Coral Reef Benthic Monitoring

Final Report / Workshop Report

Kiribati Adaptation Project

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1. Introduction

Coral reefs are central to past, present and future life in Kiribati. The Kiribati islands themselves were constructed over millions of years by corals. Today, the coral reefs protect the fragile shoreline of the atolls from erosion and provide habitat for the fish and invertebrates that compose much of the i-Kiribati diet and national exports. These same coral reefs that help sustain life in Kiribati face a number of pressures. Local threats include heavy selective fishing pressure, sewage pollution from rising human population, toxic algae outbreaks and possible spread of exotic seaweeds from aquaculture. Some of these threats have been documented in reports conducted by MFMRD and MELAD

The coral reefs of Kiribati and across the tropics also face a long-term and potentially existential threat from human-induced climate change. The most prominent and best understood threat is that of mass coral bleaching, a breakdown of the symbiosis that sustains most reef-building corals. Mass coral bleaching is caused by abnormally warm seas surface temperatures, typically 1-2°C greater than the usual annual maximum lasting for a month or two. Although corals can sometimes survive bleaching events, sustained periods of warm water temperatures and especially repeated bleaching events can lead to a reduction in live coral cover and have a cascading effect on other reef organisms.

A lesser understood threat is from the carbon dioxide itself that contributes to climate change. Dissolution of excess carbon dioxide in the ocean alters seawater chemistry and could eventually become be damaging in the future to calcifying organisms like corals, either reducing the rate of reef growth or possibly even dissolving the organisms' actual skeletons. An increase in storm activity could also have an effect on coral reefs, by altering erosion patterns.

A coral reef monitoring system is crucial to understanding the present and future effect of these local and possible global pressures on coral reef health. While no direct actions can be taken by the Kiribati government to stop a coral bleaching event from occurring or oceanic carbon dioxide concentrations from rising, monitoring the change or lack of change in the coral community over time will help determine strategies to manage coral reef resources or adapt to changes in coral reef resources.

This report summarizes the work conducted during a one-month visit to Kiribati in October and November, 2007 including the Coral Reef Monitoring Workshop, the auxiliary training of MFRMD and MELAD personnel, the establishment of a Coral Reef Monitoring Protocol and the preliminary analysis of monitoring data.

2. State of monitoring

This section of the report briefly summarizes previous known efforts to assess coral reef communities in the Kiribati Islands and their implications for the proposed monitoring system. Studies of the Phoenix and Line Islands are not discussed.

Before the initiation of this program, several independent, single visit studies of the coral reef environments of Tarawa and Abaiang were conducted by foreign scientists often with assistance of MFMRD personnel. The first is a survey of the marine ecology of Betio conducted in the early 1980s (Zann, 1982), which includes a list of coral species. A copy of this report could not be obtained, but the list of species was available in later publications. Gustav Paulay, formerly of the University of Guam, conducted extensive surveys of the Tarawa lagoon environment, and included a description of the spatial patterns in coral cover (Paulay, 2001; Paulay and Kerr, 2001).

Ed Lovell of the University of the South Pacific led coral surveys of Tarawa and Abaiang in 2000 as part of a SOPAC technical study, using several current MFMRD staff as assistants (Lovell, 2000). The study found low coral cover at shallow depths in many parts of southern Tarawa, due to the rough wave environment and local human pressure, and higher coral cover at Northern Tarawa and western outer reef of Abaiang. The study noted the surprising abundance of the usually rare coral Heliopora coerulea and the unusual lack of the usually abundant Acropora sp. in southern Tarawa and some other outer reef environments.

In 2004, Taratau Kirata of MFMRD began surveys of the Tarawa outer reef environment at three sites (Naa, Bikenibeu and Tear, with guidance from Caroline Vieux formerly of the Global Coral Reef Monitoring Program (Vieux, 2004). The method required photographing randomly distributed quadrats at 6 m depth. Benthic cover is determined using subsequent photographic analysis on the computer. Three sites in Kuria and Abemama were also visited in 2004. Surveys of the three study sites around Tarawa were conducted in each of the next two years by Kirata and an assistant (Aranteiti Tekiau). The two MFMRD staff later attended a workshop in Tahiti to formally learn the monitoring protocol. However, due to limited training in benthic identification, the photos were in each case were sent to Vieux for analysis.

In late 2004, extensive coral bleaching was reported in Abaiang, Tarawa and Tabiteuea. Satellite observations by NOAA Coral Reef Watch indicated elevated sea surface temperatures across Tuvalu and the Kiribati Islands. The degree heating week thermal stress index, used to predict the onset of coral bleaching, peaked at 14 in the area of Tarawa; values over 8 typically indicate severe coral bleaching and extensive coral mortality. Additional photo-quadrat surveys were conducted by MFMRD staff and myself at previously visited sites around Tarawa and three sites around Abaiang. The climatic causes of the bleaching event and the possible effect on coral cover in summarized in Donner (2005). This initial report found that the bleaching event initially reduced live coral cover by over 50-67% at the three sites, although subsequent confusion over the exact site locations between the post-bleaching survey and the regular surveys planned by Vieux has placed those results in doubt.

Overall, the photo-quadrat surveys suggested initially low coral cover (~20%) on the outer reef in Southern Tarawa and high (~55%) coral cover in North Tarawa, as was suggested by earlier more thorough surveys. In southern Tarawa, coral cover is thought to have been affected by bleaching but to have recovered quickly, largely to the growth *Porites rus*, a species known to be more resilient to bleaching (Taratau et al., 2007). In northern Tarawa, coral cover is thought to be recovering from the

bleaching event, but as of 2006, still below the level in the initial 2004 surveys. These results, however, are not statistically significant due to high variation in coral cover between the quadrat photographs.

The low technology monitoring method was originally thought to be ideal for Kiribati given the limited available resources and scientific expertise. However, the large variation (measured as standard deviation or standard error) in the study results and ongoing confusion over the exact location of the centre of the Naa site demonstrated some of the limitations of conducting only photography-based surveys of unmarked monitoring sites. A more complete monitoring protocol would combine the low-technology quadrat surveys with other traditional sampling techniques involving live underwater identification to ensure data quality.

In addition to this foreign-led work, MELAD and MFMRD staff have collaborated on a study of the effect of sewage outflow on the coral cover at Bikenibeu, Bairiki and Betio using monitoring techniques learned during assistance on previous assessments (Tonganibeia, 2005). The study demonstrated low coral cover near the sewage outflow at Bikenibeu but would have benefited from more detailed benthic identification and data analysis.

These past studies have provided a basic understanding of the patterns in coral cover in Tarawa and to a lesser extent Abaiang. No data is available for any of the outer atolls, with the exception of the one-time surveys of three sites around Kuria and Abemama. While some of the previous studies have been complementary, in general the monitoring of coral reefs in the Gilbert Islands of Kiribati has suffered from the use of different monitoring protocols in each study, the failure to regularly mark and monitor the same sites, and the limited local identification ability beyond broad benthic categories. These problems limit the ability to properly evaluate the changes in benthic cover over time. The reliance on foreign experts has also led to a lack of confidence among MFMRD staff in both their knowledge of coral reefs and ability to conduct or lead coral reef monitoring. Finally, the lack of a regular, institutionalized monitoring program may contribute to the decay of equipment, including everything from the measuring tapes and digital cameras to critical items like the o-rings on the SCUBA tanks and the filters in the air compressor).

3. Workshop Report

As required under the Terms of Reference, a one week training workshop was prepared for the first-week of the consultancy. Conflicts with other events caused a two-week delay. The intervening time was used to:

i) Conduct a preliminary informal workshop on benthic identification and monitoring methods, including one day of sampling, with the key MFRMD staff expected to be participating in long-term monitoring (Taratau Kirata, Toaea Beiateuea, Tebaua Sapotu, Aranteiti Tekiau, Kobure Norman).

ii) Meet with MFMRD and MELAD staff so as to best fit the proposed monitoring roadmap and the workshop to the knowledge and skills of the participants.

iii) Lead a four-day training and rapid assessment survey of the coral reefs of Butaritari (with Taratau Kirata and Kobure Norman). The expedition summarized the overall range of coral reef habitats in western Butaritari, established sites that can be used for long-term monitoring, and trained the likely National TA and a Fisheries Assistant in the monitoring protocol for the Outer Atolls where SCUBA may be impossible. The results of this study in summarized in the Preliminary Data Analysis section

The Coral Reef Monitoring Workshop was eventually held from November 12-16, 2007 with twelve participants from MFMRD, two participants from MELAD and two participants from the Betio Fishermen's Association (BFA). The Workshop included three days of lectures, discussion and data analysis at the in Fisheries maneaba at Tanaea and two days of field work. The first day of the workshop included an introduction to coral reefs and coral reef monitoring, a discussion of current knowledge of the Kiribati coral reefs and an explanation of coral bleaching and possible links to climate change. The second day of the workshop focused on the design of the coral reef monitoring system for Kiribati, including site selection, long-term monitoring methods, coral bleaching protocols and some benthic identification practice. These presentations, and all other workshop materials, are included on the CD accompanying this report.

The large number of participants interested in conducting monitoring and limited boat space forced us to spread the monitoring work over three days. On the third day of the workshop, the four most experienced personnel accompanied me in monitoring at sites of the outer reef and Tarawa Lagoon, while the other workshop participants practiced benthic identification using previously prepared practice presentations, coral photos from the trip to Butaritari and coral identification guides. On the fourth day of the workshop, another six workshop participants accompanied me in monitoring at two sites in the Tarawa lagoon, while the other personnel practiced benthic identification. The remaining workshop participants requested to join a monitoring expedition on the following Monday (they recanted at the last minute and had to be replaced by two of the more experienced MFMRD staff).

During the monitoring trips, participants performed benthic identification using point intercept transects (PITs) in which the benthic cover at 50 cm intervals underneath a measuring tape was recorded. In order to demonstrate the difference in

monitoring methods, one more experienced participant was asked to conduct line intercept transects (LITs), in which the distance along the measuring tape is marked every time the benthic cover changes, along the same measuring tape as a PIT at two sites. Additionally, while the participants conducted their work, I took a set of photographs of the randomly placed 1.1 m^2 quadrat, the method employed by MFMRD personnel and Caroline Vieux in previous surveys.

On the final day of the workshop, we reviewed data analysis and compared the results from the different monitoring methods. As is expected, the LITs provided more detailed information than the PITs, including the size of coral colonies. The participants preferred the PIT method, as LITs are more time-consuming and extremely difficult to conduct without SCUBA equipment at shallow depths. The decision is acceptable given the resource constraints. The photo-quadrats revealed a higher diversity of corals than both the LITs and PITs, again, as is expected. The participants agreed that a combination of transects and photo-quadrats at each site would be ideal. The workshop concluded with a check on the benthic identification performed the previous two days, a discussion of the agreed-upon long-term coral reef monitoring protocol and a late lunch.

On the whole, the workshop appeared to be well-received by the participants most of whom had never learned about coral reefs or coral reef monitoring in an organized fashion. The only exception was that workshop appeared challenging for the two members of the BFA due to language; many of the terms could not even be translated into Kiribati for them to understand. The participants were all initially enthusiastic about the days of monitoring, in some cases perhaps less due to the opportunity to practice coral monitoring than the opportunity to spend a day in a boat and possible catch some fish. Nonetheless, each person that participated in the monitoring trip performed their duties as requested and agreed with the recommended monitoring protocol. Unfortunately, windy weather and rough seas limited data collection to less vital sites in the Tarawa lagoon.

The workshop also presented an opportunity to gauge the interest of MFMRD and MELAD staff in participating in the proposed coral reef monitoring program. With the possible exception of the two participants from the BFA, all the participants appear at least provisionally interested in participating in the program. Their participation will depend on their interest in learning benthic identification, willingness to commit to a schedule and their fitness to perform SCUBA and free-diving work.

4. Roadmap for Kiribati Coral Reef Monitoring System

A series of Coral Reef Monitoring protocols for Kiribati was presented, reviewed and accepted at the Workshop. These cover methods of monitoring around Tarawa and Abaiang, where easier access and availability of SCUBA equipment allows for more detailed monitoring, methods for monitoring the Outer Atolls, and a special protocol in the case of a coral bleaching event. A schedule for monitoring over the next ten months was also prepared and reviewed with the Fisheries Director (Appendix C).

There are four components to the proposed Coral Reef Monitoring System:

i) Tarawa Atoll

Up to eight permanent monitoring sites, marked by stakes, are being established around Tarawa (listed in Appendix D). These sites will be monitoring on an annual basis using SCUBA equipment. Several of site visits were completed or partially completed during the past month; subsequent visits in the next month will be necessary to complete data collection, depending on weather (as indicated in Appendices C and D). The southeastern and eastern outer reefs can be difficult to visit because of rough conditions and the long boat trip around the tips of the atoll in Naa or Betio. A site to correspond with KAP coastal monitoring on North Tarawa will be investigated by the future Coral Reef Monitoring Team, but difficulty of access may be a problem

ii) Abaiang Atoll

Due to its close proximity to Tarawa, Abaiang can be visited by the Fisheries boat. Therefore the three established sites around Abaiang should also be monitored on an annual basis using SCUBA. These sites were established during the post-consultancy expedition to Abaiang on Nov 22-24, 2007. Other marked sites around Abaiang can be visited using broad survey techniques.

iii) Outer Atolls

Monitoring sites should be established at representative atolls in the north central and southern portions of the Gilberts / Kiribati island chain. The priority atolls include Butaritari in northern Kiribati (completed); Kuria and Abemama in central Kiribati; Beru; some combination Tabiteuea, Onotoa and Nonouti in south-central Kiribati; and Tamana in southern Kiribati to correspond with other KAP work. The number of sites established on each atoll will depend on the diversity of coral reef environments identified during initial broad scale surveys and the time available for sampling. The expense and time required to visit the outer atolls limits the frequency of monitoring, Ideally, each atoll will contain 4-8 monitoring sites and these sites will be monitored every two years.

In all of the atolls, as with Tarawa and Abaiang, monitoring sites are to be chosen using geographic analysis of the reef environment before each visit and manta tows of the accessible reefs of interest. Individual sites should be selected to represent each of the different reef environments. For example, if manta tows reveal two widely disparate reef environments within relatively close proximity, two separate monitoring sites should be created. For every location visited, even those that do not

become permanent monitoring sites, visual surveys of each site should also be conducted and reported.

At each site, a list of monitoring tasks (attached file) is followed. This begins with marking or checking the coordinates using the GPS and writing a site description, and ends with double-checking all the collected data. Ideally, data is collected via four 25 m point intersect transects (PITs) at both shallow (2-4 m) and deep (10 m) environments. The shallow PITs can be conducted via free-diving; deep PITs require SCUBA equipment.

In some locations around Tarawa and Abaiang, the strong wave environment prohibits shallow sampling, so photo-quadrats can be taken at 4-7 m depth instead. At the outer atolls, where SCUBA equipment is not available, photo-quadrats at 6-7 m depth should be substituted.

iv) Bleaching Protocol

The final component of the Coral Reef Monitoring System is a set of steps to be undertaken in the event of a mass coral bleaching event. This protocol was reviewed during the Workshop; the relevant forms and tables are included in the Workshop materials.

The United States government's NOAA Coral Reef Watch program (http://coralreefwatch.noaa.gov) monitors the sea surface temperatures via satellite to predict the occurrence of coral bleaching across the planet. The program produces global maps of coral bleaching indices commonly known as "hot spots" and "degree heating weeks" (DHW) twice a week. If the DHW value exceeds 4, a Bleaching Alert Level 1 is reported, indicated the possibility of some coral bleaching in that location. If the DHW value exceeds 8, a Bleaching Alert Level 2 is reported, indicated the possibility of severe coral bleaching with associated coral mortality in that location. In the event of a Bleaching Alert in Kiribati, a notice will be sent to the international Coral-List maintained by NOAA Coral Reef Watch and to all relevant personnel worldwide.

In the event of received a coral bleaching alert, the personnel in charge of the Coral Reef Monitoring Protocol should first a request to all personnel, to Fisheries assistants on the outer islands and to the local community to collect any anecdotal observations of coral bleaching. After collection of anecdotal observations, broad scale surveys (using manta tows) should be conducted in locations where bleaching was informally observed and at established monitoring sites. The benthic cover should be classified using the (0-4) bleaching category table.

Monitoring should then be conducted are established sites using PITs or Bleaching Belt transects. Corals should be classified based on the extent of bleaching and by genus, as demonstrated during the workshop. Preliminary data should be sent to the International Coral-List in accordance with standard practice with other monitoring systems worldwide.

Repeat surveys should be conducted at established monitoring sites visited during the bleaching event. The typical schedule is two month after bleaching, six months after bleaching and one year after bleaching. The schedule can be adjusted slightly to fit with the existing monitoring schedule.

5. Preliminary Data Analysis

The data collected during surveys of reefs around Tarawa, Abaiang and Butaritari are provided in separate files on the CD accompanying this report. The Abaiang survey was conducted after the official completion of this one-month consultancy, and data analysis is still ongoing. The raw survey data is provided in Microsoft Excel Files listed by site ID (site names and IDs are listed in Appendix D). A summary of the data for each site is presented in the "Site Description" files[1]. In the interest of brevity, an overview of the preliminary findings on the different atolls is presented here. A full discussion of the results is not possible until the ongoing collection and analysis of the data around Abaiang and Tarawa is completed and the other central and southern atolls have been studied.

Tarawa

Monitoring of the coral reefs of Tarawa is still ongoing so the percent cover data is not reported yet. In general, the data collected to date confirms some of the spatial pattern in coral reef environments noted in previous studies. Patch reefs in the lagoon are dominated by branching *Acropora* sp. The extent of rubble and dead coral suggests possible lingering effects from bleaching in 2004. The reefs of North Tarawa and the outer reefs of South Tarawa have a curiously low cover of *Acropora* sp. and in many areas are dominated by the usually rare coral *Helipora* sp. (or "blue coral") which is more closely related to soft than hard corals, massive *Porites* sp., coralline algae and the alga *Halimeda*. *Pocillipora* sp. is also represented, but the number of dead colonies exceeds the number of living colonies in some regions.

Further surveys are necessary to contrast coral cover in North and South Tarawa and to properly measure the extent of recovery from the bleaching event of late 2004. Little *Porites rus*, the coral thought to be favoured in South Tarawa after the bleaching event, was seen during visual surveys at 4-6 m depth or during 10 m PITs in Teaoraekeke. Surveys at Bikenibeu and additional surveys at Teaoraekeke will help determine whether the expansion of this more bleaching-resistant coral is a general phenomenon, restricted to location of past field surveys, or a statistical anomaly

Abaiang

An expedition to Abaiang was undertaken after the completion of the KAP contract. The results presented here are based on PITs and visual surveys; analysis of photo-quadrats by MFMRD personnel is ongoing and designed to serve as a final test of benthic identification abilities (it will be checked against expert analysis). As in Tarawa, sampling at the eastern and southern outer reefs is prohibited by the rough conditions.

Live hard coral cover at the 10 m depth on the western outer reef ranged from 25-35% and dominated by massive *Porites* sp., *Faviid* sp. and *Heliopora*. The alga *Halimeda* is abundant. Live colonies of the usually common branching corals *Acropora* sp. and *Pocillipora* sp. were uncommon; many dead colonies, particularly *Pocillipora* sp. but also some digitate *Acropora* sp. and some tabular *Acropora* sp.,

[1] For uninitiated readers, benthic cover during broad surveys is typically reported as follows: Category 0 = 0%, Category 1 (1-10%), Category 2 (11-30%), Category 3 (31-50%), Category 4 (51-74%), Category 5 (75-100%).

either covered in coralline algae or turf algae were noted. These species are known to be less resistant to coral bleaching.

Post-bleaching surveys in 2005 using the photo-quadrats found coral cover to be less than 25% at all three western reef sites and also noted a high number of dead colonies of *Pocillipora* sp. This preliminary data suggests some slow recovery of coral cover from the bleaching event; analysis of the photo-quadrats, to be included in the final report by the National TA, will provide a more complete picture.

Butaritari

The expedition to Butaritari was intended both for training and data analysis. Surveys were restricted to the western outer reef and western half of the lagoon due to the prevailing winds. Surveys were restricted to shallower depths due to lack of SCUBA equipment and facilities on the island (as will be the case at other outer atolls).

Live hard coral cover in the SW outer reef was high at 41% and heavily *Acropora*-dominated (comprising 79% of hard coral according to data collected by myself; other observers will still learning identification at the time). The reefs along the passage to SW outer reef were also *Acropora*-dominated, including an area of large formations of tabular and 3D branching species. *Pocillipora* sp. was rare in both environments.

. Alternatively, live hard coral cover was lower at a NW outer reef site (16%) and featured little *Acropora* sp. and a large number of dead *Pocillipora* sp. covered in coralline algae. Shallow reefs adjacent to the central lagoon passage has similarly low live hard coral cover, however deeper and cooler areas along the passage featured luxuriant growth including tabular *Acropora* sp., large boulders of *Porites* sp. and a diversity of other corals.

6. Database framework

The Coral Reef Monitoring Program requires analysis of four types of monitoring data: i) visual site surveys, ii) manta tows, iii) point intersect transects / line intercept transects, and iv) photo-quadrats. The simple database framework developed for the Monitoring Program and used in preliminary data analysis is described below.

Visual surveys

Simple visual site descriptions are to be written for the initial visit to each field site, using the descriptions provided in the Tarawa, Abaiang and Butaritari data as templates.

Manta Tows

Manta tow data should be compiled in Microsoft Excel using the template provided (Manta Form.xls) provided. The information is then summarized in the site descriptions and used to explain the choice of monitoring sites.

Point intersect transects (PITs)

Point Intersect Transects should be entered into Microsoft Excel using the template (PIT Form.xls) provided. Each 25 m PIT is entered on a separate page. Standard deviation and standard error for Hard Coral cover, Acropora cover and Algae (including Deal Coral with Algae) cover is included. The summary page shows the collective results of the four PITs at the particular site and depth. A separate file can be used for each site and depth to avoid confusion.

Line intercept transects (LITs)

Although PITs are the method of choice for the Monitoring program, a Microsoft Excel template (LIT Form.xls) is included for Line Intercept Transects in case complimentary data in collected at any sites

Photo-quadrats

The photo-quadrats are analysed using the freely available software CPCe Version 3.4. MFMRD was already in possession of a copy. The basic operation of the software was reviewed at the workshop for the uninitiated. The software generates output into a Microsoft Excel spreadsheet.

7. Summary

Coral reefs and climate change

The coral reefs of Kiribati and much of the Pacific face a number of well-documented local and global threats. Despite the dependence of the people of Kiribati on coral reef resources, for food and income, and the protection that the outer reefs provide from coastal erosion, the corals and coral reefs of the Gilbert Islands of Kiribati have not been the subject of much research or public attention. This is reflected by an anecdote from the Workshop. The MFRMD staff found it difficult to translate the presentations from English into i-Kiribati for the two representative of the BFA because there are no local words for different corals.

Preliminary data analysis and previous research suggests the coral reefs of Kiribati are already being affected by the growing human population through increasing sewage and increased demand on reef resources. These pressures are one of the explanations for the low coral cover noted on the Southern Tarawa and in those areas of lagoon where reef formation is possible. The outbreaks of toxic fish poisoning on the outer atolls may also be related to increased pressure on marine resources and the expansion of aquaculture; toxic bacteria and algae may be more likely to grow on reefs with high nutrient input (from sewage), low grazing fish biomass, and spread of exotic plants (from aquaculture, as appears to have happened in parts of the Butaritari lagoon).

Science suggests climate change may pose an existential threat to many reef-building corals worldwide and lead to widespread degradation of coral reefs ecosystems. More frequent coral bleaching events, especially when combined with local disturbances like fishing, pollution or sedimentation, are expected to keep coral, fish and invertebrate species richness low. The rise in oceanic carbon dioxide concentrations also poses a threat, though at present, this is difficult to quantify. Long-term degradation of reef ecosystems, from either cause, could have serious consequences for the marine resources that sustain the economy and the people of Kiribati.

The best present option of Kiribati is to monitor benthic cover and the associated fish and invertebrate community in hopes of identifying spatial patterns and relationship between different variable that can be eventually used for management. The aftermath of a coral bleaching event, like that in 2004, can provide an opportunity to characterize the vulnerability of different coral reef environments. Evidence from ongoing surveys also suggest that hard coral cover in Tarawa, Abaiang, possibly Butaritari and other atolls was reduced by the coral bleaching event in 2004. One of the most noticeable changes, which must be confirmed by continued monitoring and data analysis, is the number of dead colonies of *Pocillipora*, a genus of corals known to be highly sensitive to bleaching.

This preliminary evidence, however, also suggests that coral cover may be more resilient to bleaching in Kiribati than other parts of the Indo-Pacific. Mass bleaching events in some other parts of the tropics including the Seychelles and Palau, triggered by warm water anomalies similar to that which occurred in the Gilbert Islands in 2004, caused over 90% coral mortality and have required a minimum of 5-10 years for the coral cover to return to close to previous levels. It is possible that the coral reefs of the region may be more adapted to withstand warm water anomalies – either through adaptation by individual species or by selection of species that can survive in a tougher thermal environment – due to Kiribati's location in the central

equatorial Pacific and exposure to the El Nino / Southern Oscillation. Upwelling of cooler waters may also reduce the severity of coral bleaching in some areas. These factors may explain the dominance of the "blue coral" of the genus *Heliopora*, normally uncommon in the Pacific, and the low cover of the more temperature-sensitive branching corals of the genus *Acropora* and *Pocillipora*.

Long-term monitoring of sites in a variety of coral reef environments around Tarawa and the Outer Atolls is the only means by which to fully answer these questions and to diagnose the vulnerability of the coral reefs and marine resource to the combination of climate change and other stresses. The training MFRMD and MELAD staff in benthic monitoring techniques and in benthic identification has provided the capacity for Kiribati to maintain a coral reef benthic monitoring program. The continuation of this program over time is critical to identifying how Kiribati can adapt to changes in the local coral community and coral reef ecosystems that may occur in the coming decades.

Adaptation options

There are no direct management actions that can prevent a coral bleaching event. Kiribati as a nation also has little control over the predicted rise in ocean temperatures, expected to increase the frequency of coral bleaching events, or the predicted rise in oceanic carbon dioxide concentrations, expected to affect the chemical environment for corals. The adaptation strategies fall into one to two categories:

1. Actions that assist the ecosystem in surviving to the climate change

2. Actions that increase the adaptability of the human population to a change in status of the ecosystem (ie. a reduction in the delivery of goods and services to the human population by that ecosystem)

Under the first category, there is increasing evidence that reducing other local stresses to a coral reef, while not preventing coral bleaching from occurring, can increase that reef's ability to recover from the bleaching event. Sewage or nutrient pollution and removal of grazing fish both promote the growth of fleshy algae which competes with corals for space on the reef. Reducing nutrient loading and fishing pressure can provide corals with a better opportunity to reproduce and spread after a coral bleaching event.

One common method of controlling these local pressures is the creation of Marine Protected Areas (MPAs) and associated no-take zones. The Coral Reef Monitoring Program can help identify areas that are most affected by local stresses and areas that may be more naturally resilient to bleaching due to the composition of the coral community of upwelling of cooler waters (as noted in the central lagoon passage in Butaritari). The creation of MPAs could also help the development of a small snorkeling or dive-based tourism economy, a very under-exploited industry in Kiribati. A large recreational dive industry is not feasible without the availability of medical facilities to deal with potential dive accidents. However, small operations, even well-managed trips through the local hotels to the sheltered patch reefs in the Tarawa lagoon could provide an alternate source of income.

Another approach is to simply improve management of extractive coral reef resource industries and aquaculture projects, including reef fish for the aquarium trade, the sea cucumber trade, and seaweed farming. While these subjects fall outside the domain of this project, it is must be noted that these industries can have cascading effect on coral cover, with in turn can affect the sustainability of the very resource on which the industry is based. Any reef fish trade or aquaculture projects must be investigated with care. For example, anecdotal evidence suggests that the farming of exotic seaweed species in Butaritari in the past has led to extensive growth of that seaweed in the lagoon. It may also be related to the outbreaks of toxic fish poisoning. Outside expertise on aquaculture must be carefully considered; when an outside aquaculture expert states that a species is acceptable to farm in Kiribati, they are referring to the ability of the species to grow in the local environment, and not to the threat that species may pose to the local environment if not carefully controlled.

The second category of adaptation strategies – reducing reliance on coral reefs and coral reef resources – will prove challenging to Kiribati. The population of Kiribati is highly dependent on the reef fish and invertebrates for food, and income. The development of industries not related to coral reefs or coral reef resources, alternative livelihoods and shoreline protection measures are long-term strategies that fall under the auspices of other KAP projects. These strategies should be considered long-term, on the order of decades, means to adapt to possible degradation of coral reef ecosystems in the future.

8. Final Recommendations (16)

1. *Monitoring system must be continued long-term*. It is impossible to discern the effect of climate change or local pressures like pollution and fishing on the coral reefs of Kiribati and determine appropriate strategies for adaptation with one-time collection of data. The sites established during this program must be monitored on an annual or bi-annual basis. This is particularly critical in the event of a mass coral bleaching. Annual funding from the Kiribati or KAP, the World Bank, AusAID or other agencies is critical to maintaining a consistent program and learning the effect that climate change and local pressures are having on the coral reefs of Kiribati.

2. *The monitoring program must be institutionalized to ensure that it continues long-term and that data is collected in a serious, organized manner*. In my experience here, disorganization, inadequate maintenance of equipment, and lax analysis of field data, in that order, will be the largest obstacles in managing a monitoring program. The following are recommendations for institutionalizing the program:

i) Create a Coral Reef Monitoring Team of 8-10 people. The team should be led by the national TA / Team leader and consist of the four key Fisheries personnel (Taratau Kirata, Toaea Beiateuea, Tebaua Sapotu, Aranteiti Tekiau), other interested and qualified personnel from Fisheries (Koburе Norman, Tuake Teema, perhaps others) and two representatives of MELAD (Mike Foon, Noketi Karoua).

ii) To be a member of the team, an individual must be willing to participate in monthly meetings, monitoring and/or post-monitoring data analysis. The size of the team should be maintained over time; if any members leave, others should be trained to join the team.

iii) At the beginning of each month, the Team Leader should hold a meeting to review work conducted the previous month, discuss the monitoring and data analysis plan for the month and assign responsibilities for the monitoring trips. On a four-person trip, the responsibilities can be divided into trip leader / science coordinator (National TA), dive leader, transport / fuel and food.

iv) Representatives of KAP and officials from Fisheries should either attend the meeting or receive a separate briefing on work by the team.

v) To avoid mistakes, a list of the required equipment for monitoring trips and the tasks to perform at the monitoring sites should be taped to the door of the National TA's office and be attached the front page of the sampling notebooks.

vi) At the conclusion of each meeting, the Team leader should copy all data to the back up drive.

3. *The monitoring protocol must remain consistent over time*. The protocol should also be consistent across sites with variation permitted only due to resource (eg. scuba gear) or access (eg., rough conditions) limitations.

4. *The National TA should lead the Coral Reef Monitoring Team in the completion of the ongoing monitoring around Tarawa and in establishing monitoring sites at the outer atolls, as outlined in the proposed schedule (Appendix B).*

5. *MFMRD and MELAD personnel involved in monitoring without should complete PADI advanced open water dive training*. One possibility is for MFMRD and/or KAP to bring two PADI instructors for Kiribati for 1-2 weeks to complete training. Another option is to send Toaea Beiateuea of MFMRD, already a PADI Assistant Instructor, abroad to Fiji or New Zealand to train to become a full Instructor capable of certifying other divers.

6. *The monitoring team should follow a regular protocol for all SCUBA work*. This includes appointing a dive leader, setting a dive plan, conducting "buddy" equipment checks and regularly checking status of partner during dives. SCUBA work in Kiribati must be undertaken with caution due to the lack of sufficient medical facilities for treating a dive injury.

7. *Monitoring of coral reef fish and invertebrates using standard methods employed by Fisheries (UVCs, belt transects) should be conducted where feasible*. This data is useful to MFMRD and to determine whether changes in the fish and invertebrate population are affecting benthic cover, or vice versa.

8. *An emphasis must be placed on the data quality*. In order to be a part of an expedition, the participant must be: a) able to identify, with confidence, benthic cover at level three on the code list, b) a qualified SCUBA diver (for deep sites), c) competent at free-diving to avoid injury and also to avoid laziness affecting data collection, and d) willing to participate in post-monitoring data analysis, particularly identification of unknown corals in photographs or benthic identification in photo-quadrats. An experienced member of the monitoring team should accompany any inexperienced participants during transect work to double-check their findings.

9. *The future climate scenarios used by KAP must include sea surface temperature, a critical variable for corals and other marine organisms*. This request has already been made with NIWA.

10. *A list of required equipment has been advanced to the procurement officer; unspent equipment funds should be reserved for the use of coral reef monitoring team*. The funds will be able to cover the costs of any equipment breakage, excess transportation costs or unexpected needs.

11. *The subject of coral reefs, their role in i-Kiribati culture and life, and their status, should be included in the community consultation process*. This may help collect

anecdotal observations of changes in coral reef health on the outer islands and help raise awareness of the importance of corals in sustaining key marine resources.

12. *The National TA should be sent to the International Coral Reef Society Conference in Florida, USA in July 2008*. This meeting of the world's coral reef experts is held only once every four years. Presenting results from the Coral Reef Monitoring program at the ICRS Conference would be the best opportunity to share the results of the work with the scientific and marine conservation community and to raise awareness of the need for ongoing funding of monitoring in Kiribati. I would also be an educational opportunity for the TA. Travel grants may be available to participants from developing countries.

13. *The Leader of Coral Reef Monitoring Team should join the international Coral-list (via NOAA Coral Reef Watch) to receive notices about findings in the region and to report findings from Kiribati*. This will also ensure that the Coral Reef Monitoring Team is informed of possible development of coral bleaching in advance, and can properly follow the bleaching protocol.

14. *Any decline in coral cover and associated increase in dominance of macroalgae (and Halimeda), either in response to a direct event like coral bleaching, or not should be viewed as an indicator of an overall decline in the health of the coral reef ecosystem*. More specific changes in benthic cover, including shifts in dominance within the coral community, can also have important effects on the functioning of the entire ecosystem, but are more complicated to diagnose and predict.

15. *The Kiribati government should consider transforming any areas of coral reefs deemed particularly resilient to coral bleaching (by the Final Report of the National TA or future reports) into Marine Protected Areas or provisional no-take zones*. The creation of Marine Protected Areas (MPAs) can increase resilience of coral reef to external stresses like bleaching. The MPAs may be able to help "seed" neighbouring reefs affected by external stresses.

16. *The Coral Reef Benthic Monitoring TA should be serve as an advisor to the National TA and be actively involved in the preparation of the final report to KAP in one year's time*. The MFMRD and MELAD staff have been trained and are prepared to perform the sampling and the data analysis and to report the findings. There will, however, be instances where benthic identification and decisions of site selection require external advice. The interpretation of the data would also be improved by the involvement of a scientist with expertise on corals in general and, specifically, the coral reefs of the region.

Key References

Coral reefs in Kiribati

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Taratau, K, Vieux, C and E Clua (2007) Monitoring Activities in Kiribati 2006; Comparison Of Results With 2004 and 2005. Presentation prepared for the 21st Pacific Science Congress, Okinawa, Japan.

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Suggested Coral Reef Monitoring References

Allen GR and Steene R (1994). Indo-Pacific Coral Reef Field. Tropical Reef Research, UK.

Hill, J and C Wilkinson (2004) Methods for Ecological Monitoring of Coral Reefs: A Resource for Manager. Australian Institute for Marine Science, Townsville, Australia.

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Veron, JEN (2005) Corals of the World, Volumes 1-3. Australian Institute of Marine Science, Townville, Australia.

Appendix A. List of Attached Files

Coral bleaching and monitoring workshop presentations (Powerpoint)

- Day One – Morning
- Day One – Afternoon
- Day Two
- Day Five

Sampling Guide: a short guide for planning field trips including equipment lists, steps to take at field site and recommendations of taking underwater photographs (Word)

Benthic identification presentations, practice materials and list of coral codes for benthic analysis (in Benthic Identification folder)

Database templates for data analysis (In Data Forms Folder)

Monitoring data from Tarawa, Abaiang, Butaritari (In Data Analysis Folder)

Site summaries from Tarawa, Abaiang, Butaritari

A copy of the 2005 Report on Bleaching in the Gilbert Islands, Kiribati prepared for the NOAA Coral Reef Watch Program.

Coral photos taken during monitoring (In Coral photos folder, arranged by site). The species in these photos continue to be analysed.

All computer materials and files – including the workshop presentations and the benthic identification materials – are intended for the use of KAP and the future Coral Reef Monitoring Team. They are not to be shared with outside parties. Some materials include images and figures which belong to Simon Donner or a publisher of Simon Donner's work, and are thus cannot be reproduced without his written permission.

B. List of Workshop Participants

Below is a list of workshop participants along with their self-reported field experience and SCUBA training who were present to complete a survey.

Name	Organization	Field Experience	Scuba experience
Karibanang Tamuera	Fisheries	Some	None
Teitioma Ukerlo	Fisheries	Transects	None
Aranteiti Tekiau	Fisheries	UVC, fish counts	Learning
Tebaua Sapotu	Fisheries	UVC, fish	NAUI
Taratau Kirata	Fisheries	LITs, Quadrats	NAUI
Toaea Beiateuea	Fisheries	LITs	PADI Divemaster
Tuake Teema	Fisheries	Fish, invertebrates	PADI Advanced
Arolati Beia	Fisheries	None	None
Ioane Kaotia	Fisheries	Some	None
Kobure Norman	Fisheries	Little	None
Noketi Karoua	MELAD	Little	NAUI
Mike Foon	MELAD	Sewage outfall study	Some
Itaaka Monokoa	BFA	None	None
Takui Katatia	BFA	None	None

C. Proposed Schedule for National TA

The eight month schedule is spread over almost an entire calendar year, to accommodate the TA's other professional obligations and the best periods for conducting field work. In general, the goal of this schedule is to maintain 2-3 weeks in Tarawa between sampling trips to the outer islands. The time will be necessary for data analysis and planning the subsequent trip. The schedule must be flexible because monitoring is often disrupted and postponed by inclement weather.

NOVEMBER and DECEMBER (KAP MONTH 1)
- Complete sampling around Tarawa (Na'a, Bikenibeu, Teaoraereke)
- Conduct one-week sampling trip to Tamana
- Perform analysis of Tarawa and Tamana data

JANUARY – KAP break; Fisheries excursion (PROCfish) to Fanning Island

FEBRUARY (KAP MONTH 2)
- Conduct one-week sampling trip to Kuria and Abemana
- Perform analysis of Kuria, Abemama and possible Fanning data

MARCH (KAP MONTH 3)
- Conduct one week trip to Beru
- Additional trip to Abaiang, depending on results of ongoing work
- Perform data analysis

APRIL (KAP MONTH 4)
- Conduct one week trip to representative southern island (Tabiteuea, Onotoa or Nonouti)
- Perform data analysis
- Begin preparation of preliminary report for presentation in July

MAY and JUNE – KAP Break; return to Fisheries work

JULY (KAP MONTH 5)
- Present results at International Coral Reef Society Conference in Florida, USA
- Conduct three day trip to Maiana, perform data analysis

AUGUST (KAP MONTH 6)
- Conduct field trip to alternate southern island (Tabiteuea, Onotoa or Nonouti) depending on success and location of previous trip
- Perform data analysis

SEPTEMBER (KAP MONTH 7)
- Prepare report for KAP and scientific analysis of data, with assistance from consultant or outside collaborator
- Complete any outstanding field surveys

OCTOBER (KAP MONTH 8)
- Conduct return trips to Tarawa field sites and Butaritari
- Do comparative data analysis

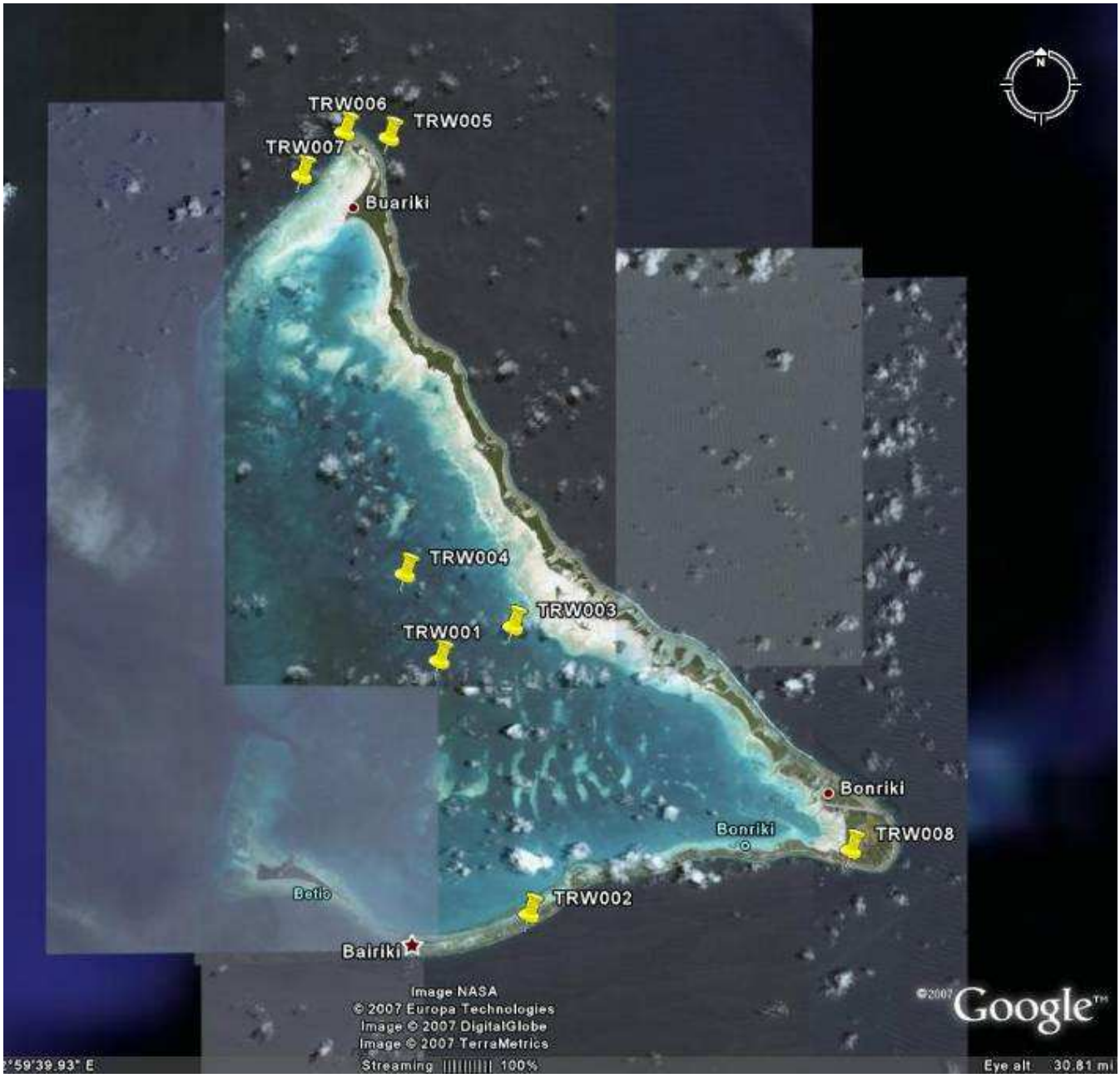
D. Site list (to date) with Site maps

The tables below contain the list of monitoring sites visited during the KAP consultancy, as well as recommended further sites in Tarawa. Sites in italics in Tarawa would benefit from a return visit to complete data collection. Further monitoring sites on other outer atolls will be established during future visits by the National TA.

ID	Site	Latitude	Longitude	Description
Tarawa				
TRW001	Central Lagoon	N01°25'51.4"	172°59'12.6"	Patch reef, #14 from Lovell 2000, SST logger placed on Nov 1 07
TRW002	*Teaoraereke*	*N01°19'59.4"*	*173°01'17.4"*	*SST logger placed Nov 14 07 at 10 m depth on reef slope*
TRW003	N Central Lagoon	N01°26'38.7"	173°00'54.6"	Small; informal surveys
TRW004	N Lagoon Patch	N01°27'51.5"	172°58'24.8"	Like001, #15 from Lovell, 2000
TRW005	*Naa*	*N01°37'57.0"*	*172°58'02.1"*	*Difficult access due to currents*
TRW006	N Tarawa Tip	N01°38'04.2"	172°57'00.5"	Start manta tow to 007
TRW007	*NW Reef*	*N01°37'04.0"*	*172°56'01.0"*	*#7, Lovell 2000*
TRW008	*Bikenibeu*	*N01°21'28.5"*	*173°08'44.7"*	*Off hospital, low cover*
?	*N Tarawa*			*KAP field site*
?	*Bairiki or Betio?*			*Sites of sewage survey*

ID	Site	Latitude	Longitude	Description
Abaiang				
ABG001	Confusion Reef	N01°51'30.7"	172°52'46.6"	Photo quadrats in 2005, 2007
ABG002	Western Reef	N01°52'55.1"	172°49'04.6"	Photo quadrats in 2005, 2007
ABG003	Tebontike	N01°43'04.6"	172°58'59.1"	From 2005 surveys
ABG004	Channel	N01°51'45.2"	172°52'48.7"	Informal survey only
ABG005	NW Reef	N01°55'15.3"	172°48'14.3"	Start of manta tows, 2007
ABG006	Tow end	N01°53'16.1"	172°47'03.3"	Near Nuotea; video, 2007

ID	Site	Latitude	Longitude	Description
Butaritari				
BUT001	SW Lagoon Access	N 3°05'33.2"	172°44'50.1"	High cover at depth to north
BUT002	SW Tip	N 3°02'34.3"	172°45'28.7"	Start manta tows
BUT003	SW Outer reef	N 3° 4'23.0"	172°44'48.6"	High Acropora cover
BUT004	NW tip	N 3°16'15.0"	172°40'48.4"	Start manta tows
BUT005	NW Outer reef	N 3°12'38.5"	172°42'04.7"	No Pocillipora
BUT006	Pearl Farm	N 3° 8'18.5"	172°43'12.1"	Installed SST logger, Nov 7 07
BUT007	Central lagoon	N 3°08'39.3"	172°43'24.5"	Start manta tows
BUT008	Central passage	N 3°09'15.8"	172°42'57.3"	High cover, larger colonies at depth along cool channel



Tarawa site map, created with Google Earth. Sites include permanent monitoring sites and locations visually surveyed during November, 2007. Additional permanent monitoring sites may be added at a later date

Abaiang site map, created with Google Earth. Sites include permanent monitoring sites and locations visually surveyed during Nov 22-24, 2007 expedition.

Butaritati site map, created with Google Earth. Sites include permanent monitoring sites and locations visually surveyed during Nov 4-8, 2007 expedition.

Appendix E: Equipment needs for Coral Reef Monitoring

A. Dive and dive-related equipment

Recommended vendors for scuba-related equipment:

Oceanic Australia
Abyss Scuba Diving
Scubadoctor.com
Scubatoys.com (US)
Leisure Pro (US)

1. THREE Standard Scuba Diving Kits, each including:

- One Buoyancy Compression Device (BCD) made from fadeless Denier nylon, with two Velcro pockets, quick release shoulder adjustments and plastic d-ring attachment points (order two size large, one size medium)

- One regulator and first stage with integrated purge button, demand valve designed to US Navy's Class A standards at 198 feet

- One alternate air source and second stage device with yellow hose, yellow purge button and demand valve

- One scuba tank pressure gauge, recording in PSI

- OPTIONAL (if available as a part of a package) one maximum depth gauge, recording in metres

NOTE: These items are available separately but MUST be purchased as one package unit from one vendor to ensure compatibility.

2. Weight belts (3)

Three weight belts, minimum 60 inches in length with either a Delrin or stainless steel buckle. No weights are required.

3. Desiccant silica gel packs (50)

Desiccant silica gel packs designed to absorb moisture in underwater camera housings. They are commonly sold in packages of five.

NOTE: The gel packs must remain inside the sealed plastic bag until use or they will be spoiled.

4. Flat underwater slates (four)

White 6 x 8 inch underwater writing slates with clip or buckle and pencil with safety leash. We require four.

NOTE: Slates must have no markings on either side (e.g. the company name). Otherwise the area for taking notes is limited.

5. Wrist slate

One three-panel white underwater writing slate with Velcro wrist strap and pencil with safety leash.

6. One medium dry bag

One sealable clear or semi-clear dry bag, volume of 20 L.

7. Waterproof writing notebooks (five)

Five all-weather 4 inch x 6 inch spiral notebooks with polyethylene cover and waterproof paper. Each should contain a minimum of 50 pages.

8. One scuba diving equipment tool kit

Many kits including multiple tools use for maintenance of dive gear are commercially available. It is best to order the tools as a kit NOT as individual items.

The kit should include, at the very minimum: Scuba Wrenches designed to fit regulator 1st stage hose attachments, a professional o-ring tool, a 10 piece o-ring kit, a small (1/4 oz.) jar of silicone grease. Other tools in the kit may include tie wraps, Phillips and flat head screw drivers, needle nose pliers and a hex wrench set.

B. Electronic Equipment

These items should be available from any electronics vendor in Australia or the United States.

1. Digital Camera

One 7.1 megapixel digital camera with the following specifications:

- 6x optical zoom
- 1 cm macro functionality
- a 2.5 inch LCD screen
- eight position white balance

- some form of optical image stabilizer
- camera must also be designed to fit the Canon WP-DC6 underwater camera case.

NOTE: A camera not matching these specifications will be incompatible with other equipment

2. Geographical Positioning System (GPS)

One handheld GPS designed for outdoor use, with the following specifications
- minimum 16 MB storage
- 4-level grayscale LCD screen with backlight, minimum 2 inches,
- WAAS/EGNOS-enabled
- storage of at least 300 waypoints, 10 routes and five track logs with up to 2000 points each
- rubber-armored, water resistant and shock resistant
- at least 14-parallel channel

C. Software

1. Coral ID CD

This coral identification software is produced by, and only available from, the Australian Institute for Marine Sciences (AIMS). Only the CD is required: http://www.aims.gov.au/pages/coralsworld/cotw-01.html

It can be ordered by e-mail or fax (61 7 534481).

D. Specific needs

1. Air Cartridge and Filter for Compressor

One replacement air cartridge and one replacement filter designed for the Junior II-G Bauer High pressure breathing air compressor with P21 filter system. The manufacturer is German: http://www.bauer-kompressoren.de/

E. Items for local purchase

The following items were described with full technical specifications in a separate list provided to the procurement officer

1. Two 50 m measuring tapes with plastic case and handle

2. One laptop, with minimum 2 MB Ram, 120 GB Hard Drive

3. One external hard drive, with 150 GB memory