UNIHI-SEAGRANT-SS-15-02

Reef Morphology and Marine Life Assessment for the Proposed Monloklap Weto Seawall Project

DTown, Uliga, Majuro Atoll

Prepared for

Tabwi Nashon

and

RMI Environmental Protection Authority Prepared

by

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1 Summary

This report presents the findings and recommendations from a marine survey carried out on July 6, 2015 at the Monloklap Weto in DTown, Uliga, Majuro Atoll. Its purpose is to assess marine biodiversity on the ocean side adjacent to the site, and to inform environmental management for the proposed seawall project. The proponent for the project is Tabwi Nashon, a local resident. The report findings are intended as documentation to support donor funding for the construction.

The report does not constitute a Preliminary Environmental Assessment (PEA). The results of marine life assessments are usually combined with a PEA to determine whether a full Environmental Impact Assessment (EIA) is necessary, or if work can proceed based on the recommendations made. However, the RMI Environmental Protection Authority (EPA) has already approved the proposed works. The recommendations may therefore be incorporated as necessary into the proponent's Environmental Management Plan (EMP) and approved by the RMI EPA.

The outer seawall works would entail a seawall foundation 65ft. from the high tide mark that is 3ft. high and 4ft. wide, with an overlying 12ft. seawall being narrower at 2ft. wide. The basin defined by the adjacent and outer seawalls is to be reclaimed with rock and gravel. It is expected that the 4ft. wide seawall foundation will require a 4-6ft. wide dredged trench that is up to 3ft. deep.

The most obvious direct local benefit of the reef ecosystem is the shoreline that exists today. Shores along Majuro Atoll have been selectively weathered and eroded into sand and coral bedrock/beachrock over time. Great care needs to be taken in any shoreline modification effort because the effects of impacts are not easily predicted and are usually impossible to reverse. The structural integrity of the reef and reef flat protects against the daily swells and waves, and the occasional storm surge. It does this by dissipating wave energy.

If the health of the thin layer of marine life on any coral reef is compromised, there will be gradual erosion of the reef foundation and rubble fields will ensue. This rubble will cause further damage as it moves, and eventually the barrier provided by the reef will be reduced so much so that high energy waves will pound the shoreline and possibly erode much more than the adjacent foreshore land area. Such features exist to some degree naturally, and are expressed through V cuts or small drop-offs along the lower edge of the reef flat.

Locals obtain some of their food from the reef. Traditional fishing activities for subsistence and local commercial sales are acceptable as long as the reef does not suffer from other impacts. Parrotfish and other sand makers on the reef such as green coralline algae are important sources of sand for our beaches. Red coralline algae act as the cement that bonds the rubble of the reef together, and precipitates from seawater on a healthy reef. The pink and white crustose variety is especially good at providing an excellent surface where new coral gametes settle on and grow.

Local threats to reef health are typically related to run-off. Few stressors affect corals adversely as much as sedimentation. A coral polyp obtains part of its food from the derivatives of photosynthesis. But a significant portion of its nutrition comes from filtering plankton and other organic detritus from the water. Sedimentation reduces the amount of sunlight getting through for photosynthesis as well as smothering the polyp tentacles that it uses for filter feeding.

Beyond the physical impact of sedimentation in run-off is the nutrient nature of the material. Ground coral rock contains phosphates and nitrates that act as liquid fertilizer in the marine environment. While nutrients entering the marine environment is normal, the excessive rates at which they enter from excavated shorelines, sewage and grey water, and agricultural areas in particular is causing eutrophication. Coral reefs are gradually being replaced by algae.

The method used for this assessment is *in situ* observation of the substrate and water column to gather information about reef morphology and marine life in the vicinity of the proposed works at the Monloklap property. Techniques employed include intertidal walks and skin diving along the reef flat, as well as spot checks on the reef edge and slope. Data is interpreted in the context of the importance of marine biodiversity and the complexity of relationships among reef inhabitants.

This reef morphology and marine life assessment is primarily an inventory with interpretation based on a formal method of collecting and analysing data. It does not, however, have a table matrix of impacts with their effects rated in terms of magnitude and direction. This is within the realm of a Preliminary Environmental Assessment or an Environmental Impact Assessment and is at the discretion of the RMI EPA. It instead highlights important issues and places them in the context of shoreline modification and coral reef health. The marine survey of the Monloklap Weto ocean side shoreline in Uliga is encouraging in terms of coral quality, yet disturbing for overall reef health in terms of sedimentation, algae, and available substrate for coral recruitment. It raises several ecological concerns:

1. Non-coral invertebrates are largely absent from the reef, especially giant clams. The scope of this survey does not include a formal investigation into historical uses of the reef that may have negatively impacted the variety and abundance of invertebrates harvested in the past.

2. Large (>8inches) fish are also largely absent from the reef. The ‘snapshot’ nature of the fish survey does not necessarily encompass enough information to conclusively state that fishing pressure has resulted in this situation. The lesson learned however, is that precaution in the face of scientific uncertainty is a valid approach and overfishing has likely resulted in the loss of large predators and herbivores.

3. There is upwards of 10% cyanobacteria/blue-green algae (mainly deep) and 60% *Hypnea* sp./turf algae (mainly reef flat and shallow subtidal) on the reef. These are significant amounts. It can quickly deteriorate further if algae-eaters are not allowed to re-populate the area and sources of nutrient input continue. Despite the relative abundance of medium and small-sized fish herbivores, only marginal cleaning of rock surfaces for coral recruitment is taking place.

4. Almost one-quarter of the reef crest and slope is covered in fine silty sediment 1/16th inch thick. The current amount is significant. If siltation is allowed to increase it may suffocate reef inhabitants, especially coral. Recruitment of new coral may be unsuccessful because the substrate that newly spawned coral settles on is not clean. Fertilised egg packs cannot attach to loose material and subsequently they die.

5. Corals on average make up only about 25% of the substrate cover from the lower reef flat to the reef slope. The growth form is dominantly submassive and encrusting, suggesting a transition from more diverse forms in the past (i.e. *Acropora* sp. to *Porites rus*). The exception are the large table coral colonies on the reef crest.

From that perspective, the recommendations below offer opportunities for mitigation and protection. They also identify where the scope of work can be improved for application on similar projects in the future, or for continued monitoring efforts in Majuro.

Based on the scope of the marine assessment in this study the author recommends that the proposed works be allowed to proceed subject to the conditions below. If there is to be any significant modification to the recommendations or the scope of the proposed work, the author recommends that the project be further evaluated by the RMI EPA.

There are eleven (11) recommendations: Five (5) are directly related to the proponent and six (6) require Government action but are only indirectly related to the proponent.

1.1.1 Recommendations Related to the Proponent (Developer Actions)

1. *Notification*: The RMI EPA is to be notified of the days that the works will be taking place, at least 3 working days prior to the onset of works.
2. *Equipment and Access*: An excavator working from shore is to be used for the works. The area to be dredged is to be limited to the foundation needed for the length and width of the proposed seawall. No work is to take place beyond the boundary defined by the seawall.
3. *Timing*: All work in foreshore or marine areas must take place from 2 hours before to 2 hours after low tide. This minimizes the potential for a sediment plume to disperse and settle across coral colonies on the lower reef flat and beyond.
4. *Materials*: No sediment curtain needs to be deployed as long as all excavated material is relocated to above the high water mark on a daily basis. No excavated aggregate is to be left exposed to incoming water on the tidal cycle.
5. *Coral Relocation*: No coral needs to be transplanted as none is in proximity to the location of the proposed works.

1.1.2 Recommendations Unrelated to the Proponent (Government Actions)

6. The EPA should commission a preliminary environmental assessment on similar projects in the future, to be evaluated in conjunction with marine survey reports.
7. The EPA coastal compliance officer is to be present during the dredging operation.
8. Consider the development of a coral reef restoration fund that proponents of aggregate sourcing and shoreline armoring projects pay into to offset potential damage to coral reefs. It is not be used as a justification to allow purposeful damage to coral, but as a fund to pay for incidental or small-scale loss of coral reef habitat. This fund can also be used for coral restoration in other areas. This is especially important in the context of the current El Nino, where coral bleaching is expected to worsen beyond the amounts observed in this survey.
9. Establish a national policy in the RMI in regards to sourcing sand and rip-rap aggregate for development projects. This policy should at a minimum include specific guidelines for dredging and excavation, including the use of sediment curtains, so that recommended best practices do not need to be re-visited and re-stated for every development project.
10. Implement a program of marine life monitoring in old and new dredge areas in Majuro atoll. This can partially be integrated into specific remedial or monitoring actions recommended through the PEA-EIA-EMP process. At a minimum, carry out regular surveys of the marine sites with their results compared with the baseline reference provided by this report.
11. Use the relationships established in local communities and among government agencies to encourage limits to herbivore fishing and the establishment of additional no-take marine protected areas in Majuro. The return to historical levels of herbivorous fishes is key to the success or failure of the reef to mitigate the growing situation of excessive sediment leading to siltation and algal overgrowth on the reef.

2 Introduction

2.1 Scope

This report presents the findings and recommendations from a marine survey carried out on July 6, 2015 at the Monloklap Weto in DTown, Uliga, Majuro Atoll. Its purpose is to assess marine biodiversity on the ocean side adjacent to the site, and to inform environmental management for the proposed seawall project. The proponent for the project is Tabwi Nashon, a local resident. The report findings are intended as documentation to support donor funding for the construction.

The report does not constitute a Preliminary Environmental Assessment (PEA). The results of marine life assessments are usually combined with a PEA to determine whether a full Environmental Impact Assessment (EIA) is necessary, or if work can proceed based on the recommendations made. However, the RMI Environmental Protection Authority (EPA) has already approved the proposed works. The recommendations may therefore be incorporated as necessary into the proponent's Environmental Management Plan (EMP) and approved by the RMI EPA.

The survey may also provide a baseline reference for future monitoring or research that may not necessarily be for development purposes. More directly, it allows landowners and Government to understand the environmental value of the coral reef along the Monloklap ocean side shoreline.

2.2 Site Location

Figure 2.2.1 and 2.2.2 are satellite image of northwest Uliga. The small yellow L shape depicts the location of the proposed seawall within the Monloklap weto.

Fig. 2.2.1 Northwest Uliga in Majuro Atoll

Fig. 2.2.2 Monloklap Weto, Uliga in Majuro Atoll

Figures 2.2.3 & 2.2.4 show the Monloklap ocean side shoreline looking northwest and southeast, respectively. There is scrap metal and an *ad hoc* revetment fronting the northwest adjacent property and a seawall around the southeast property.

Fig. 2.2.3 from southeast shoreline looking northwest

Fig. 2.2.4 from middle of shoreline looking southeast

Figures 2.2.5 to 2.2.8 show the shoreline from different angles at low tide. The rocky shore shown is the elevated mid-Holocene reef flat, which is covered at high tide. The mean high water mark is at the sandy gravel to the left of figure 2.2.5.

Fig. 2.2.5 from middle of shoreline looking north

Fig. 2.2.6 from middle of shoreline looking east


Fig. 2.2.7 from middle of shoreline looking northeast


Fig. 2.2.8 from inner reef flat looking southwest

2.3 Site and Development Characteristics

The proposed seawall depicted in yellow in figures 2.2.1 and 2.2.2 has an outer NW-SE and an adjacent NE-SW portion. The outer portion fronting the property is detailed in an elevation design shown in figure 2.3.1. The adjacent portion is proposed to be along the northwest property line, and of similar design to outer seawall (possibly not as high).

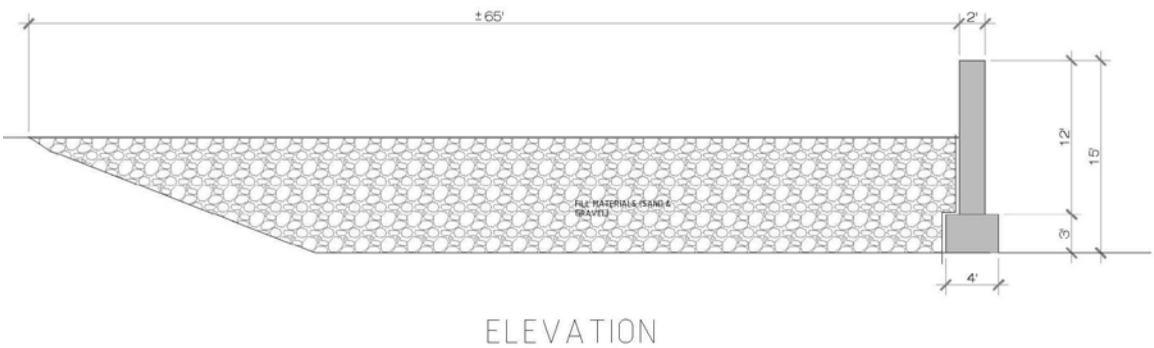

Fig. 2.3.1 proposed seawall and reclamation design, provided by Tabwi Nashon Feb 2015

The outer seawall works would entail a seawall foundation 65ft. from the high tide mark that is 3ft. high and 4ft. wide, with an overlying 12ft. seawall being narrower at 2ft. wide. The basin defined by the adjacent and outer seawalls is to be reclaimed with rock and gravel. It is expected that the 4ft. wide seawall foundation will require a 4-6ft. wide dredged trench that is up to 3ft. deep.

2.4 Benefits of Maintaining a Healthy Reef

Marine life quality on the reef flat and coral reef along the Monloklap shoreline will be discussed at length in this report. This section highlights the many ecological relationships fundamental to understanding the marine life quality along this stretch of Majuro. Coral reefs in this area are fully adjusted to the dynamic nature of the wind and swells that are the norm across the Marshall Islands. Coral colonies are generally compact and resilient in the shallows (fig. 2.4.1) and more fragile and diverse with depth (fig. 2.4.2).

Fig. 2.4.1 submassive corals 12 ft. depth

Fig. 2.4.2 branching and table corals 30 ft. depth

The most obvious direct local benefit of the reef ecosystem is the shoreline that exists today. Shores along Majuro Atoll have been selectively weathered and eroded into sand and coral bedrock/beachrock over time. The Uliga shoreline is in a state of dynamic equilibrium. Great care needs to be taken in any shoreline modification effort because the effects of impacts are not easily predicted and are usually impossible to reverse. The structural integrity of the reef and reef flat protects against the daily swells and waves, and the occasional storm surge. It does this by dissipating wave energy.

If the health of the thin layer of marine life on any coral reef is compromised, there will be gradual erosion of the reef foundation and rubble fields will ensue. This rubble will cause further damage as it moves, and eventually the barrier provided by the reef will be reduced so much so that high energy waves will pound the shoreline and possibly erode much more than the adjacent foreshore land area. Such features exist to some degree naturally, and are expressed through V cuts or small drop-offs along the lower edge of the reef flat (figs. 2.4.3 and 2.4.4).

Fig. 2.4.1 groove channel 10 ft. depth

Fig. 2.4.2 spur-and-groove channel 15 ft. depth

Locals obtain some of their food from the reef. Traditional fishing activities for subsistence and local commercial sales are acceptable as long as the reef does not suffer from other impacts. Parrotfish and other sand makers on the reef such as green coralline algae are important sources of sand for our beaches (discussed further in section 3.1). Red coralline algae act as the cement that bonds the rubble of the reef together, and precipitates from seawater on a healthy reef (fig. 2.14, not from Monloklap). The pink and white crustose variety is especially good at providing an excellent surface where new coral gametes settle on and grow. Corals with their associated photosynthetic algae are the second most important provider of oxygen for the world after rain forests (fig. 2.15). Moreover, the coral reef in all its splendour is the habitat for a myriad of animals and plants that have intrinsic value beyond direct or indirect benefits to humanity.

Fig. 2.14 *Linkia sp*. Seastar on Red and Pink Coralline Algae

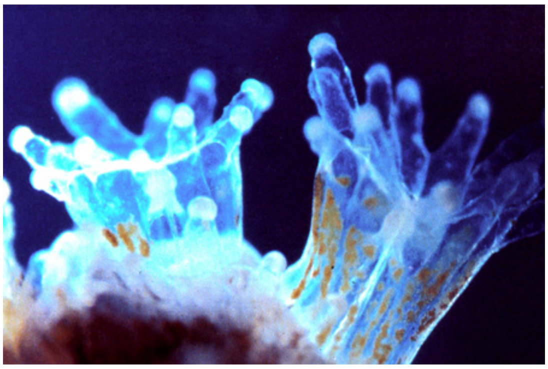

Fig. 2.15 Coral Polyp with Symbiotic Algae

2.5 Reef Threats

2.5.1 Global

Few people purposely damage our reefs. Most issues arise from our assumption that reefs can handle our excesses. By far the two greatest threats to reef health today are global; coral bleaching and ocean acidification stemming from increased carbon dioxide levels in the atmosphere. Reef-building colonial corals are found in both tropical and subtropical areas across the globe (fig. 2.16). Coral bleaching is a term referring to the loss of symbiotic algae living within the coral polyp in response to thermal stress (fig. 2.17). Acidification refers to the stunting effect on coral skeleton growth with changing ocean chemistry and increasing acidity of the water.

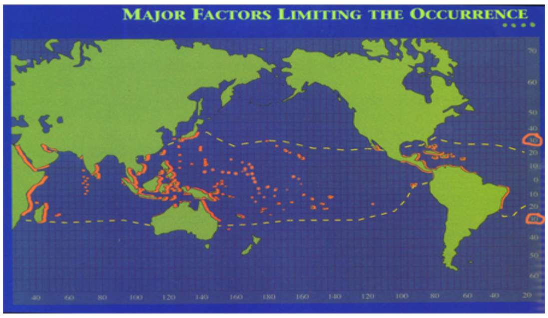

Fig. 2.16 Global Reef-building Coral Distribution

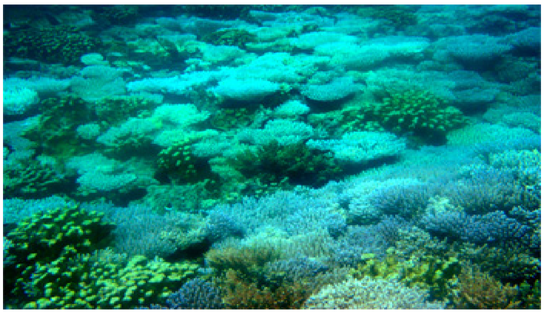

Fig. 2.17 Bleached Coral Reef [Palau, 2000]

The coral colonies along the Monloklap shoreline do not currently display significant evidence of coral bleaching. However, bleaching is already occurring elsewhere in the RMI. There was a significant bleaching event in late 2014 associated with elevated sea surface temperatures and it is expected that the 2015/2016 El Nino will result in widespread bleaching across the region. This will be discussed further in section 4, as there is some localized bleaching of coral colonies observed at the time this survey was carried out.

The overriding point is that even pristine reefs cannot escape these global killers. Practically it means that even the outwardly intact reefs in the Marshall Islands are already under threat and therefore survive somewhat precariously. Seemingly benign impacts can have serious consequences because the reef immune system is already under attack. Reefs already under threat from local impacts are less capable of embracing the adaptation needed to dampen the effects of global climate change.

2.5.2 Local

Local threats to reef health are typically related to run-off. Few stressors affect corals adversely as much as sedimentation. A coral polyp obtains part of its food from the derivatives of photosynthesis. But a significant portion of its nutrition (depending on the species) comes from filtering plankton and other organic detritus from the water. Sedimentation reduces the amount of sunlight getting through for photosynthesis as well as smothering the polyp tentacles that it uses for filter feeding. Sedimentation effectively starves and suffocates the coral. The stress response may be similar to coral bleaching, but usually polyp death sets in whether the coral symbionts have been ejected or not. Typically within days there appears on the former coral colony a thin layer of anaerobic algae called cyanobacteria. If not controlled by algae eaters such as surgeonfish and sea urchins and other herbivores, this layer will grow into a thick mat or stringy assemblage of brown or black filamentous algae (fig. 2.18). Having up to 5% of the reef covered in cyanobacteria is considered to be the lower limit of a healthy reef. One excavator working on one section of the shoreline can conceivably produce enough sediment discharge over a short time period to wipe out an area of reef much larger than the section itself. Usually it depends on the rate at which the material enters the system. Nature is used to dealing with large volumes of sediment. It only becomes a problem when it enters the system rapidly.

Fig. 2.18 Stringy Black Cyanobacteria

Beyond the physical impact of sedimentation in run-off is the nutrient nature of the material. Ground coral rock contains phosphates and nitrates that act as liquid fertilizer in the marine environment. While nutrients entering the marine environment is normal, the excessive rates at which they enter from excavated shorelines, sewage and grey water, and agricultural areas in particular is causing eutrophication. Coral reefs are gradually being replaced by algae. Examples around Majuro include the lagoon from Rita to Delap, both sides of the bridge, and the area surrounding the sewage discharge at MWSC. Local point source impacts in these areas also contribute, include leaking septic tanks and poorly maintained septic fields, as well as general road and industry run-off bringing a toxic sleuth of chemicals into the mix. Other ways that Uliga could have run-off issues beyond shoreline modification is the removal of vegetation. Tree roots and the associated forest floor cover have an incredible ability to hold nutrients.

Both Majuro and Arno have had infestations of the Crown-of-Thorns (COTs) sea star (*Acanthaster plancii*). It is a growing problem all over the world. Fortunately, neither the animals themselves nor their feeding scars were seen on this survey. COTs eat stony coral (fig. 2.19). Much research takes place on these animals and the consensus is that they thrive in polluted, nutrient-rich areas. There are also outbreaks in pristine areas so there is some speculation that they control fast-growing coral from taking over a reef. Nonetheless, they are considered to be pests and the policy over most of the world is to remove them from the water and to avoid the high nutrient water quality conditions that attract them in the first place.

Fig. 2.19 COTs on Table Corals [Mele Bay]

3 Method

The method used for this assessment is *in situ* observation of the substrate and water column to gather information about reef morphology and marine life in the vicinity of the proposed works at the Monloklap property. Techniques employed include intertidal walks and skin diving along the reef flat, as well as spot checks on the reef edge and slope. Data is interpreted in the context of the importance of marine biodiversity and the complexity of relationships among reef inhabitants.

3.1 Marine Biodiversity

Biodiversity is a measure of species richness and evenness. Species richness is the *variety* or number of species within an area. For example, a site may have many kinds of reef fish species including hexagon groupers and napoleon wrasses. Species evenness is the *relative abundance* or number of individuals of a species compared with another species within the same area. For example, a site may have many hexagon groupers but very few napoleon wrasses. Scientists measure richness and evenness for many target species and taken together, they indicate HIGH or LOW biodiversity. Complexity of ecological relationships among species and their habitats do not always mean that high biodiversity is preferred in all environments. But high biodiversity is always preferred on coral reefs. More specifically, abundance within keystone species indicates a healthy environment. For example, larger predators like reef sharks, napoleon wrasses, and large groupers need variety and relative abundance across many smaller prey species in order to survive. Measuring relative biodiversity on the coral reef can be done without conducting a complete species inventory. It does require a certain amount of representative sampling across areas and depths, but it is also about observing ecological relationships among reef inhabitants that indicate whether the reef is functioning as it should[1]. Understanding the general relationships among producers, consumers, decomposers, and sand makers is necessary for assessing RELATIVE biodiversity and overall coral reef health.

A reef is a wonderful example of an ecosystem. This word ‘ecosystem’ combines ECOLOGY and SYSTEM. Ecology means the way in which all living things interact with each other and their physical environment. System means a complex, organized, interacting, and interdependent set of parts. The coral ecosystem is like a family and its community. Certain fishes, for example, have certain jobs. If small fishes called *cleaners* are removed from a reef, the result is an increase in parasites in the fish that would otherwise be cared for. Eventually the fish abandon that part of the reef and go elsewhere. It is important to learn the parts of the coral ecosystem and the roles its members play, since this tells us which animals to focus on and how best to protect their habitat.

The entire reef depends on the PRODUCERS, the plants and special animals that turn sunlight and carbon dioxide into food and release oxygen as a byproduct. In addition to plants and algae, an important producer is the coral itself. The brown colour of many kinds of coral comes from countless tiny, microscopic single-celled algae called *zooxanthellae* that live inside the coral animal, the polyp (fig. 3.1). Other rich colours result from a pigment mix of the algae and the often ‘faded’ colour of the polyp itself. Without the algae, the polyp would not have the strength to make its hard skeleton, and the coral rock of the reef would not form.

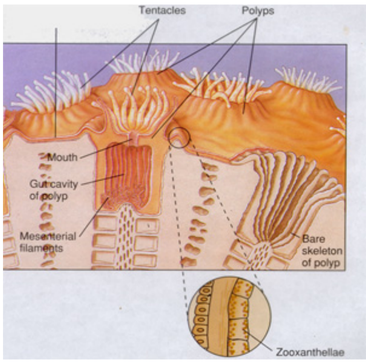

Fig. 3.1 Coral Polyp x-section

[1] Biodiversity information on an already impacted reef should ideally be compared to some sort of pre-impact baseline at the same location. Whether a control site or pre-impact baseline reference is used, observing reef function requires both quantitative and qualitative measurement.

Algae both produce and feed off nutrients in the water. There are *good* algae, and *bad* algae, and even good algae can disturb the delicate coral reef balance if there is too much of it. As animals on the reef die to make room for new life, their tissues and skeletons provide yet more nutrients and solid material for the next generation. Algae grow everywhere, and the most edible types are so small that they are easily overlooked. They grow on dead coral rock, and are scraped up by schools of herbivorous fish. Another kind of producer is the microscopic algae that drift in the ocean, known as phytoplankton. They are the food for the zooplankton, the tiny animals that live everywhere in the water column of the world ocean. CONSUMERS are the animals that eat algae, zooplankton, corals, and other marine life. These include fish, worms, crabs, mollusks, and other animals. It also includes the coral polyp itself as well as larger zooplankton. All animals produce waste, which act as fertilizer for the producers. A healthy coral reef takes care of its wastes through decomposition. DECOMPOSERS are microscopic bacteria whose job is to eat the waste of everyone else. Dead animals and animal waste is subsequently turned into nutrients. In the coral world, we must include another special category of creatures, the SAND MAKERS. Sand is the home for many worms that are eaten by fish and it is where sea cucumbers find their food. It is also habitat for many fish, which bury themselves at night and spend all their lives in or near burrows in sand. Some sand comes from the dead remains of green-segmented coralline algae (fig. 3.2). Other sand comes from microscopic shells of small pink animals called *forams*. Much of it is excreted from Parrotfish after feeding on corals (fig. 3.3). Large pieces of coral are crushed by their special *throat teeth*, which are essentially flat plates. The thin layer of living coral, as well as tiny tunneling algae inside the coral skeleton, provides the actual food for these fish. Parrotfish are actually herbivores, as they only target coral to get at the algae. A large adult parrotfish can produce upwards of a ton of sand per year. Other important herbivores include Surgeonfish and sea urchins, which along with Parrotfish and others are critical for keeping the abundance of both good and bad algae under control on the reef.

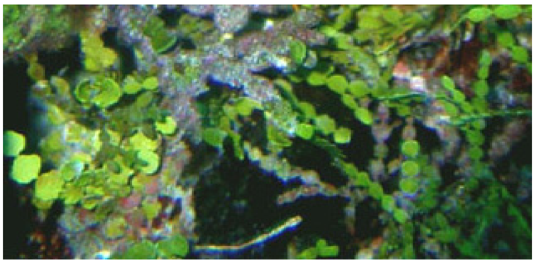

Fig. 3.2 *Halimeda sp.*

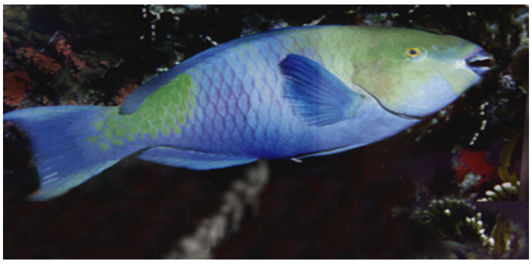

Fig. 3.3 Parrotfish - *Scarus sp.*

3.2 Survey Techniques

Characteristics of the underwater environment are adapted from the method developed by the Australian Institute of Marine Science. Surveys are often conducted using underwater tape measures, quadrats and photography equipment (figs. 3.4 & 3.5).

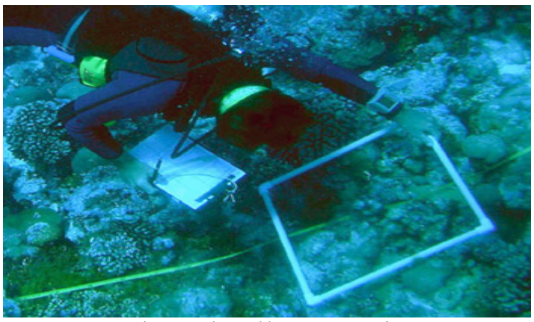

Fig. 3.4 Diver with Survey Quadrat

Fig. 3.5 Camera Housing

Options for the survey scale range from surface observations of general site characteristics to spot checks and permanent transects at variable depths across a range of physical, biological and ecological features. The latter includes variables related to water motion, sedimentation, slope stability and erosion, reef morphology, substrate, coral cover, coral growth form, algae cover and characteristics, and invertebrate and fish variety and abundance. Most corals and other invertebrates can be identified in the field to the level of genus. There are many marine plants and animals that cannot be accurately identified *in situ*, and others where positive identification to the species level can be made. Fish are identified by family with selected species information documented as required.

3.2.1 Reef Flat and Shallow Subtidal

A reef flat walk and swim is conducted at the proposed dredge site, shown as sites 1 and 2 in figure 3.6. It is used primarily in shallow environments across large areas where it is not possible to use a tape measure within acceptable movement, nor obtain enough data from within one sample site. Reef flat walks or swims focus on representative photographs and qualitative information about the type and condition of substrate and marine life present.

Fig. 3.6 Marine Survey Sites

3.2.2 Spot Checks

Spot checks are visual inspections by survey divers at variable depths. Figure 3.6 shows coral reef sites 3 and 4 beyond the reef flat.

The intent of spot checks is to familiarise the survey divers with the area, and to provide preliminary results on select variables using three 10m transects. Typically the spot check area is on a slope and each transect is taken at a different depth. The results are averaged and can be useful for site selection if a longer permanent transect is deemed necessary in the future.

The type of substrate is noted every 0.5m along the tape. Some entries are basic, such as sand. Other types of substrate are divided into further categories. Solid rock can be with or without surface cover of coralline algae. Rubble is either partly consolidated with coralline algae (on its way to becoming rock) or unconsolidated (loose). Coral is alive or dead. Dead coral can also be recently killed. Live coral is stony or soft, and can also be bleached. Stony coral has a number of growth forms ranging from massive to branching, and both stony and soft coral can often be identified to the level of genus. Because there are 10 data points in 5m, it is straightforward to present the data as frequency percentages. At a minimum this yields the amount of coral cover on the reef. By itself, coral cover is only a general indicator of reef health. But taken with select information from other substrate details, along with explanatory photos, an understanding of the reef bottom emerges. It is important to note that a 10m transect does not have enough data points to be significantly reliable. Therefore, information is complemented with qualitative observations and quantitative estimates in the area of the spot check.

4 Results and Discussion

Reef flat swims and spot check site results are discussed descriptively with explanatory photographs, but without tables and pie charts. Relative survey locations are shown again in figure 4.1.

Figure 4.1 Marine Survey Sites

4.1 Reef Flat and Shallow Subtidal

Sites 1-2 in figure 4.1 are in the intertidal area of the reef flat.

4.1.1 Site 1 Upper Reef Flat

Site 1 is exposed on all low tides, with its mid-point at 0.5ft. depth at mid-tide (fig. 4.1.1). It is entirely flat, and devoid of any marine life other than undesirable algae. Figure 4.1.2 shows 60% cover of microalgae dominated by fleshy varieties less than ¾ inch in height, known as turf algae. It is typical on reef flats where water quality is less than ideal, such as the Uliga near shore environment.

Fig. 4.1.1 from 150 ft. from shoreline (mid-point of upper reef flat) looking northeast

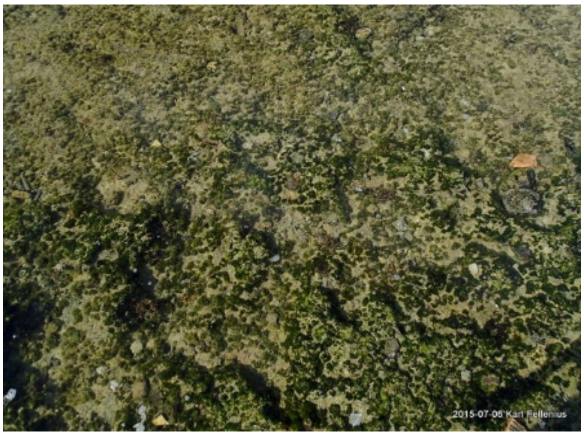

Fig. 4.1.2 turf algae dominant on shoreward end of upper reef flat

Also typical of reef flats where algae has overgrown and displaced coral, is *Hypnea* sp. seaweed (figs. 4.1.3 & 4.1.4). It is present as a patchwork of 25% cover at the mid-point of the upper reef flat, increasing to 90% at the seaward end. The presence of *Hypnea* sp. correlates with proximity to the sewage outfall in Delap.

Fig. 4.1.3 *Hypnea* sp. and turf algae at mid-point of upper reef flat

Fig. 4.1.4 *Hypnea* sp. dominant on seaward end of upper reef flat

4.1.2 Site 2 Lower Reef Flat

Site 2 is exposed only on extreme low tides, with its mid-point at 1.5ft. depth at mid-tide (fig. 4.1.5). It is largely flat at its shoreward end with one groove channel, and devoid of any marine life other than undesirable algae. Figures 4.1.6 and 4.1.7 show a decreased cover of 50% *Hypnea* sp. with turf algae and sand making up the balance.

Fig. 4.1.5 from 350ft. from shoreline (shoreward end of lower reef flat) looking northeast)

Fig. 4.1.6 *Hypnea* sp. less dominant on lower reef flat

Fig. 4.1.7 *Hypnea* sp. in groove channel

Fig. 4.1.8 Blue-banded surgeonfish (*Ancanthurus lineatus*) at seaward end of lower reef flat

Marine life increases towards the seaward end of the lower reef flat, with small schools of surgeonfish and damselfish present (fig. 4.1.8). There is about 10% coral cover near the wave break, although half of it is bleached (figs. 4.1.9 to 4.1.10).

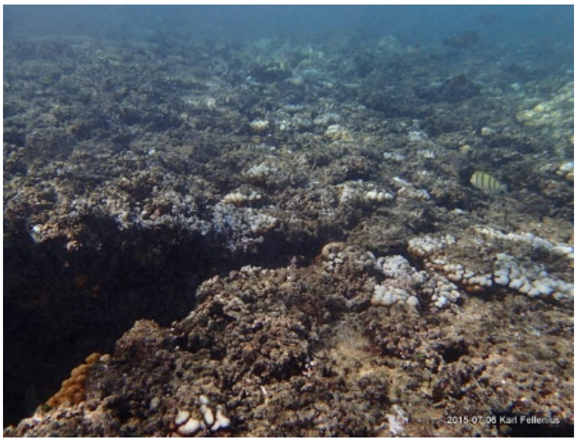
Fig. 4.1.9 Bleached submassive coral colonies at seaward end of lower reef flat


Fig. 4.1.10 Bleached Broccoli coral (*Pocillopora* sp.)

The common submassive Majuro coral, *Porites rus* makes up most of the non-bleached coral on the lower reef flat (fig. 4.1.12). It is a fast-growing variety that grows well under reduced water quality conditions, although it does not support habitat for larger fish species.


Fig. 4.1.11 from 550ft. from shoreline (mid-point of lower reef flat) looking northeast

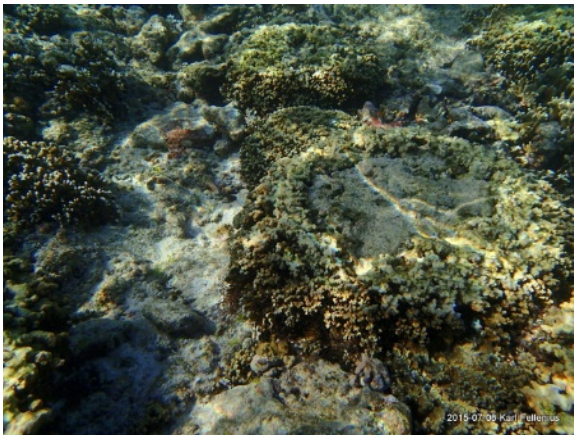
Fig. 4.1.12 Bleaching-resistant Majuro coral (*Porites rus*)

The seaward end of the lower reef flat has no *Hypnea* sp. algae, but three-quarters of the bottom is covered in a thin layer of silt and turf algae (figs. 4.1.13 & 4.1.14). The turf algae has a higher proportion of cyanobacteria algae as compared with the fleshy varieties closer to shore, although few patches of the more concentrated cyanobacteria mat algae are observed.

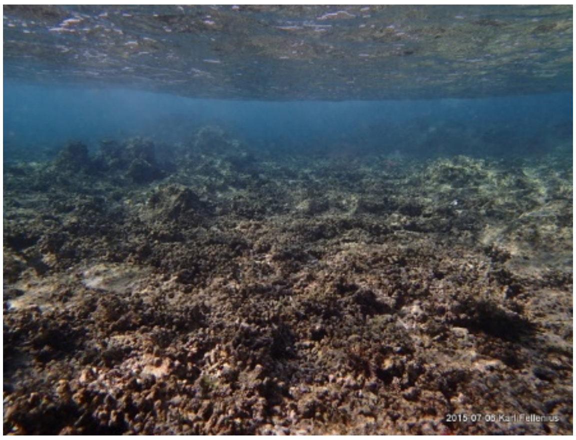
Fig. 4.1.13 silt and turf algae-covered substrate


Fig. 4.1.14 silt and turf algae-covered substrate

The zooanthid *Palythoa* sp. thrives under high nutrient conditions. It can displace coral, although it is preferred over macroalgae and microalgae as they are soft coral-like animals in the same phylum as stony and soft corals. They so far only make-up about 15% of the seaward end of the lower reef flat. Some bleaching of the zooanthid colony is observed (fig. 4.1.16).

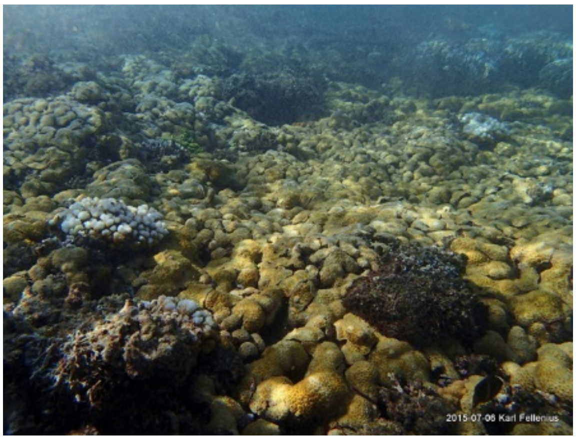

Fig. 4.1.15 *Palythoa* sp. zoanthids

Fig. 4.1.16 *Palythoa* sp. zoanthids and sea grape (*Caulerpa* sp.) fleshy algae

4.2 Spot Checks

Sites 3-4 in figure 4.1 have survey details at variable depths from the subtidal area approaching the reef crest to the lower reef slope.

4.2.1 Site 3 Reef Crest and Upper Reef Slope

Site 3 is 700-900ft. from shore, and includes the spur and groove channels (5-15ft. depth) approaching the reef crest, the reef crest (20-30ft. depth), and the upper reef slope (35-45ft. depth). The area has moderate reef relief, with coral cover ranging from 10% on the shallow spurs to 40% on the upper slope. The groove channels in figures 4.2.1 and 4.2.2 are devoid of marine life and have a sand and rubble substrate. These channels and material are the source of aggregate that washes up and down from reef to shore during storms and erodes/accretes on the shoreline.

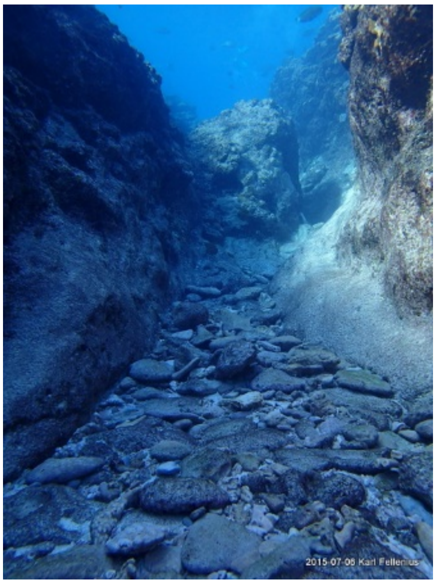

Fig. 4.2.1 spur and groove channel

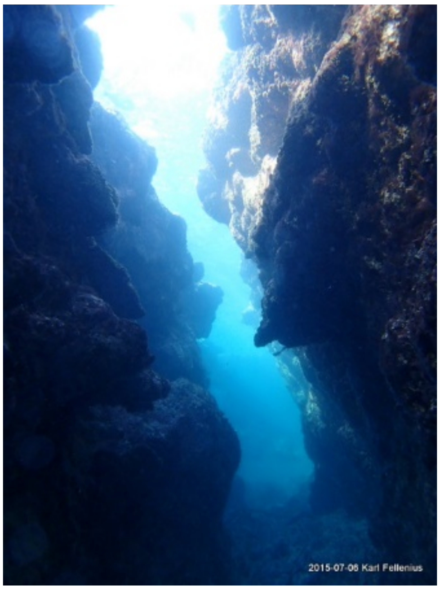

Fig. 4.2.2 spur and groove channel

Figures 4.2.3 to 4.2.6 show the topography of the spur and groove channels from further afield, and exemplify their habitat and sheltering qualities for schools of reef fish and other marine life.

Fig. 4.2.3 spur and groove channel 10-15ft. depth, looking seaward to the northeast - parrotfish (*Chlorurus and Scarus* spp.)

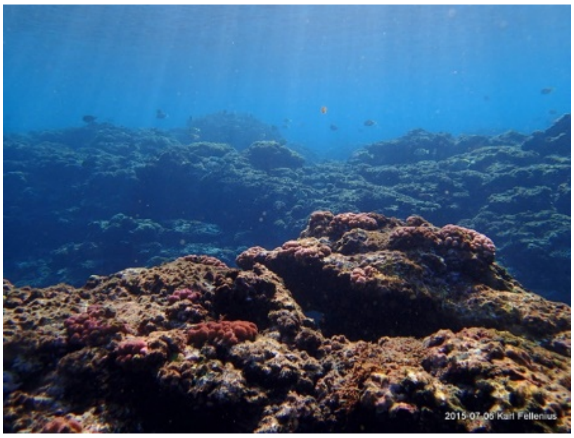

Fig. 4.2.4 looking across the coral *spurs to the southeast, 10ft. depth*

Fig. 4.2.5 groove channel 10ft. depth - Convict surgeonfish (*Acanthurus triostegus)*

Fig. 4.2.6 spur channel 10ft. depth - Forktail rabbitfish (*Siganus argenteus*), parrotfish (*Scarus* sp.), and a juvenile

Coral cover on the spurs is only 10% and colonies are surviving precariously due to excessive amounts of fleshy coralline algae and patches of cyanobacteria algae (figs. 4.2.7 & 4.2.8). There are more dead colonies than live ones, and most of the live colonies are either in early stages of coral disease or bleaching. Algae on dead coral skeletons and coral rock surfaces are being cleaned off by existing herbivores, and therefore there is a strong likelihood that new coral recruits will settle and grow. Reef fish that carry out these functions include parrotfish, surgeonfish, rabbitfish, and damselfish. Much depends on fishing pressure, and point source pollution of run-off high in nutrients.

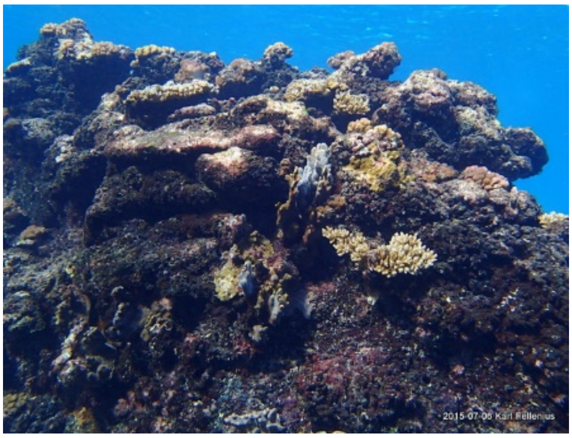

Fig. 4.2.7 coral spur 10ft. depth with dominant fleshy coralline algae

Fig. 4.2.8 coral spur 10ft. depth with typical mortality and low coral cover

Examples of new coral recruits are shown with the encrusting varieties in figures 4.2.9 and 4.2.10. Adjacent to the patch colonies is white and pink crustose coralline algae. A combination of herbivore cleaning and good water quality allows this to take place by providing adequate surfaces for re-growth. Overfishing and nutrient run-off promotes the fleshier and cynobacteria-rich varieties seen at the margins.


Fig. 4.2.9 encrusting *Montipora* sp. coral 15ft. depth on crustose coralline algae


Fig. 4.2.10 encrusting *Acropora* sp. coral 15ft. depth on crustose coralline algae

Coral health and diversity increase with a cover of 30% on the reef crest (figs. 4.2.11 & 4.2.12). There is significantly less fleshy coralline algae, cynanobacteria algae, and turf algae compared with the shallow coral spurs.


Fig. 4.2.11 table and branching (*Acopora sp.*) coral 30ft. depth on reef crest


Fig. 4.2.12 table and branching (*Acropora* sp.) coral 30ft. depth on reef crest

However, turf algae is still abundant in patches, with at least 10% of the reef crest substrate consisting of unconsolidated rubble of low relief (figs. 4.2.13 & 4.2.14).


Fig. 4.2.13 turf algae on dead coral, 30ft. depth on reef crest


Fig. 4.2.14 pale-lipped surgeonfish (*Acanthurus leucocheilus*), 30ft. depth on reef crest

Coral cover increases further to 40% on the upper reef slope, although diversity is less with fewer table corals and a dominance of Majuro coral (figs. 4.2.15 to 4.2.18). There are mainly small surgeonfish and damselfish present, typical of low diversity coral environments.

Fig. 4.2.15 upper reef slope, 35ft. depth looking northwest

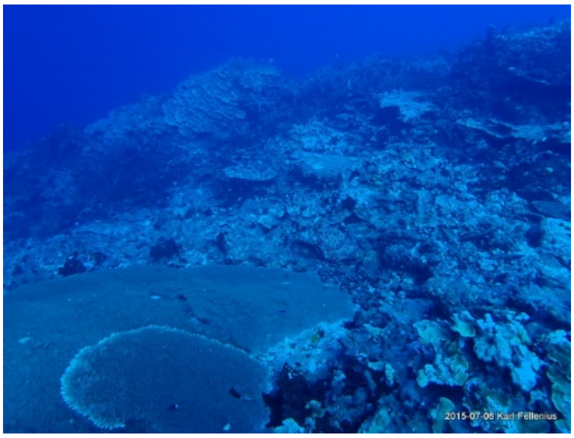

Fig. 4.2.16 upper reef slope, 35ft. depth looking southeast

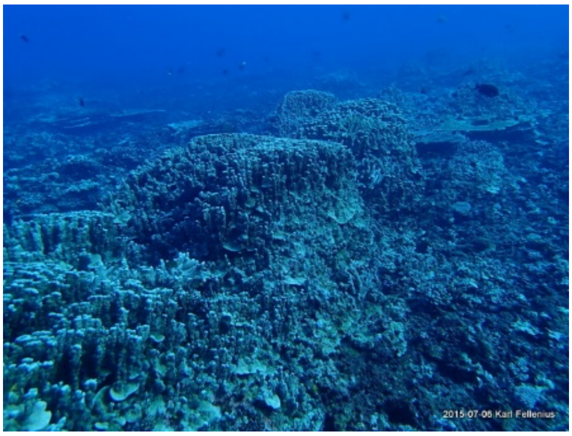

Fig. 4.2.17 Majuro coral (Porites rus) on upper reef slope, 45ft. depth

Fig. 4.2.18 Majuro coral (*Porites rus*) on upper reef slope, 45ft. depth - Blue-green chromis (*Chromis viridis*)

4.2.2 Site 4 Lower Reef Slope

Site 4 is the lower reef slope 1000-1100ft. from shore, covering depths from 60 to 140ft. The area has low reef relief, with about 25% coral cover at all depths, and coral diversity increasing with depth. The slope is steep at roughly 60-75 degrees (figs. 4.2.19 & 4.2.20).

Fig. 4.2.19 lower reef slope, from 80ft. depth looking up slope

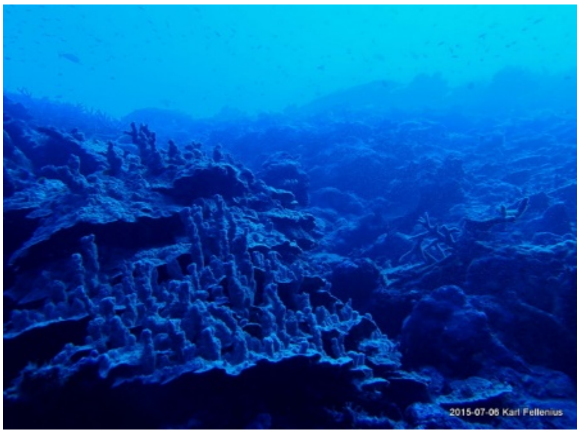

Fig. 4.2.20 lower reef slope, from 100ft. depth looking up slope

The most unique feature on the lower reef slope are a field of large gorgonian sea fans between 95 and 135ft. depth (figs. 4.2.21 to 4.2.24). These soft corals are more concentrated at the survey site than in adjacent areas, and appear to taper off in both directions along the reef.

Fig. 4.2.21 Gorgonian fan (*Subergorgia mollis*) 95ft. depth, looking up slope and southeast

Fig. 4.2.22 Gorgonian fan 135 ft. depth, looking northwest

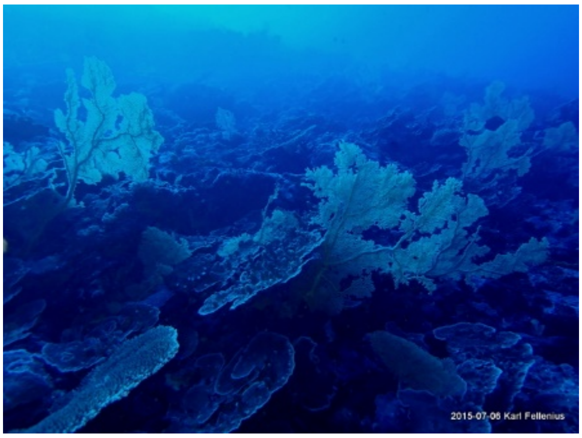

Fig. 4.2.23 Gorgonian fan (*Subergorgia mollis*) 110ft. depth, looking up slope and northwest

Fig. 4.2.24 Gorgonian fan 110 ft. depth, looking down slope and north

Coral diversity increases with depth on the lower slope. Majuro coral (*Porites rus*) dominates depths from the reef crest to about 80ft. More thinly-branching non-*Acropora* sp. and a variety of encrusting growth forms are more prevalent between 80 and 140ft (figs. 4.2.25 & 4.2.26). Even some small *Acropora* sp. submassive colonies are found at depth.

Fig. 4.2.25 Majuro coral (*Porites rus*) 70ft. depth

Fig. 4.2.26 non-*Acropora* sp. branching coral, 120 ft. depth

Blue-green algae including cyanobacteria mat algae occurs in patches at all depths on the lower reef slope (figs. 4.2.27 & 4.2.28). Unfortunately they also persist at the bases of many of the gorgonian fans noted above. Total cover is approximately 10% of the substrate.

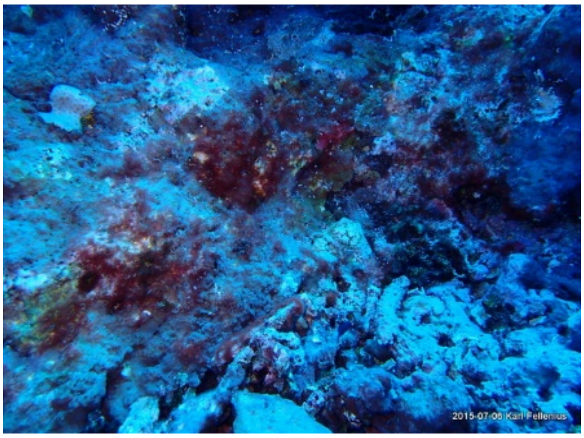

Fig. 4.2.27 cyanobacteria mat algae at 70ft. depth

Fig. 4.2.28 cyanobacteria mat algae at 110ft. depth next to encrusting coral

5 Recommendations

This reef morphology and marine life assessment is primarily an inventory with interpretation based on a formal method of collecting and analysing data. It does not, however, have a table matrix of impacts with their effects rated in terms of magnitude and direction. This is within the realm of a Preliminary Environmental Assessment or an Environmental Impact Assessment and is at the discretion of the RMI EPA. It instead highlights important issues and places them in the context of shoreline modification and coral reef health. The marine survey of the Monloklap Weto ocean side shoreline in Uliga is encouraging in terms of coral quality, yet disturbing for overall reef health in terms of sedimentation, algae, and available substrate for coral recruitment. It raises several ecological concerns:

1. Non-coral invertebrates are largely absent from the reef, especially giant clams. The scope of this survey does not include a formal investigation into historical uses of the reef that may have negatively impacted the variety and abundance of invertebrates harvested in the past.

2. Large (>8inches) fish are also largely absent from the reef. The ‘snapshot’ nature of the fish survey does not necessarily encompass enough information to conclusively state that fishing pressure has resulted in this situation. The lesson learned however, is that precaution in the face of scientific uncertainty is a valid approach and overfishing has likely resulted in the loss of large predators and herbivores.

3. There is upwards of 10% cyanobacteria/blue-green algae (mainly deep) and 60% *Hypnea* sp./turf algae (mainly reef flat and shallow subtidal) on the reef. These are significant amounts. It can quickly deteriorate further if algae-eaters are not allowed to re-populate the area and sources of nutrient input continue. Despite the relative abundance of medium and small-sized fish herbivores, only marginal cleaning of rock surfaces for coral recruitment is taking place.

4. Almost one-quarter of the reef crest and slope is covered in fine silty sediment 1/16th inch thick. The current amount is significant. If siltation is allowed to increase it may suffocate reef inhabitants, especially coral. Recruitment of new coral may be unsuccessful because the substrate that newly spawned coral settles on is not clean. Fertilised egg packs cannot attach to loose material and subsequently they die.

5. Corals on average make up only about 25% of the substrate cover from the lower reef flat to the reef slope. The growth form is dominantly submassive and encrusting, suggesting a transition from more diverse forms in the past (i.e. *Acropora* sp. to *Porites rus*). The exception are the large table coral colonies on the reef crest.

From that perspective, the recommendations below offer opportunities for mitigation and protection. They also identify where the scope of work can be improved for application on similar projects in the future, or for continued monitoring efforts in Majuro.

Based on the scope of the marine assessment in this study the author recommends that the proposed works be allowed to proceed subject to the conditions below. If there is to be any significant modification to the recommendations or the scope of the proposed work, the author recommends that the project be further evaluated by the RMI EPA.

There are eleven (11) recommendations: Five (5) are directly related to the proponent and six (6) require Government action but are only indirectly related to the proponent.

5.1.1 Recommendations Related to the Proponent (Developer Actions)

1. *Notification*: The RMI EPA is to be notified of the days that the works will be taking place, at least 3 working days prior to the onset of works.
2. *Equipment and Access*: An excavator working from shore is to be used for the works. The area to be dredged is to be limited to the foundation needed for the length and width of the proposed seawall. No work is to take place beyond the boundary defined by the seawall.
3. *Timing*: All work in foreshore or marine areas must take place from 2 hours before to 2 hours after low tide. This minimizes the potential for a sediment plume to disperse and settle across coral colonies on the lower reef flat and beyond.
4. *Materials*: No sediment curtain needs to be deployed as long as all excavated material is relocated to above the high water mark on a daily basis. No excavated aggregate is to be left exposed to incoming water on the tidal cycle.
5. *Coral Relocation*: No coral needs to be transplanted as none is in proximity to the location of the proposed works.

5.1.2 Recommendations Unrelated to the Proponent (Government Actions)

6. The EPA should commission a preliminary environmental assessment on similar projects in the future, to be evaluated in conjunction with marine survey reports.
7. The EPA coastal compliance officer is to be present during the dredging operation.
8. Consider the development of a coral reef restoration fund that proponents of aggregate sourcing and shoreline armoring projects pay into to offset potential damage to coral reefs. It is not be used as a justification to allow purposeful damage to coral, but as a fund to pay for incidental or small-scale loss of coral reef habitat. This fund can also be used for coral restoration in other areas. This is especially important in the context of the current El Nino, where coral bleaching is expected to worsen beyond the amounts observed in this survey.
9. Establish a national policy in the RMI in regards to sourcing sand and rip-rap aggregate for development projects. This policy should at a minimum include specific guidelines for dredging and excavation, including the use of sediment curtains, so that recommended best practices do not need to be re-visited and re-stated for every development project.
10. Implement a program of marine life monitoring in old and new dredge areas in Majuro atoll. This can partially be integrated into specific remedial or monitoring actions recommended through the PEA-EIA-EMP process. At a minimum, carry out regular surveys of the marine sites with their results compared with the baseline reference provided by this report.
11. Use the relationships established in local communities and among government agencies to encourage limits to herbivore fishing and the establishment of additional no-take marine protected areas in Majuro. The return to historical levels of herbivorous fishes is key to the success or failure of the reef to mitigate the growing situation of excessive sediment leading to siltation and algal overgrowth on the reef.

6 Conclusion

This report is the first systematic assessment of reef morphology and marine life on the ocean side shoreline of Monloklap Weto, Uliga in Majuro. It provides photographic, qualitative, and some quantitative evidence in support of the local assumption that its reefs are in an aesthetically pleasing yet unsatisfactory ecological condition. The primary method employed in the survey is spot check observations of substrate, invertebrates, and fish. The results are presented in the context of an understanding of the general relationships among different flora and fauna. Therefore, integral to the method is a broad explanatory introduction of pertinent signs that indicate whether the reefs are functioning as they should. The recommendations section includes a summary of several ecological concerns that are commonly noted on reefs in Majuro.

It is concluded that as long as the specific development recommendations are followed that the proposed dredging and seawall construction be granted approval.