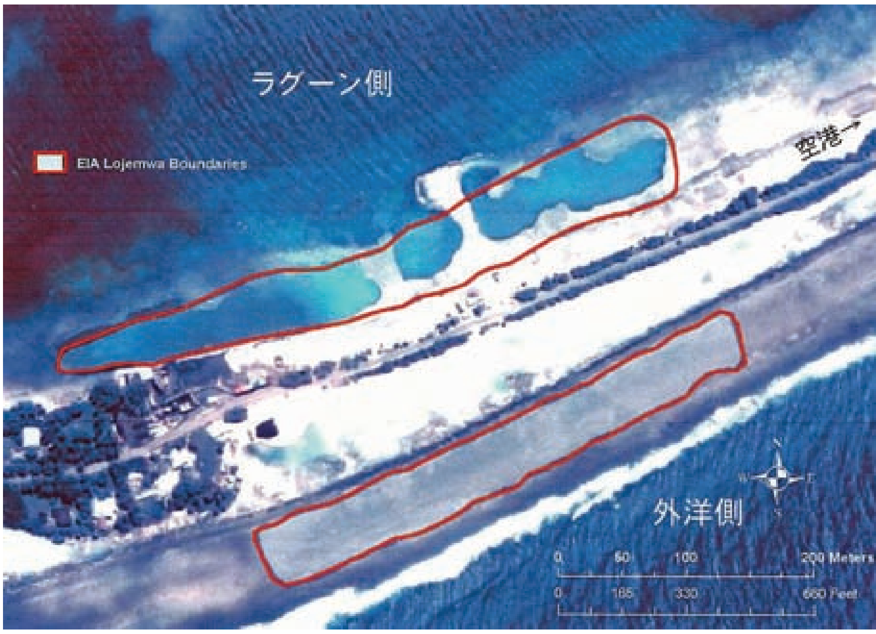
8-4 現地調達事情

(1) コンクリート用骨材【粗骨材（砂利）／細骨材（砂）】

採取場所：砂は空港西側のラグーン側、砂利は外洋側よりの石をクラッシャー

採取業者：PII (Pacific International, Inc.)

- その他 ナウルより砂を PII の保有するバージ（400 ﾄﾝ・4000 ﾄﾝ）にて輸送している。ポンペイからの輸送も試みている。



写真上：クラッシャープラント が稼働している。

※左図の赤枠は EPA が許可した採掘エリアを示す

図 1:採石場の範囲

(2) 埋立土

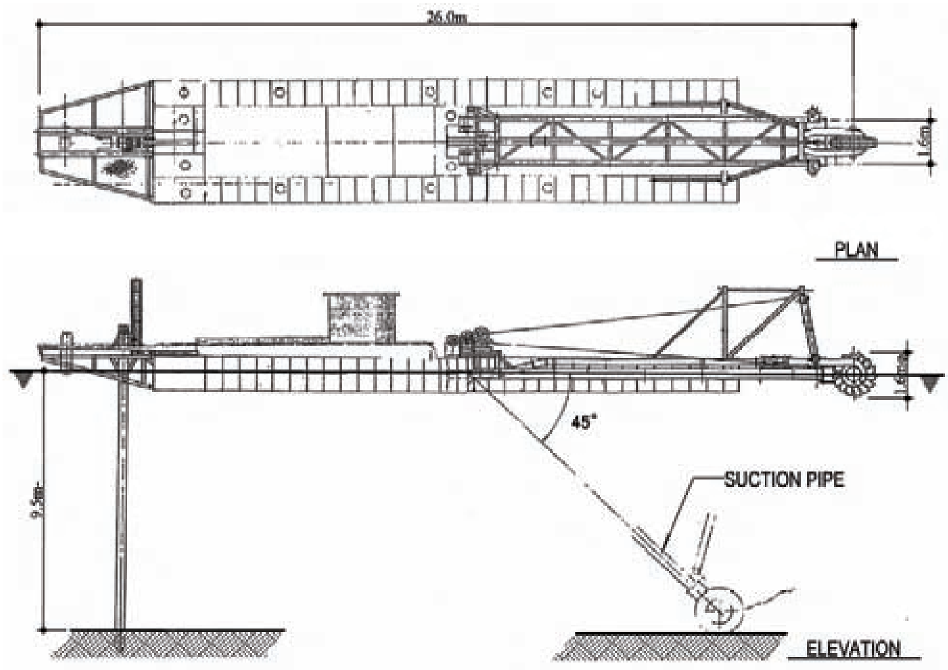
現在マジュロにおいて岩を含む土砂の採掘場は、民間建設会社（PII：「マ」国最大手企業）によるもので空港西側約 4km 付近（計画サイトから約 19km）にあり、クラッシャープラントも装備されている。採掘は汀線付近の浅場の外洋側（主に岩）およびラグーン側（主に砂）で行っている。これらは EPA の採取許可によるものであるが、2009 年 3 月までの許可であり、その後の延長については未定とのことであった。

EPA は、水際の浸食を防止するためには沿岸域のサンゴ礁の保全が最重要であるとの認識を持ち、その保全のためには砂採取をサンゴ礁によって形成された岩盤域で行うのではなく、浚渫によって行うことを推奨しているため､今後の採取はサンゴ礁域である沿岸域の浅場でなく、30 フィート (9.1m) 以深の海底からの砂の浚渫を推奨し、規制を行うとしている。

PII はこのような状況から、砂をナウルなどの海外から大型バージにて輸入を行うとともに、海底の土砂掘削・採取のためにサクションバージ（図 2 参照）を購入した。PII によるとバージは、2008 年 8 月にはマジュロに到着し採取試験を始めたが、試験操業の結果は思わしくなく、調査期間中には 30 フィート以深からの砂の確保見通しは確認されなかった。

既存の採掘場の許可の延長および 30 フィート以深の砂の掘削が確実でない現在の状況から、

本計画の埋立土の確保については、埋立土の輸入調達が適切であると考えられる。



※PII 社所有の Suction Berge の平面･立面図。本バージ（全長 26m）はオーストラリアの作業船メーカーより購入したもので、回転ハンマー（ドラグヘッド）を海底に接地させ、コーラルを砕き、サクションパイプにて砂を吸い上げる。水深 15.0m 位まで可能である。

図 2：サクション・バージ

(3) レディミクストコンクリート

商港近くに PII 所有の生コンプラントが存在し活動している。生産能力は 30 立方ヤード／時間（≒23m^3／時間）である。セメント・骨材・水をデジタル自動計測し、ミキシングはミキサー車のアジテーターにて行うプラントである。また使用する現場によっては砂の水洗いを専用の機械にて実施している状況が確認された。本プロジェクトでも生コンの使用は可能である。

品質管理状況については、コンクリート圧縮試験、骨材試験等を行う PII のラボがあり品質管理機材は整っており、ラボを統括する専門の技術者も存在する。

生コン（洗い砂使用）を採取し、カンタブにて塩分濃度測定を行った結果、JASS5 基準の 5.8 倍を超える値であった。塩化物対策は必要であると思われる。

(4) 鉄筋

MPW（公共事業省）等で行う RMI の公共建築は現在すべてエポキシ鉄筋を利用している。実際に現場（ウリガ学校工事、ウリガ・ドックの MOP の倉庫等）を確認したが、RC 造のみならずブロック造においてもエポキシ鉄筋が利用されていた。エポキシ鉄筋は主に日本製が使用されていた。

Biological Assessment Survey of Uliga Dock site, Majuro Atoll

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Executive summary:

While this site has previously been severely abused by the underwater disposal of solid waste and construction materials, it hosts a surprisingly rich and healthy coral reef community including 21 species of hard coral and over 60 species of resident fish. Algal growth is minimal except for *Padina* on coral-free sediments. Bivalves, sponges and algae-eating urchins dominate the invertebrates. Construction and in-filling of the seawall will destroy a small portion of this reef; some coral can be transplanted. Coral destruction can be minimized by careful placement of the seawall, as shown. The remaining reef needs to be protected by preventing the introduction of fine particulates and larger debris during construction. In the longer term, nutrients (by-products of marketed fish such as blood and viscera) should be prevented from entering the near-shore water to avoid further eutrophication and degradation of the reef.

Methods

The site was visited using snorkel and SCUBA on three occasions to assess biodiversity of algae, fish, coral, and other invertebrates and ecological health. Numerous transects were examined, spaces a few meters apart, and representative images captured from each corner and side. A single transect 5 meters wide by 75 meters long was photographically documented as a baseline for future monitoring studies. This photographic record, created by assembling two image ribbons into a single composite image, documents the size and locations of hundreds of coral colonies, including the most common genera: *Pavona*, *Lobophyllia*, *Acropora*, *Porites* and *Pocillopora*. This photo-transect is shown at the end of this report. A fish census (species list) was accumulated over three dives, but quantitative density estimates were not made. The wider environment within 200 meters of Uliga dock was also briefly surveyed.

Regional context:

The south eastern lagoon of Majuro atoll has suffered the highest reduction in coral biodiversity in Majuro, and perhaps the entire RMI region. Coral that are vulnerable to disturbance (including Crown of Thorns outbreaks) and poor water quality, including selected species of genera such as *Acropora, Pavona, Symphillia, Astreopora, Goniastrea*, etc., which dominate pristine lagoons in the RMI, are either absent or increasingly rare in this region. Conversely, species that resist or thrive in such conditions are either unusually common (i.e. *Pocillopora damicornis*) or have become super-dominant (particularly *Porites rus* and *Porites cylindrica*), replacing what once must have been a much more diverse and attractive coral assemblage.

Macroalgae are particularly sensitive to poor water quality (i.e., eutrophication). Typically one finds an over-abundance of algae, including *Padina, Dictyota* and *Halimeda*, including dense mats that partially cover and smother coral. A pristine, unpolluted lagoon, in a comparable location, would be expected to entirely lack *Padina* and *Dictyota*. A good example of the degraded, eutrophied condition is a site several hundred meters north of Uliga Dock, called "Bing's reef" where a single coral species, *P. rus*, is utterly carpeted with *Dictyota*. Large colonies of some mussid corals such as *Lobophyllia* and *Symphillia* can be found with *P. rus* in the downtown region, but small, younger colonies are very rare. A particularly large recent disturbance, a multi-year COTs (*Acanthaster*) outbreak (2003-2008) has destroyed most of the formerly widespread *Pavona cactus* beds in the northern lagoon, as well as much *Acropora* (including most colonies near M.I. Resort), *Lobophyllia*, and other coral.

Fish diversity is directly related to coral diversity and abundance; for example, only 20 species of mostly herbivorous fish (parrots, surgeons, damsels) are found in recently mined and coral-free hard rock quarry pits on the Ajeltake reef flat. Similar quarry pits mined seven years ago, containing significant coral growth, host over 40 species of fish; a year later the community grew to 110 species! Butterfly fish (Chaetodontids) are a good indicator of coral reef health and diversity: only two butterfly fish species are found in coral-free Ajeltake rock quarry, but the older quarry supports 4 butterfly fish species (40 species total). The Uliga dock site has an impressive 9 chaetodontid species and over 60 fish species, total.

Results

Surprisingly, given the highly disturbed nature of the locale (including the presence of thousands of beverage cans and other debris), the near-shore environment within Uliga dock supports a relatively rich, diverse and attractive coral community of at least 21 species. Most coral are alive and apparently healthy; the few corals found dead are most likely the victims of COTS or cushion stars (several fresh feeding scars were found on *Acropora* and *Pocillopora*). Live coral are typically free from algal overgrowth. The rare algae-covered coral colony was due to the activities of farmer damsel fish. A few dead *Acropora* colonies on the reef flat may be victims of bleaching during low tides. Further, hard, rocky substrate is nearly algae-free, perhaps due to intense grazing by urchins, with some *Halimeda* spp..

However, other characteristics of the algal community reflect the nutrient pollution typical of the eastern lagoon. The nearby soft bottom features super-abundant *Padina* forming a nearly continuous blanket. A single cohesive mat of brown *Lyngbya* cyanobacteria was found on hard substrate, measuring over a meter across, an indictor of eutrophic conditions.

This coral reef supports a comparatively diverse fish community, including 60 resident fish, along with several vagile, visiting species, an unusually high number for this locality, but much lower than the 100+ species typically found on pristine reefs. Many species (i.e., the scarids) are dominated by juveniles; in many cases adults are absent. Uliga dock supports 9 species of butterfly fish. Fish diversity and abundance drops dramatically outside of Uliga dock and in the regions inside of the dock that are coral-free, dramatically illustrating how coral-rich habitat attracts reef fish. The one abundant species that prefers rock to live coral is the orbiculate cardinal fish, which emerges at night.

Coral, fish, and invertebrate species lists follow: (* asterisk indicates most abundant spp.)

Scleractinian coral:
*Porites rus**
Porites cf. *lobata*
*Porites cylindrica**

Acroporids
*Acropora cytherea**
Acropora cf. *muricata*
*Acropora nasuta**
Acropora austera
*Acropora digitifera**
*Acropora vaughani**
Acropora loripes
Acropora subglabra

Fungids
Fungia sp.
Herpolitha limax

Mussids
Lobophyllia corymbosa
Symphillia recta

Misc
*Psammocora contigua**
(mostly restricted to shallow reef flat)
*Pavona cactus**
Pavona varians
*Pocillopora damicornis**
Leptastrea purpurea
Plerogyra sinuosa

Soft corals.
Rhodactis sp

Fish: *asterisk indicates species common in disturbed habitats
# indicates especially uncommon species in Majuro lagoon

- **Resident fish:**

Mullids
Yellowstripe goatfish *Mulloidichthys flavolineatus*
Multibar goatfish *Parupeneus multifasciatus*
Dash dot goatfish *Parupeneus barberinus*

Chaetodontids
Threadfin butterflyfish *Chaetodon auriga*
Bennetts *Chaetodon bennetti* #
Racoon *Chaetodon lunula**
Redfin *Chaetodon lunulatus*
Saddled *Chaetodon ephippium*
Pacific Doublebar *Chaetodon ulietensis*
Blackback *Chaetodon melannotus*
Lined *Chaetodon lineolatus*
penant bannerfish *Heniochus chrysostomus*

Pomacentrids
7-banded sergeant *Abudefduf septemfasciatus**
Staghorn damselfish *Amblyglyphidodon curacao**
Humbug dascyllus *Dascyllus aruanus*
Sapphire damsel *Pomacentrus pavo*
Tracey's demoiselle *Chrysiptera traceyi*
Blue-green chromis *Chromis viridis*
Three band anemonefish *Amphiprion tricinctus*
Dusky anemonefish *Amphiprion melanopus*
Whiteband damsel *Plectroglyphydodon leucozona*

Labrids

Slingjaw wrasse *Epibulus insidiator*
Black eye Thicklip *Hemigynus melapterus*
Floral wrasse *Cheilinus chlorourus*
Red Breasted *Cheilinus fasciatus*
Napoleon *Chelinus undulatus* #
Three spot wrasse *Halicoerus trimaculatus*
Blue striped cleaner wrasse *Labroides dimidiatus*

Scarids *(mostly juveniles)*
Bullethead parrotfish *Scarus sordidus*
Bridled *Scarus frenatus*
Pacific longnose *Scarus longiceps*
Bluebarred *Scarus ghobban*
Dark-capped *Scarus oviceps*
Bleekers *Chlorurus bleekeri*
Bicolor *Cetoscarus bicolor*

Microdesmids
pearly dartfish *Ptereleotris microlepsis* (only in north eastern sand flats)

Acanthurids
Whitecheek surgeon *Acanthurus nigricans*
Convict tang *Acanthurus triostegus*
Blackstreak surgeon *Acanthurus nigricauda*
Striped surgeon *Ctenochaetus striatus*
Zebra tang *Zebrasoma veliferum*
Whitemargin unicornfish *Naso annulatus*

Zanclidae
Moorish idol *Zanclus cornutus*

Siganids
Forktail rabbit *Siganus argenteus*

Balistids
humu humu *Rhinecanthus aculeatus* (only in northeastern zone)

Serranids
Hexagon Grouper *Epinephelus hexagonatus*

Lutjanids *(only juveniles)*
Twinspot snapper *Lutjanus bohar*
Humpback snapper *Lutjanus gibbus*

Lethrinids
Lethrinus sp.
yellowspot emperor *Gnathodentex aurolineatus*
Bigeye emperor *Monotaxis grandoculis*

Other groups
Soldierfish *Myripristis* sp.
Cardinalfish *Apogon* sp.
orbiculate cardinalfish *Sphaeramia orbicularis*
Scribbled pipefish *Carythoichthys intestinalis*
Cornetfish *Fistularia commersonii*
Trumpetfish *Aulostomus chinensis*
Lined Spinecheek *Scolopsis lineata*
White-spotted puffer *Arothron hispidus*
Giant morey eel
Several blennies and gobies, including Brown-barred goby, *Amblygobius phaelena* and yellow coral goby, *Gobidion okinawae*

- **Vagile visitors:**
  Leatherback *Scomberoides lysan*
  Bluefin trevally *Caranx melampygus*
  Striped mackerel *Rastrelliger kanagurta*

Conspicuous Invertebrates:

Echinoderms:
black diademnid urchins *Echinothrix sp.*
Crown of thorns seastar *Acanthaster plancii*
Cushion seastar *Culcita sp.*
Large *Thelenota* sea cucumbers on sand flat
Tunicates*:*
yellow solitary tunicates
Mollusks:
Mussel
Pearl oyster *Pinctada marguerita*
reef squid
Other Cnidarians:
Sand anemones (3 species)
including *Actinodendron* sp.

Sponges:
numerous species (blue, black, yellow, orange)

Annelids:
Sabellid tube worms

Rock anemone
zoanthids on overhanging edge of reef flat
invasive "upside down" jellyfish, *Cassiopea*

Coral were found colonizing a large number of man-made objects, including tires, PVC, steel, aluminum, etc., including a folded wheel chair. Live coral cover was locally high, over 50%, and provided important habitat for fish; in fact, almost all fish remained in close proximity to the coral-rich sector. It was noted that a number of relatively small, young *Lobophyllia* and at least one *Symphillia* colonies were roughly the same size (less than 60 cm), indicating they may be about the same age. (It is unusual to find young colonies of these species in this part of the lagoon.) Most surprising was the presence of two small, young *Plerogyra* (bubble coral) colonies, the only specimens so far known from such shallow water in Majuro lagoon (other colonies have been found between 12 and 30 meters in the lagoon, from Delap to Calelin).

Most coral genera are widely scattered on the hard substrate area, and some large patches are dominated by only one species of *Acropora*.

The abundance of *Pocillopora damicornis, Porites rus* and *Porites cylindrica* was not unexpected, as these species typically thrive in marginal, disturbed habitats. (*P. rus*, in particular, consistently escapes mortality from disease, bleaching and COTS.) *Pavona cactus* appears to thrive both in pristine and disturbed sites (it can also be found adjacent to the MIMRA dock) but given the dramatic and widespread recent mortality of this species due to the COTS outbreak, this small site can be considered to be a sort of refugia, worth protecting. There is evidence of past heavy COTS predation of *Pavona cactus* along the edge of the reef flat, but most colonies appear to have escaped damage.

Among benthic invertebrates, a species of *Echinothrix* urchin is super-abundant, no doubt accounting for the scarcity of macroalgae. At night, densities of 10 animals/m^2 are found along the edge of the reef flat. Large bivalves are also somewhat common.

The abundance of coral and reef fish at this site is higher than in the immediately surrounding region, with the exception of a large school of goatfish and small emperors near the outer southern corner of Uliga dock. Very little *Acropora* or *Pavona* is found in surrounding localities.

Relatively uncommon fish worth noting include a young Bennett's butterfly fish (one was found at MIR in previous years, but this species is not found in most Majuro locales) and a juvenile Napoleon wrasse. By far the most numerous fish are the herbivorous parrotfish and surgeonfish. The number and diversity of wrasses was surprisingly low; species of the two most widely encountered lagoon genera, *Halichoeres* and *Thalassoma*, were entirely absent.

Environmental considerations:

Immediate impacts of construction

Obviously some coral will be destroyed directly by the reef flat and reef flat-edge reclamation. This includes some "desirable", attractive species (a *Plerogyra* colony, 2 or 3 *Lobophyllia* colonies and approximately a dozen *Pavona cactus*) as well as less attractive *Porites rus*.

Longer term impacts:

The processing of large amounts of reef fish in the market will generate fish by products (blood, viscera, spoiled fish). The dumping of any of this material would increase the local nutrient load, possibly leading to enhanced algal growth and reduced coral health (it is known that some algae, including cyanobacteria, may release compounds that reduce coral recruitment).

Recommendations

Mitigation of coral damage

The best way to protect coral is to prevent their destruction, rather then trying to replant or restore a reef. Therefore, the idea of reducing the footprint of the reclamation should be considered, i.e. relocating the seawall landward a few meters. It is possible that given the unusual attractiveness of this small reef that it might be promoted in the future as a local tourism destination (i.e., for those without the time or resources to visit less accessible reefs). The preservation of some intact reef flat would provide a safe and convenient resting spot for snorkelers.

Moving the seawall will not save all coral, however. Certain "desirable" coral species that can be readily detached, including *Pavona cactus*, can be transplanted out of the construction zone, allowing their continued growth. An obvious receiving site is the three experimental solar, PV electric-powered "Biorock" structures located at the western end of Enemonit Island. These steel rebar structures were installed by Dr. Thomas Goreau in 2007, with a small solar-powered DC electrical current providing a growth stimulus to coral fragments (including *Pavona*, *Acropora*, *Goniopora* and *Porites*) that were attached. Electrical stimulation can result in a 4-5 fold increase in growth rates and provide resistance to thermal bleaching. These Enemonit coral fragments have thrived and grown considerably during the first year of the Biorock project, attracting hundreds of small *Chromis*, humbug damsels, and other plankivorous or herbivorous fish. The project currently lacks *Pavona cactus* and *Lobophyllia*, so their transplantation from Uliga Dock would significantly enhance the appearance and value of these reefs. As a test (and as a CMI class demonstration), a few fragments of *Acropora* and *Pavona* were transplanted from Uliga Dock to one of the biorock structures in November 2008 with the assistance of several students.

An alternative, less expensive artificial reef construction method is the use of commercially available cinder blocks. These blocks can be prepared by drilling shallow holes in which coral fragments will later be inserted and cemented into place using underwater epoxy. In areas of strong wave action, many blocks can be fixed into place by running steel pipe or rebar through the cinder blocks, but this would not be necessary in protected sites, such as within Uliga dock.

Divers to perform the transplanting work are readily available; a budget for SCUBA tank air, fuel and boat time would amount to less than $400. The cost of cinder blocks and epoxy would be an added expense, but a block reef could be installed on site, eliminating the need to transport coral fragments.

A discarded wheel chair that has been richly colonized with coral (and provides habitat for fish) rests near the reef flat on sand, in the construction zone, and can be easily relocated using a lift bag. An underwater clean up of the area (including the recycling of thousands of aluminum cans) would be desirable.

To insure the continued health of this small but significant reef, it is important to prevent any material from entering the water, including effluent (sediment-filled water) from the construction site. The use of "dams" of geotextile fabric would be appropriate.

The long-term use of the fish market will generate some nutrient-rich waste, in the form of fish blood and viscera. Release of such effluent into the near-shore environment should be avoided, perhaps using a small outfall pipe to redirect flows to deeper water or a septic system.

Finally, as a gesture of public awareness and environmental sensitivity, the Uliga dock reef should be cleaned up, using volunteer help. A budget should be provided for refreshments, and perhaps a T-shirt ("I cleaned up Uliga Dock"). Large steel "I" beams can be recycled, necessitating the use of a heavy crane (many items can be moved away from the coral using lift bags, to avoid damage to the reef), but man-made items that have been heavily colonized by coral should be allowed to remain.

Uliga dock permanent transect (upper end adjacent to Harbor Patrol boat, roughly parallel to outer dock)

10 August 2008
by Dean M. Jacobson, PhD

Approximate coral census:

Pocillopora damicornis:	**285 colonies**
Porites cf. *lobata*:	**2**
Porites cylindrica	**17**
Porites rus	**85**
Acropora: large tabulate	**8**
Acropora: small tabulate	**30**
Acropora: bushy	**65**
Acropora: branching	**1**
Lobophyllia corymbosa	**6**
Pavona cactus	**40**

Approximate beverage can count:
950