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Introduction

Critters@Lembeh, the dive operation associated with Lembeh Resort is located in North Sulawesi, Indonesia. Halfway down Lembeh Island, it sits across the strait from Bitung, which is about an hour and a half from the Manado city airport. For six weeks, I stayed at Lembeh Resort as their in-house volunteer. Over the years, Lembeh Resort's house reef had been damaged by storms, pollution, and previous human abuse. The biologists of Critters@Lembeh in association with Lembeh Resort have since initiated a restoration project, in efforts to rehabilitate the damaged areas using a variety of artificial reef structures and advocating ocean awareness and conservation.

My duties as a volunteer were broken into two categories: on-going maintenance of the house reef and my own independent research project. Maintenance projects included coral and sponge transplantation, invasive sponge removal, and trash pickup. My independent research project focused on observing trends in artificial reef recruitment, night diving on the house reef, and mapping. Recruitment refers to the attraction of animals to the artificial reef. 61 of 92 dives were conducted on the house reef, the rest of which were completed throughout Lembeh Strait. Included also in this report is a brief description of other projects initiated by previous volunteers.

House Reef Artificial Structure Overview

The house reef has several artificial structures currently in place. From shallowest to deepest they include: three biorock structures (the tunnel, pagoda, and dome); stacked concrete bricks known as fish houses; two sets of reef balls; two fish net structures; and a small wooden wreck. In addition, a new structure was installed during my visit called the drum ladder. Although my research touched on all of these, I focused primarily on the tunnel, dome, fish nets, and drum ladder.

The biorock structures feature a steel rebar skeleton through which flows a mild electric current. This current accelerates the precipitation of calcium carbonate, as well as other minerals essential to coral growth onto the structure, thereby speeding up the accretion of wild corals and raising the survival rates of transplanted specimens. In 2009 the biorock project suffered an unfortunate setback when the cable supplying the electricity to the structures failed. Despite the lack of electricity, the survival rate of previously seeded corals and those that are transplanted is still relatively high.

The two fish net structures are made of cross-hatched ropes strung between four or five large metal and concrete objects. Because of their location in deeper water, sponges and soft corals are preferred over corals for transplanting, since they are better adapted to grow in lower light. Transplanted specimens are tied directly to the ropes or to the anchoring objects themselves.

The drum ladder is comprised of a PVC pipe ladder that has been roped across two oil drums. Strung along each rung are several rows of rope weighted to the ground by colored stones; painted as per the hypothesis that certain colors are more attractive to fish. Since it is situated in the same depth as the fish nets, sponges and soft corals are again best suited for transplantation here.

Transplanting

Because the rate of natural settlement and growth of wild species is very slow, transplanting existing specimens onto the structures greatly accelerates the recruitment process on new or otherwise vacant structures. Structures with a lot of empty surface area are more likely to leave opportunity for aggressive spreaders to overrun or otherwise inhibit other species from getting a foothold. It is also important to continue transplantation of a variety of coral and sponge pieces onto the structures, thereby ensuring greater species diversity within the surrounding area. By transplanting large mature specimens to the structures, the mortality rate remains low while providing more immediate habitat for fish and invertebrates. More mature specimens are also likely to have a higher tolerance of transplantation stress and a greater probability of resistance to more aggressive spreaders. Proper transplanting candidates are free standing mature specimens of coral or sponge, preferably found within a similar depth range as the desired transfer location.

Materials and Methods

- wire
- scissors
- brush
- crate/bin
- small lead weight

Transplanting is a simple process. After finding a suitable coral or sponge, attach it to the desired structure using wire or a zip tie. Take care to avoid excessive damage when transporting the specimen to the new site by handling as minimally as possible. Sponges are a bit more tolerant of handling than corals, and can regenerate from fragments faster. If the coral is attached to rock, it is recommended to try to attach the coral piece by way of the rock to limit contact. The crate should be big enough to hold a few medium sized specimens, but small enough size so it is easy to carry around. The weight is placed in the bottom of the crate to keep it from floating away when not in use. When preparing the new site, use the brush to clear the surface of the structure so that it is free from any overly aggressive or otherwise invasive species. Also, make sure there is adequate space between the surrounding corals so as to reduce overcrowding. Then, spool out an ample length of wire to attach the specimen to the structure. It is important to tie it securely to the structure so it will not shift or fall off in strong currents. If the specimen you find is too big to carry in the crate, carry it in your arms or between two people as is most comfortable and reduces the amount of handling or chafing.

Invasive Sponge Removal

All around the reefs of Lembeh Strait grows Chalinula nematifera, previously known as Nara nemafitera,[1] an aggressive purple encrusting sponge, which normally is kept in check by the natural balance of the reef. On the bio rock however, it grows quickly and will smother newly transplanted corals if left unchecked. As with any newly installed feature, the first things to colonize that much clean surface area are the fastest spreaders and reproducers. Without adequate competition, there is little keeping those organisms in check.

Materials and Methods

- Toothbrush, bristlebush, and/or wire brush
- Gloves, optional

Chalinula grows quickly on the biorock structures, and should be scrubbed off with a soft brush at minimum once every two weeks. I found the most effective tools for cleaning Nara were a big bristle brush for the larger surface areas and a toothbrush for hard to reach areas. Gloves are optional but beneficial when working around Celleporaria sibogae, a black bryozoan with a hard calcareous crust and white commensal stinging hydroids.

All three biorock structures were equally affected by Nara; however the pagoda structure is the hardest to keep under control. The pagoda structure has the smallest volume of all three and it consequently has the most condensed internal structural support. One of the reasons that Nara is so difficult to manage is that it is difficult to clean the sponge off the underside of the biorock. Whereas you could enter the tunnel and dome structures to scrub from the inside, the same is not possible for the pagoda. Another factor that makes the pagoda difficult to maintain is that it is also a favorable structure to Celleporaria. In such close quarters this bryozoan can be very difficult to clean around without fear of infliction. Despite the presence of Nara throughout the reef, the biorocks are the only structures where active management of the sponge is needed. That being said, the fish houses should also be monitored for possible future maintenance but current populations are stable.

Further study is necessary to accurately determine the speed at which Nara can colonize a new area, and what kind of effects substrate composition and depth (light intensity) have on the sponge's growth rate. Moreover, since there is no longer current

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[1] http://www.marinespecies.org/porifera/porifera.php?p=taxdetails&id=166294

running through the biorocks, we cannot determine what kind of effect electricity had had on the sponge. Previous studies have been done to support the hypothesis that epibenthic organisms are capable of settling and growing on any nontoxic structure with a suitably rough surface. It should be noted that in such areas as coral reefs, materials used in an artificial structure with a similar chemical composition to the surrounding area would be of greater benefit to local infauna over the use of other materials.[2]

Trash Removal

Waste management has become one of Indonesia's topmost environmental issues today.[3] Inefficiency, out-dated methods and lack of funding are some contributing factors Indonesians are faced with concerning solid waste collection and disposal. As a result, a large portion of debris ends up the ocean. Currents sweep the refuse out to sea, bringing trash to Lembeh resort throughout the year; the worst of it comes during the windy season in August. Often the resort has to send staff out daily to pick up the rafts of garbage that float into the bay. Bottles mainly populate the surface, but many plastic bags, bottles, and wrappers float mid water or sink to the bottom and snag on the reef.

Materials and Methods

- gloves
- rice bag or other large bag for collection
- scissors for cutting debris away from the reef

A weekly trash removal is usually sufficient to keep the reef clean. Since trash that has been underwater for a while can grow a film of algae and hydroids, gloves are recommended when handling larger quantities.

Independent Project

Artificial Reef Recruitment

The idea to study recruitment occurred to me after I noticed several transplants induced remarkable reactions from fish populations. After transplanting a number of corals and sponges, I noticed a few pieces that attracted immediate attention, some that produced only a temporary interest, and some that attracted hardly any attention at all. Still other pieces gained long term associations shortly after arrival, and others that appeared to gradually increase over time. Furthermore, I noticed that medium to large specimens were more successful in attracting animals than smaller ones.

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[2] M. Hixon and W. Brostoff, 1985

[3] http://www.indowaste.com

The purpose and benefit of studying artificial reef recruitment helps us to better understand what structural environments different coral reef communities prefer. By examining a variety of habitats and which animal communities associate with them, we can determine if certain types or characteristics of these habitats are more likely to attract one community over another. By observing how animals behave and interact in natural coral settings, we can attempt to duplicate those conditions on artificial reefs, thereby enhancing their effectiveness. We could even use this information to customize an artificial reef to its specific location, or to specialize in attracting a specific animal or community.

We can implement these findings to further our understanding of coral reef ecology, as well as our understanding of such phenomenon as the 'new habitat effect', and the 'edge effect'. The 'new habitat effect' is what happens when a new structure is introduced into a community that is in some way more desirable than an existing piece, and any previously established behavioral hierarchies are potentially dissolved in a territory free-for-all. The 'edge effect' deals with community cohabitation around infringing ecological niches.

Materials and Methods

- wire
- scissors
- brush
- crate/bin
- small lead weight
- notebook and pencil and/or underwater slate
- camera
- critter id book

My first dive on a typical day was a general sweep of the area looking for suitable coral and sponge candidates to transplant onto the artificial structures. Since most good candidates had already been picked from the proximate area around the artificial structures, the most productive searches came from sweeping the northern and southern perimeters. The best route I found was to start at the southern end of the reef, work my way north and turn around to end up back at the artificial structures. After transplanting several specimens, I returned at various times throughout the day to check on the recruitment process for the individual piece as well as the overall incorporation into the structure. I used a Sealife DC 1000 to document my findings. In addition to scouting for transplantable candidates, I used my camera during my tours to document commensal behavior throughout the reef. I would also use this time to check on all the pieces I had previously transplanted and make observations on their progress.

<u>Biorock</u>

I transplanted several pieces of hard corals, soft corals, and sponges onto the dome throughout my stay. Of the pieces I observed, hard corals showed the most immediate results with long term recruitment, and also turned out to be the best examples of the new habitat effect. The most successful formations of hard corals typically incorporated some kind of branching or interlocking growth pattern.

On 19 July I transplanted several arborescent, tabulate, and corymbose-caespitae Acropora corals onto the south side of the tunnel.[4] Over the next three weeks, I consistently observed several damsels and wrasses hiding in the corymbose pieces and a juvenile Eight-band Butterflyfish (Chaetodon octofasciatus) living in the tabulate piece. On 27 July 2010, I installed two tabulate Acroporas onto the dome; one on the south side and one on the east. On that same day I returned to find a mixed school including Purple-eyed Gobies (Bryaninops natans) and juvenile Golden Damsels (Amblyglyphiodon aureus) that had started to associate with the southernmost coral plate. Observations thereafter showed the school remained with the new coral, however little observable change had yet to occur on the easternmost piece.

Previously, a small school of Purple eyed gobies was seen on a digitae piece located on the southeastern top of the pagoda biorock. After the table coral installation on the dome, the purple eyed gobies were not seen on the pagoda again. This is the best example I witnessed of the 'new habitat effect'; when presented with a more suitable living space, fish will gravitate towards it, seemingly regardless of any existing behavioral hierarchy.

Soft corals and sponges on the biorock occasionally showed immediate interest from fish populations, but more often the attraction was only temporary. Butterflyfish, Angelfish, Soapfish, Tangs, and Damsels arrived as foragers and cleaners anywhere from one to three days after transplantation, and soon left after the initial curiosity wore off. Specimens observed with invertebrate inhabitants such as commensal shrimp or coral crabs prior to transplantation often retained those associations afterwards as well. This supports the hypothesis that continuing to add as many different species of corals and sponges contributes to the overall biodiversity and complexity of the structure.

<u>Drum Ladder</u>

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[4] Tabulate (table like), arborescent (tree like), corymbose (clustering), caespitose (bushy interlocking)

On 14 July 2010 we began the installation of the drum ladder. Two cleaned and perforated oil drums were set and secured in place between the fish nets at roughly 75 feet/ 23 meters. A ladder constructed out of PVC piping connects the two drums in the middle and has colored stones of green and red hanging in several rows along each rung. To further encourage natural seeding to the PVC pipes, it is recommended that the pipes be lightly sanded. Most sponges and soft corals transplanted on the drum ladder were gathered within a fifteen foot depth range of the structure, to reduce stress incurred by acclimation.

After the first day little fish activity was observed; only the already present Grubfish and a few passing Angelfish and Tobies showed any interest in the structure. Moderate sedimentation began to accumulate on the structure soon after installation. One week later, self-seeded tunicates including Oxycorynia fascicularis began to attach themselves to the walls of the drums and fish populations continued to increase with additional sets of sponge and soft coral transplants. Soapfish, Angelfish, and Butterflyfish repeatedly came and went inspecting and grazing on newly transplanted sponges, however Blennies, Grubfishes, and Tobies were found most consistently living in or around the structure. Sponges attached to the ropes and rungs of the ladder were favored by Blennies and Grubfish, and chimney sponges were popular with the foragers.

On 25 July, a large number of big sponges were moved onto the drum ladder in stages, ranging from two to four feet in length. The largest was secured to the drum first, and within the fifteen minutes it took to bring back the next load of transplants, that sponge was already being feverishly picked over by several Butterflyfish, Angelfish and Soapfish. Also on that day a small Wonderpus was found out in the open not ten feet from the structure. On 3 August, one large Reef Octopus was found sitting on top of one of the drums, although soon after I arrived it ducked down under the drum between the supporting rocks. No further record of that octopus was noted. The location of the drum ladder poses some interesting ecological questions. It is situated on the edge of three different environments; pelagic, sandy bottom and coral reef. These environments give host to distinct communities, yet in such areas where these communities mix together a greater variety of species can be seen as opposed to observations made in just one. Further study of this ‘edge effect’ could be of great interest to future volunteers.

The installation of the drum ladder is also a good example of the ‘new habitat effect’ on a larger scale. In the initial weeks after its installation, I observed almost daily a particular Grubfish hanging out by the Eastern most drum. Anytime I brought down tools and sponges to transplant, the Grubfish was always there protecting its new territory, sometimes even venturing as far sitting directly on the wire I brought. Additionally, I consistently observed blennies swimming around and resting on the ladder.

Night Diving on the House Reef

The house reef at night is dominated by invertebrates and nocturnal predators, while most fish retire to sleep or hide in crevices and sponges. Several species of octopus and cuttlefish were found hunting at night, as well as catfish and banded sea crates[5]. Of note, moon phases seem to have at least some role in the abundance of nocturnal activity. Nine night dives were recorded during the span of one lunar cycle, from 2 July to 3 August[6]. The period of time from the new moon (11 July) to the first quarter (18 July) showed the most activity from predators and foragers. Of particular significance, on 15 July a pair of Fingered Dragonets was observed mating in approximately 10 feet of water. Half a month later, a small cuttlefish was found hunting in about 50 feet on the south side, and a large spiny lobster was similarly found just south of the dome, in roughly 20 feet of water. Two to six squid were also seen on most dives throughout the month. Most active fish and predatory animals were found in 40 feet or less, but several nudibranch species were found anywhere from 15–80 feet. The deeper structures were predominantly occupied by nudibranchs and shrimp, and were mostly vacant of fish with a few exceptions hiding within the structures.

Night Diving and Recruitment on the Artificial Reef

Observations of the biorocks at night showed the overall structures to be vacant. Little to no animals were found throughout the structure as a whole, and most coral pieces appeared to be uninhabited, with exception to the tabulate pieces. The fish that associated with those specific corals during the day remained there at night, but did not venture out from inside the coral. Sponges at all depths of the reef had much higher recruitment numbers of both fish and invertebrates at night. The folds and funnels were utilized as sleeping and hiding places, and shrimp were most often found populating the exterior surfaces of the sponges.

Equal utilization of these hiding places was noted in the infrastructure of the surrounding natural reef and the deeper artificial reefs. Characteristics of a typical hiding place consisted of a small area with three walls, or otherwise only one entry/exit. On the existing reef, fish favored rocky crevices closer to the ground over those situated higher. The deeper artificial structures had more crevices to utilize in the folds and corners of the metal structures. Funnel and barrel sponges were used throughout the natural and artificial reefs.

Mapping

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[5] See Addendum B for a full list of animals surveyed.

[6] See Addendum C for complete list of moon phases and night dives

With the addition of so many artificial structures in the past few years, the map of the house reef had become outdated. The trails throughout the reef were also positioned inaccurately as some of the structures had been moved. Over the course of my stay I mapped the house reef to scale and repositioned the trail buoys into more distinct and easy to follow trails. I started with a hand drawn map and then redrew it using Adobe Illustrator. With the continued addition of new structures, the map may need to be updated from time to time.

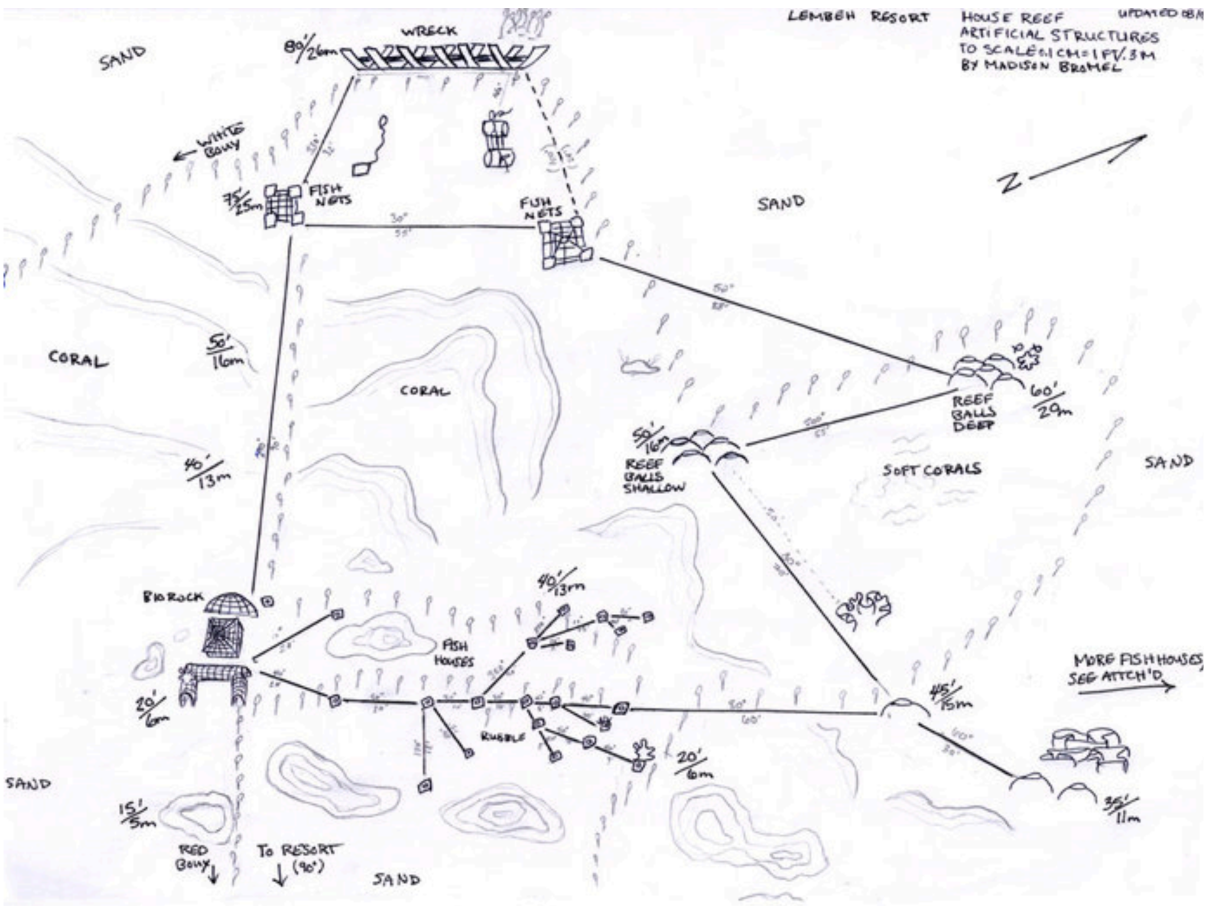
Materials and Methods

- compass
- finger spool marked out in ten foot or metered increments
- slate
- depth gauge
- paper
- pencil
- ruler

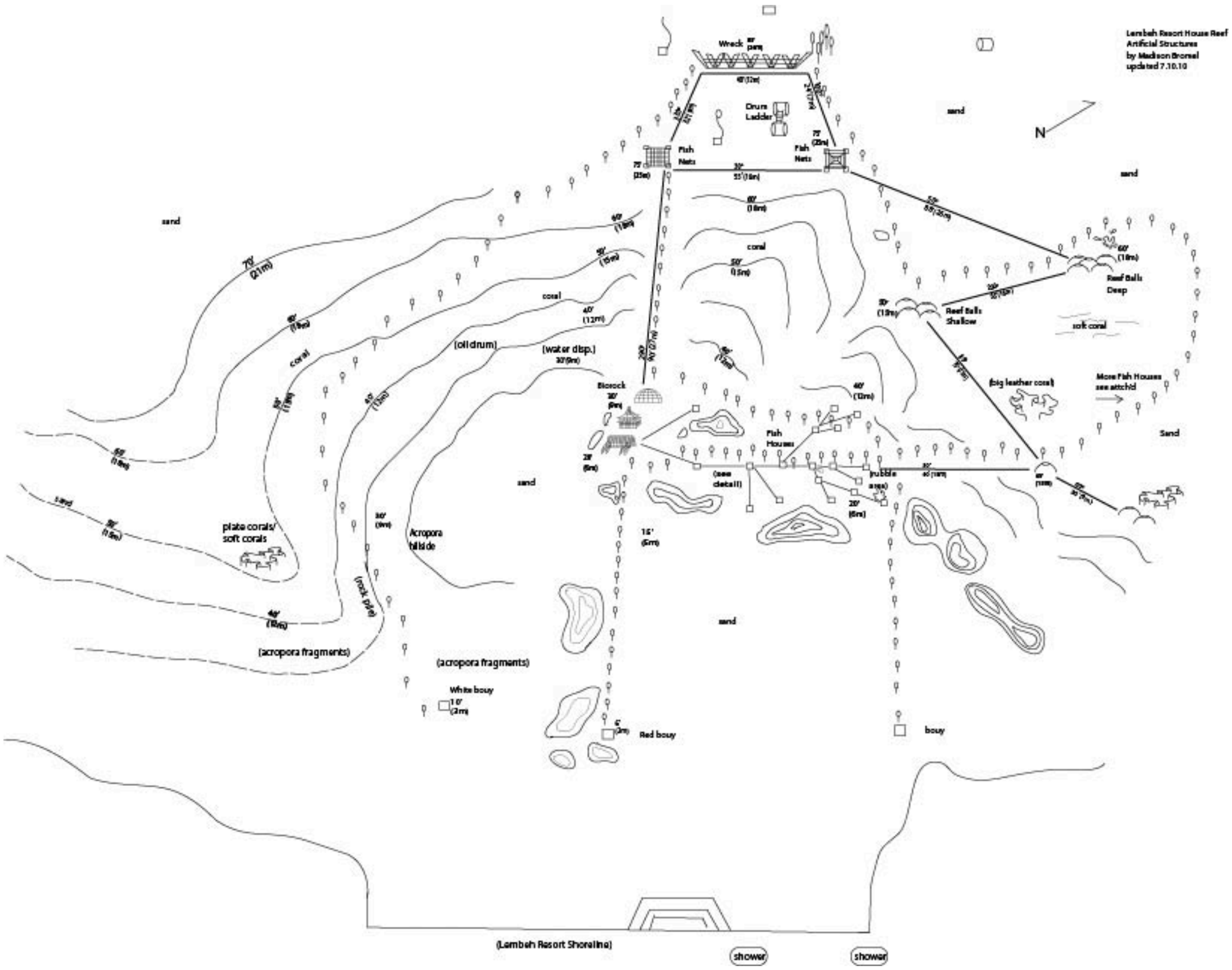
Mapping is easiest done between two people, but can be done individually. After deciding on a starting point, have one person (diver A) stay stationary at the starting point holding the reel. The other person (diver B) then takes the line and swims in a straight line to the next object. Dividing the task load between each person not only allows you to double check your data but also reduces confusion. Have diver B take a compass bearing upon reaching the next object, as well as note depth. Diver A counts the tick marks as the spool unravels, and double checks their numbers by recounting the ticks as they reel in towards diver B. Diver A notes depth of each object as well, and can also take a compass bearing before heading towards diver B. This method is especially useful when mapping objects that are a greater distance apart than visibility allows. Once the swimmer reaches the next object, they can give a few tugs on the line to signal the other diver to start reeling up the line. Its beneficial for the mapping team to make a few dives on the site to familiarize themselves to the area, so they have an idea of what needs to be mapped and which route to map it through.

Having each diver write down the data collected on their own slate enables the divers to cross reference each other throughout and after the dive. The data can be collected in whatever fashion is most comprehensible to the divers; however I found that sketching the object as you mapped was the most helpful in visualizing the structures. Another method I sometimes find useful is writing down the data in list form. Once all the data has been collected, transfer it to paper using a compass and ruler. Orient the paper to a designated compass bearing (e.g. parallel to shore), and then secure it in place. Use the ruler to scale the map to the paper and to guide straight lines between each object. Align the compass and the ruler to the bearing and length assigned between each object during data collection, and redraw onto the paper according to scale.

The artificial structures are mapped to scale; however, the natural topography of the reef included in the map is only a general outline. Additional and more accurate mapping of the contour could be taken upon by a future volunteer.



Map 1 (hand drawn)



Map 2 (Illustrator)

<u>Observations on Miscellaneous House Reef Structures</u>

Additionally, three other small artificial installations are in place separate from the majority of the artificial structures; a small rock pile, an oil barrel, and a water dispenser. Installation dates for these structures remain unknown; however Gils Winstanley, a volunteer from September- October 2008, took initial observations of these structures, and since then I have noticed some changes and offer some speculation into their progress. His observations are as follows: the rock pile was noted to have a small colony of massive porites, but little additional growth. The oil barrel had little to no marine growth, although substantial rusting had contributed to its perforated appearance. The water dispenser had accumulated a biofilm, but the smooth painted surface most likely inhibited settlement.[7]

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[7] Giles Winstanley, 2008. http://www.lembehresort.com/reef_wreck_critter_coral_diving_lembeh_strait_north_sulawesi_h9b27.html

Since then, roughly a period of two years, I have noticed improvements on the conditions of all three of these structures. First, the rock pile has several seeded hard corals, all roughly six inches in height or less. The largest of these were moved onto the substrate to give them more room to grow. The oil barrel has several soft corals (bubble corals) growing on it, mostly around the rusted out holes. Lastly, the water dispenser remains unsettled, however, two pairs of Two Spot Damselfish were observed laying eggs on either side.

Conclusion

The house reef at Lembeh Resort holds a unique opportunity for researchers to observe and document the effectiveness of artificial reef systems. Since many structures have already been in place for several years, observers can document the progress of the older structures' integration into the natural reef community, as well as the incorporation of newer structures. This information, in conjunction with consistent reef surveys, can be used to determine the greater effectiveness of some materials and methods, such as roughened surfaces for coral seeding and folded surface area for hiding. With the continual addition of new structures and the natural evolution of the reef itself, maintaining an updated map can help with the efficiency of data collection as well as cultivate interest from resort guests.

Appendices and Addendums

Addendum A: Additional observations on fish and behavior near wreck, fish nets, drum ladder

- Trumpet fish fight at 90 feet, past the wreck. Observed circling and sparring for over 10 minutes.
- Cleaning station at wreck; cleaner pipefish
- School sweetlips, one/two Red Emperor Snapper
- Grouper
- Spadefish living in fishnet sanctuary go to cleaning station at wreck
- Lizardfish
- Octopus
  - Wonderpus
  - Reef Octopus
- Cuttlefish

- Shrimp
- Butterfly fish
- Angelfish
- Big pelagics
    - Trevali
    - Mackerel
- Porcupine fish
- Boxfish
- Puffers
- Soldier fish
- Robust Ghost pipefish
- Pegasus Sea moths
- Scorpionfish
- Lionfish
- Blennies
- Shrimp gobies
- Soapfish
- Tobies

<u>Addendum B: Survey of animals found at night on house reef</u>

- Banded Sea Snakes
- Cuttlefish
- Squid
- Octopus
    - Long Arm Octopus
    - Starry Night Octopus
    - Reef octopus

- Moray
- Black Tipped Catfish
- Striped Catfish
- Crabs
  - Decorator crabs
  - Hermit crabs
  - Helmet crabs
- Shrimp
- Tube dwelling anemones
- Humpback scorpionfish
- Spiny devilfish
- Flat worms
- Sea cucumbers
- Spiny lobster
- Fingered dragonets
- Pajama Cardinals
- Blue Spot Rays
- Nudibranch sp.

<u>Addendum C: Moon Phase Data</u>

Last Quarter, 4 July 2010

- Night dive 2 July
- Night dive 4 July

New Moon 11 July 2010

- Night dive 14 July
- Night dive 15 July

First Quarter 18 July 2010

- Night dive 19 July
- Night dive 20 July
- Night dive 25 July

Full Moon 26 July 2010

- Night dive 30 July

Last Quarter 3 August 2010

- Night dive 3 August

New Moon 10 August 2010

Addendum D:

Possible Future Experiments:

- With proper equipment, a salinity test would be fairly simple to conduct, taking samples at various locations on the surface and at depth, to test levels of salinity at the source of the freshwater runoff, and track the progress of homogenization. Data collected would need to be compared to a control, possibly another nearby reef. Also, sedimentation would need to be taken into account, and possibly even turned into another experiment.
- Evaluate growth rate of Nara sp. in varied conditions, possibly including: substrate, light exposure, depth, salinity, and tidal conditions.
- Continue documentation of artificial reef recruitment and integration overtime
- Continue coral growth rates on the biorock structures using previously collected baseline measurements
- Continue reef surveys

Previous projects initiated by past volunteers:

- Survey and analyze data changes in fish species and family populations around the artificial structures
- PADI ocean clean up
- Baseline and continuous coral measurements on the biorocks
- New structure installations

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