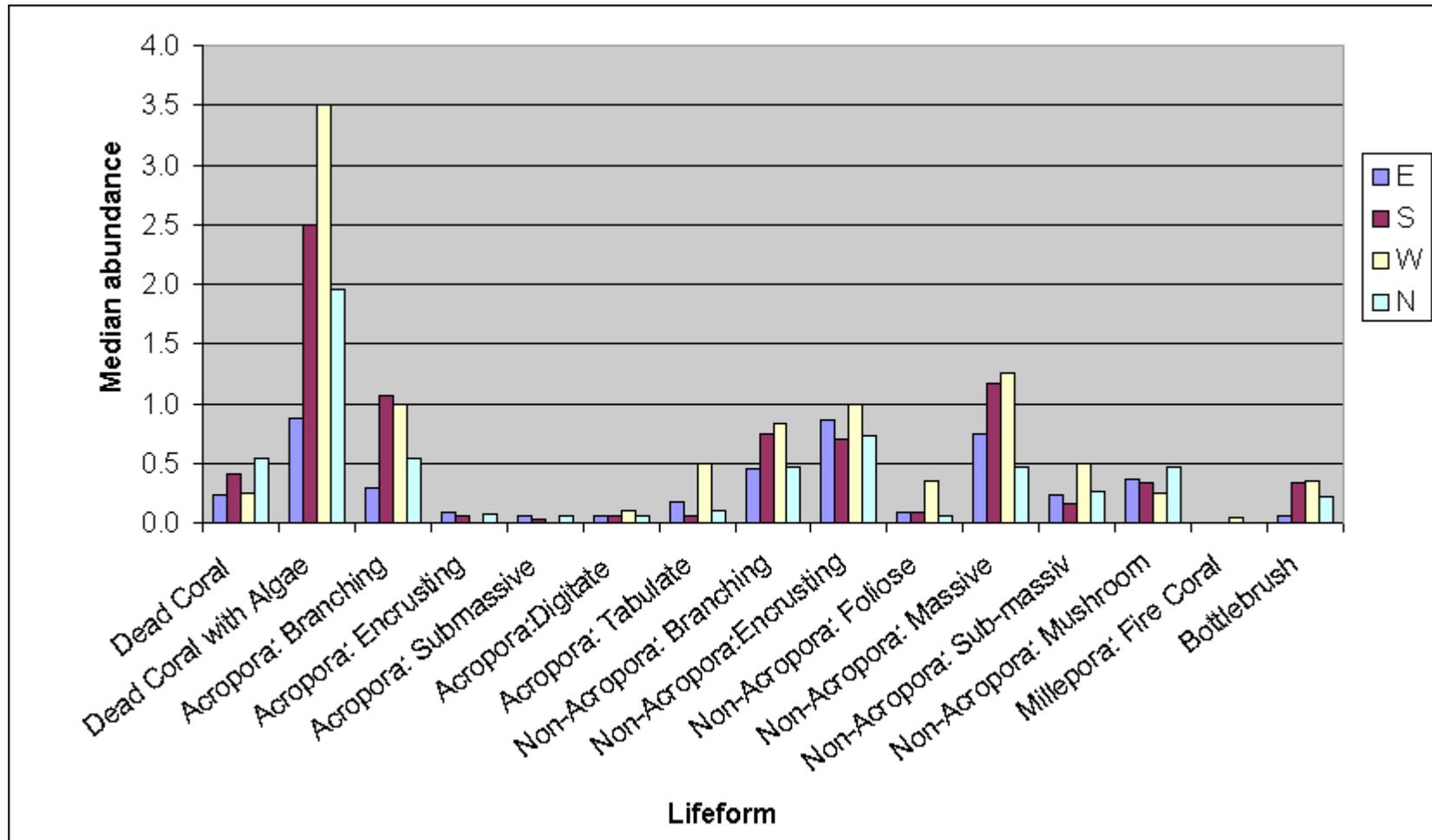
4.4   Reef fish abundance

Median abundances of the main fish families recorded by divers are presented in Figure 24. Although not presented here, there were no significant differences in the median abundance of targeted fish species between survey sectors (ANOVA F, *P* >0.05). Abundances of recorded fish families were also not significantly different between survey sectors (ANOVA, *P* >0.05).

However, there does appear to be a slight pattern in the relative abundance of fish families between sectors in that ten of the twelve recorded families were most abundant in either the western and northern sectors. This phenomenon is particularly apparent for Surgeonfish (Acanthuridae), Groupers (Serranidae), Snappers (Lutjanidae) and Fusiliers (Caesionidae). For example, abundance of Surgeonfish was observed at 0.50 and 0.62 for the western and northern sectors respectively, whereas their abundance was lower in the eastern (0.18) and southern (0.27) areas.

Some marked differences were recorded in the abundance of different families. In particular one family, damselfish (Pomacentridae) was considerably more abundant than any other. Other prominent families were Butterflyfish (Chaetodontidae), Surgeonfish (Acanthuridae) and to a lesser extent Goatfish (Mullidae). The latter were recorded most often in the southern sector where sandy habitats were predominant.

Other families were more noticeable by their absence. In particular very few Snappers, Emperors (Lethrinidae) or Rabbitfish (Siganidae) were recorded. Jacks (Carangidae) were also not observed very often but are not solely associated with reef environments although they are important commercially. Low abundance ratings were also found for Groupers, Parrotfish (Scaridae) and Triggerfish (Balistidae).

Figure 22.   Median abundance of reef fish families recorded in the four survey sectors around Castaway Island.
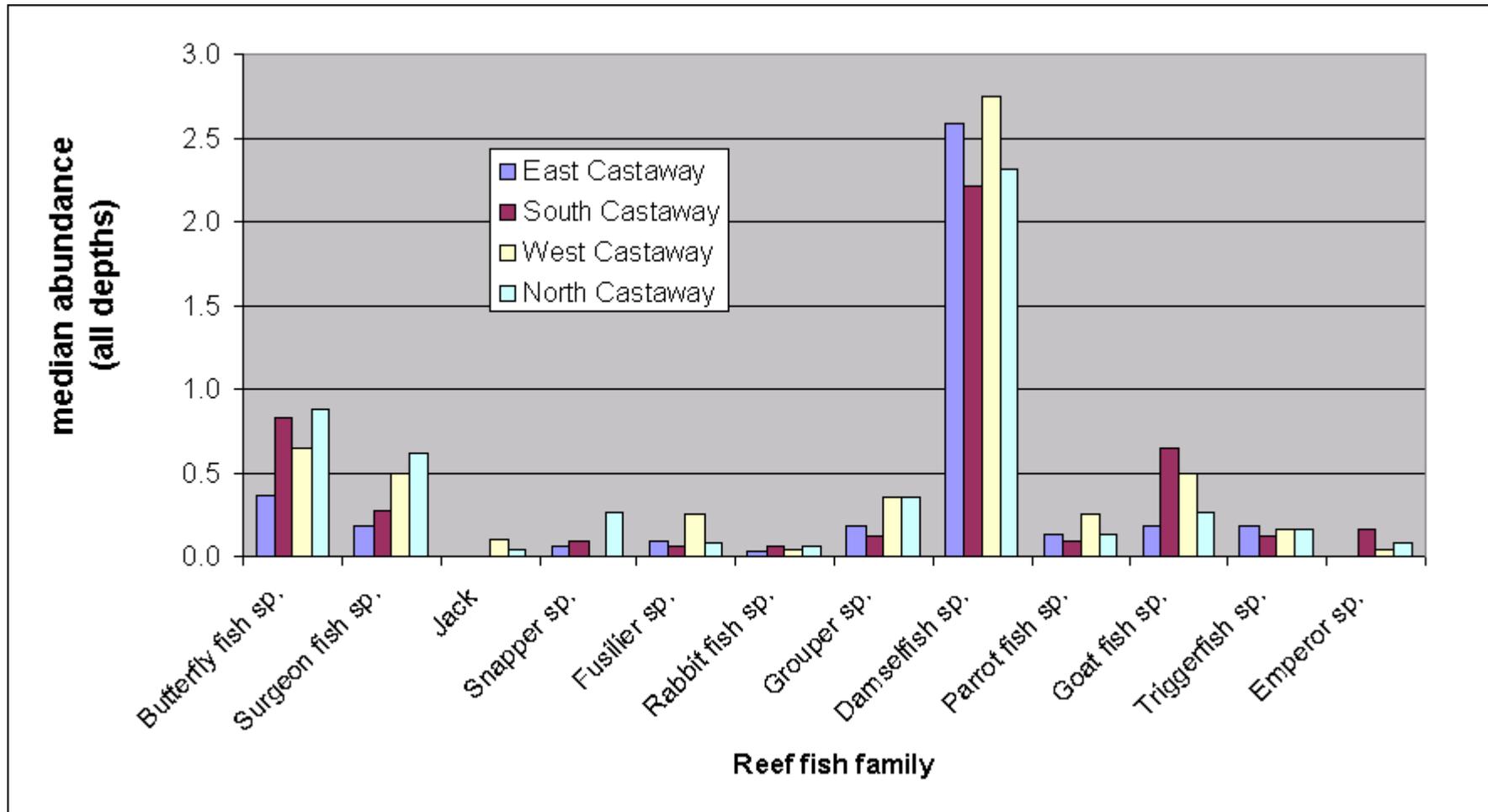
4.5   Invertebrates

Invertebrate data showed no occurrences of lobster on any one of the 85 survey dives completed. The most abundant ecologically important invertebrate was the long-spined echinoid *Diadema spp.*. These echinoids were found most commonly in coral rich habitats off the western and northern sections of the island. Crown-of-thorns (COTs) sea stars and Conch were very rarely seen. Holothurians or sea cucumbers occurred in largest abundances in the south and west areas of the island.
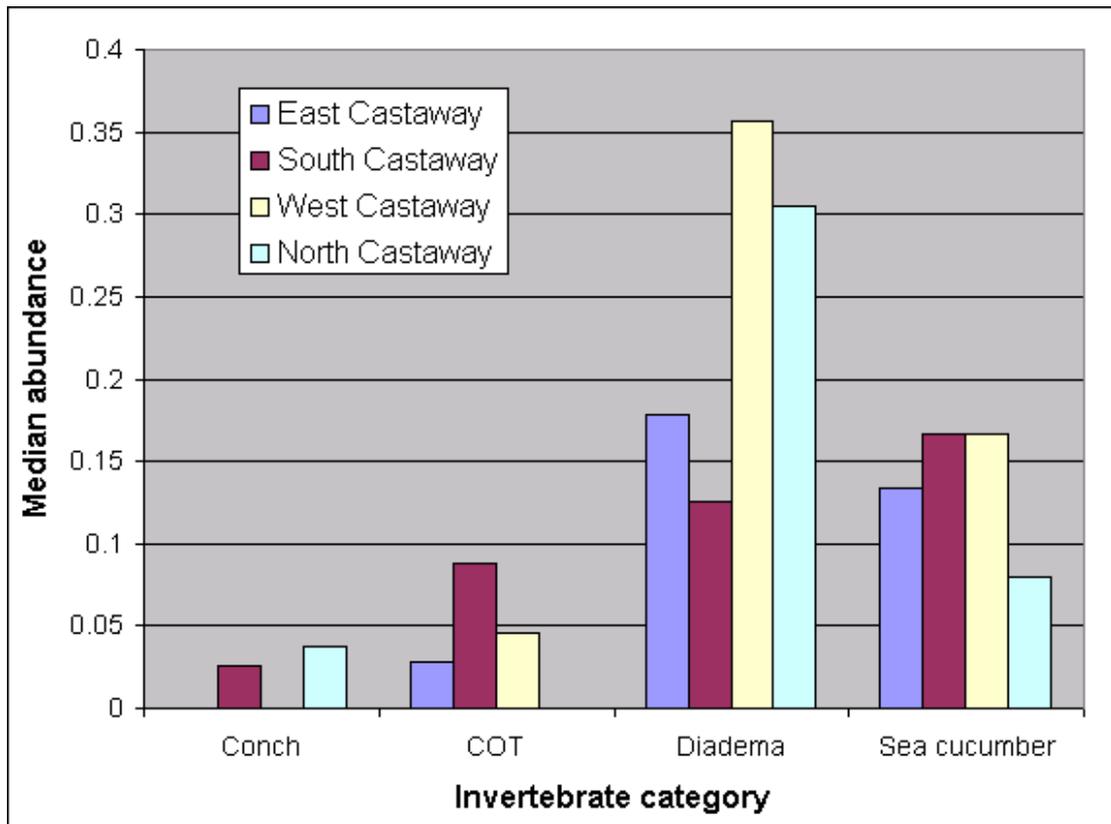

Figure 24.   Abundance of four key invertebrate groups in four survey sectors around Castaway Island.

Note: Lobsters were absent from all surveys.

5   DISCUSSION

The data collected by CCC volunteers around Castaway Island between March and May 2002 has been presented in this report.   Although some data-sets are comprehensive for this time period (e.g. benthic habitat data) others are insufficient to draw any strong conclusions. Wind and current data in particular is insufficient and will not be discussed here. Further measurements of current strength and direction are required to produce an accurate pattern of current flow around Castaway Island.

The west side of Castaway Island appears to have the healthiest and most diverse reefs with higher hard coral cover when compared to other areas of the island's coastline. The coastal topography for the island indicates that the reef slopes generally have a steeper gradient on the western and northern sides with considerably more hard substrata (bedrock, boulders or reef rock) than the southern and eastern sides.

The structure of the reef on the west side of the island is also more complex which, combined with the steeper profile provides a more spectacular 'reefscape' for pleasure divers. High topographical complexity also provides many microhabitats and cryptic refuges for marine fauna, which can increase biodiversity on a small local scale. Indeed the number of defined habitats (benthic classes), which arose from the CCC benthic data for Castaway was highest on the northern and western sectors.
The reefs of the western sector of the island are also further away from Malolo Island and may be less exposed to runoff with the related factors of elevated nutrients and increased sedimentation. Water clarity was highest in the western sector (Fig. 10).

Branching *Acropora* lifeforms were seen in relatively abundant levels in the western and southern parts of the island. These two sectors also have large *Acropora* tables (ACT) in shallow water (see plate 3). Although the southern sector is not as visually spectacular as the west coast of Castaway Island it does contain the same number of defined benthic classes. Indices of species diversity and abundance were also highest in the southern sector although more transects were completed here. Even though most of the survey dives in the southern sector were over sand dominated habitats (BC 1 – BC 3) there are patchily distributed areas along the southern coast, which are rich in benthic fauna and have considerable hard coral cover.

The recent bleaching event in the Mamanucas may be partly responsible for the generally low abundance ratings recorded for hard corals around Castaway Island. Recovery from such an event will take time. Initially the abundance of macroalgae can increase in the absence of their superior competitors (hard corals) which may substantially explain the high levels of 'dead coral with algae' recorded in all sectors

Data for invertebrate groups recorded on surveys revealed a lack of reef lobster around Castaway Island. Although cryptic and often hard to see underwater the complete lack of any recorded suggests that overfishing may have occurred for this species in the past. Other invertebrates that were recorded infrequently were Conch and Crown-of-thorns sea stars. The lack of the former may also be indicative of overfishing whilst the absence of the latter is beneficial for coral reefs around Castaway Island. Holothurians were also recorded in low numbers around the island and may be subject to over harvesting.

The most abundant fish family on Castaway Island is the damselfish family. This family comprises over 300 species and they are extremely successful inhabitants of coral reefs. This is to be expected, as this family usually constitutes a major part of the fish community on most coral reefs. However, their abundance may be artificially elevated in that they are not a preferred food fish and so are not selected by fishermen. Conversely other herbivorous fish such as parrotfish, surgeons or rabbitfish are subject to fishing pressure allowing the pomacentrids to utilize the extra resources available once their competitors are removed. Survey data appears to support this in that, apart from surgeonfish, very few roving herbivorous reef fish were recorded on dives. With the removal of herbivorous parrot and rabbitfish there is the opportunity for territorial damselfish abundance to increase. This can have a detrimental affect on the reef environment in that damselfish can accelerate the growth of filamentous algal turfs, which in turn can out compete recruiting corals for light and space.

The low recorded abundance of parrotfish and also rabbitfish may also be related to the patchy distribution of these families on the reef. Both families aggregate in large often mixed roving schools that travel along the reef, feeding on the epilithic algal community. A survey diver may encounter such a school but the chances are that these schools are not observed on a dive or not on the actual survey transect.

Other targeted families (Groupers, Snappers and Emperors) were also low in abundance, suggesting that the level of fishing around Castaway Island may be unsustainable. Records of fishing activity indicate that fishermen are now concentrating their efforts in the western sector where many fish families were recorded as most abundant. Some regulation of fishing activity may be required to prevent existing populations from falling in this sector.

Butterflyfish were the second most abundant family recorded by surveyors. Many species in this family are obligate corallivores depending on hard corals for both food and shelter. Their relatively high abundance in all sectors except the eastern part of Castaway Island is an asset that should be preserved. They have previously been proposed as indicators of reef health (see Crosby and Reese, 1996).

Altering the tropho-dynamics of reef systems through the removal of commercial fish families (both predatory and herbivorous) can be highly detrimental to the coral reef environment. If other factors come into play, for example, a major die-off of corals due to hurricanes and/or bleaching (as in early 2000 for Fiji) then reefs can be at serious risk of severe damage. Recovery from such multiple stresses may take years to decades. If reef fish populations are drastically altered then a phase shift can occur where the corals are permanently outcompeted by macroalgae, as was the case in Jamaica in the early 1980's (see Hughes, 1994).

An important issue in terms of tourism and revenue for any resort-based business is the quality of the diving available on the local reefs. Steep or complex reef topography as well as abundant reef fish populations and benthic fauna normally provide good criteria for a 'quality' dive. The reefs of the western side of Castaway Island meet these criteria to a great extent and aesthetical ratings by CCC volunteers on survey dives appeared to confirm this. Biological ratings by volunteers were also highest for the western and northern sectors.

6   RECOMMENDATIONS

If one part of the coastal environment of Castaway Island is to be designated as a marine reserve with restrictions on resource extraction then of the four sectors surveyed and reported here it should be within the western sector. This area has all the prerequisites for a potential reserve; high cover of hard substrata (both living and dead), an even mix of defined habitats plus the greatest abundance of many coral lifeforms and fish families. An alternative approach would be to designate a number of smaller marine protected areas around the island, for example, three reserves within the north, west and east sectors. 'No-take' zones in reserves are the most effective way to conserve marine resources but the benefits of such an action should be considered against the costs of restricting resource extraction for the dependant fisherfolk populations. At this stage there is a need for intensive discussion between all stakeholders within the local community so that an acceptable agreement can be made for the benefit of all parties.

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