Restoration of a functional ecology to Florida's coral reefs

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Introduction

The coral reefs of the Florida Keys are in major decline. Environmental stress due to global warming, unprecedented coral mortality due to disease and bleaching, and direct damage from abusive human impacts have led to a loss of healthy coral reefs in the range of 50% to 90% over the last 30 years in most areas. One of the major stresses on Keys coral reefs, one that contributes negatively to all other stresses, is the overgrowth of coral by algae. Algae overgrowth traps sediments, inhibits settlement of coral larvae and growth of post larval corals, outcompetes corals for light and substrate, and actively destroys and inhibits growth of long established coral formations. The ecology of Florida's coral reefs has been gravely damaged and whatever restoration may be possible, it can not occur unless the basic ecology of the reefs is repaired. **It is very clear that coral reef restoration in the Florida Keys is dependent upon reduction and control of macro algae growth.**

Apparently, it was the loss of only one species that made all the difference. The reefs of the tropical western Atlantic have evolved and developed within a complex ecological balance between photosynthetic algae and coral, and those organisms, herbivores and carnivores, that subsist directly and indirectly on the organic base that algae and coral create through the energy capture of photosynthesis. Throughout millennia, herbivores grazed the reefs and maintained the balance between coral and algae growth that allowed corals to flourish and build the vast calcium carbonate structures that are the foundation of the reef. Among all the grazers, however, it was the long-spined sea urchin, *Diadema antillarum*, the keystone herbivore of the Atlantic reefs, that maintained the ecological balance between coral and algae. They controlled algae growth to the point that corals could dominate and build the physical structure of the reef. Competition with algae growth is one of the major factors driving the decline of the coral reefs.

Prior to 1983, the populations of long-spined *Diadema* urchins on the Atlantic reefs were immense. Throughout this vast region the long-spined urchins were present on the reefs in numbers of 2 to 20 urchins per square meter, and in the Florida Keys, 4 to 6 *Diadema* per square meter could easily be found on most reef formations. The urchins are gone now. Macroalgae growth dominates the eroding limestone skeletons of the ancient coral formations that were alive and vibrant only two decades ago. The complex ecological web that built and sustained these reefs is disappearing and the biodiversity of life on living Atlantic coral reefs diminishes with every passing year.

The long-spined *Diadema* sea urchins of the tropical western Atlantic coral reefs died in 1983. Harilaos Lessios, a Senior Scientist at the Smithsonian Tropical Research Center, noticed in mid January that the ubiquitous long-spined sea urchins were in trouble. Just how serious this trouble was would soon be very evident. The urchins became lethargic, did not retreat to shelter during the day, lost color and began to drop spines, and became

easy prey for fish predators. Within a few days all the *Diadema* on that reef were dead. The disease spread rapidly from where it was first observed at the Caribbean end of the Panama Canal. Soon the entire Caribbean was affected and within a year the disease had spread rapidly through the Florida Keys and the Bahamas northward to Bermuda. It is estimated that 92 to 99.9 percent all the billions of *Diadema* sea urchins in this vast 1.35 million square miles of oceanic habitat died within 12 to 13 months.

It was first thought that if small numbers of *Diadema* were able to survive the plague, then, because of the enormous reproductive capacity of the species (a single female may produce 10 to 20 million eggs at one spawning), these populations would rapidly recover. This did not occur. Although there are encouraging signs of some *Diadema* population recovery in a few Caribbean areas, and some scattered clusters of *Diadema* urchins along the reefs of the Florida Keys, this species is present only in small numbers of individuals scattered widely among the reefs.

The reasons for the lack of resurgence of the *Diadema* are not specifically known, but there are a number of possibilities. Despite their great reproductive potential males and females must be quite close to each other, within a few feet, for fertilization to be successful. If the urchins are too far apart (which for the most part, they are), fertilization does not happen and of the millions and millions of eggs produced; only a few develop.

Predation from fish and various invertebrates on the juvenile sea urchins that do survive to settle is also very great. Massive numbers of juvenile urchins are needed just to maintain a normal population density of this species. Immense numbers of larval *Diadema* are just not present today. The lack of adequate numbers of larval *Diadema*, coupled with the intense predation on the few juveniles that do survive the larval stage, is apparently the major constraint preventing return of dense populations. The strong tendency for *Diadema* to occur primarily in dense aggregations indicates that some mechanisms, substrate preparation, late larval attraction, juvenile protection, and others, must function to create and maintain these dense clusters of adults.

Replacement of lost coral colonies with farmed coral fragments and juvenile corals is of critical importance to the rapid repair and expansion of the reefs. These farmed corals can and should be selected for environmental resiliency. **However, unless the underlying causes of coral reef decline are addressed and mitigated, the corals reintroduced to the reefs will be subject to the same negative conditions that created the decline of the reefs.** Replacement corals will have the best chance of survival if a population of *Diadema* sea urchins is also introduced and maintained on the reef as well. The *Diadema* will control algae and prevent overgrowth of the newly planted corals.

Without restoration of *Diadema* and proactive protection of many reef areas a great economic engine in South Florida, our coral reefs, will continue to degrade and decline. The tourist industry, the recreational dive industry, the boating industry, and recreational and commercial fishing industries, all these and more, depend in great measure on restoring and maintaining a healthy coral reef. The return of ecologically functional populations of *Diadema* to Florida waters may not occur for decades if ever, and by that

time there will be little left of the glorious coral reefs of the Florida Keys. It may be possible, however, to aid the return of these urchins to the reefs and to protect and restore certain of the most valuable reefs all along the great Florida reef tract.

Coral Reef Restoration

There are three categories of reef restoration efforts.

1. Specific site restoration after human impacts such as ship groundings, cable laying, anchor damage, frequent diver visitation, and storm impacts at vulnerable sites by debris such as wrecks and lobster traps. This type of damage covers a small area, usually physically impacts coral formations, and can be restored by individually repairing, replacing, and resettling dislocated corals, and in greatly impacted sites, by actually rebuilding the structure of the reef that was destroyed. This category of coral reef restoration is largely funded by fines imposed on grounded vessels and is well underway by FKNMS staff. The technology for site restoration is well developed.

2. Preventative restoration efforts on a regional scale. Such efforts include water quality improvement from on shore human activities, establishment of MPAs, control of ship traffic, control of at sea discharge from large vessels, prevention of oil and chemical spills and other controls on human activities that negatively impact coral reef organisms. Although recognized as producing great benefits to coral reef and general ecosystem health, efforts to repair and prevent negative environmental impacts from human activities are an indirect means of coral reef restoration and the results on the reefs are difficult to measure and evaluate.

3. Ecological restoration on specific sites and on a regional scale. This includes reestablishment and continued maintenance of a population of the keystone herbivore, the long-spined sea urchin, *Diadema antillarum*, general repair of storm damage when possible, outplanting of farmed coral fragments and juveniles where appropriate, and general ecological care of specific reef sites. Although it is not possible to directly restore the ecology of all the coral reefs in South Florida, it is possible, with enough human effort, to repair the ecology of specific reef sites all along the reef tract. And these ecologically maintained reefs will have a positive effect on surrounding reef areas through increased coral reef health at these sites, which will result in increased coral and *Diadema* spawning and increased survival of juvenile corals and *Diadema* at that location and possibly in surrounding areas.

A community based reef restoration program

Ecological restoration of the Florida reef track is an immense task. It will require many divers trained in ecological restoration techniques and a program developed and designed to train, guide, direct, and analyze the progress and results of the program. Although difficult, this is not impossible and it can be done perhaps most rapidly and cost effectively through a well directed community volunteer program. The great importance of a healthy coral reef ecosystem to the economy of South Florida and the immeasurable

value to the nation of this unique marine resource make a program of this nature of critical importance.

Any program of this type, of course, must be developed and conducted with the cooperation, direction, and under the auspices of the FKNMS and the State of Florida agencies. It will also require the science and central direction of marine laboratory facility and in the Keys, and the Mote Marine Laboratory is uniquely structured to house and direct such a program.

How would a reef restoration program be structured?

The core of the reef restoration program would depend on community involvement. An "Adopt a Reef" program could be established in near-by communities perhaps loosely patterned after the "Adopt a Highway" program. Community based organizations, either already established businesses, schools, and environmental and/or service organizations, or organizations established for this express purpose would be encouraged/solicited to appoint or recruit a "Reef Mentor", an individual that would be responsible for scientific and volunteer conduct of the restoration of the reef "deeded" to the organization for the restoration effort.

Program Director

The Reef Mentor program would have to be established and administered by a professional organization that would be able to secure grants to fund the program, train and direct the Reef Mentors and volunteer participants, collect, record, and analyze data and observations generated by the program, and publish the results of the program. The program director would be a full time employee of the umbrella organization. Depending on funding, a team of professional ecological restoration divers may work at the direction of the program director to monitor the activity and accomplishments of the volunteer efforts.

Reef Mentors

An individual with appropriate qualifications would fill the position of "Reef Mentor" for each selected reef site. Depending on the structure and funding of the program, the Reef Mentor may be a volunteer or may be compensated in various ways for his of her participation. A Reef Mentor may be retired, or represent a dive shop or community organization or simply an individual with a commitment to improve our coral reef ecosystem. The Reef Mentor would be responsible for all field work and data collection on the selected reef site. The Reef Mentors are the lynchpins of the program and the extent and success of the program will depend on the number and quality of Reef Mentors recruited for the restoration program. The program director will be responsible for the recruitment and supervision of the Reef Mentor.

Volunteers

Individuals volunteering as part of the Reef Mentor's team will be selected and supervised by the Reef Mentor. They may or may not be approved by the program director. The Reef Mentor will be responsible for the conduct and safety of the volunteers and will direct the efforts of the team. The volunteers may be long term, which would be best, or may be temporary volunteers. They will function at the direction and supervision of the Reef Mentor.

Reefs will be selected for the Reef Mentor restoration program based on established general criteria and Reef Mentor and/or Project Director recommendation. Program and reef site approval by FKNMS and FWC authorities will be an important part of the program.

Ecological restoration of specific reef areas

What can a team of 3 to 5 divers trained in ecological reef restoration do?

There are many tasks that a trained volunteer team can accomplish that will result in ecological restoration of small reef areas. The list below is just a beginning.

1. Selection of reefs that would most benefit from restoration. The reef area would be selected with regard to a number of factors, including: The presence of valuable coral formations, species, age, and extent of structure considered, location, proximity to home base of team members, placement with regard to other reef restoration areas, size of the reef area,) varying roughly from 50 to 200 square meters), depth (relatively shallow areas, 15 to 40 feet would be the broad range of depth), and general value to the ecology and economy of the area.

2. Record of observations (with photos) and a record of the activities on each reef will be kept by the Reef Mentor. These will be submitted at appropriate intervals to the Program Director. Forms for submittal of the recorded data will be devised, generated, and maintained by the Program Director.

3. Initially, a scaled map will be created of the selected reef area including the size and location of the major coral formations. Photos of the reef area and the major coral formation will be included.

4. The Reef Mentor under the general direction of the Program Director will create a photographic and descriptive account of the condition of the area at inception of the program and subsequently at periodic intervals. This will include periodic estimates of coral cover, algae cover, coralline algae cover, *Diadema* numbers, and sediment and rubble presence on the reef. Other descriptive measures such as reef rugosity may also be included.

5. A record of bleaching events and the short and long term effect of bleaching on specific coral formations, including photographic records of bleaching events will be submitted to the Program Director. In some instances, it may be possible to conduct

experimental mitigation of bleaching conditions on specific coral formations. Damage to the reef caused by storms and human visitation will also be documented.

6. One of the primary responsibilities of the Reef Mentor will be the establishment and maintenance of a *Diadema* population on the reef. The fate of the out planted *Diadema* will be closely followed by the Reef Mentor and maintenance of a specific density of *Diadema* will be a critical task of the reef keeping team. The source of the juvenile *Diadema* for the program will be the hatchery production of reef competent *Diadema* juveniles.

7. Initially, *Diadema* juveniles will not be able to quickly clean the reef of large algae growths that are impacting coral formations. One of the initial and continuing tasks of the reef keeping team will be the physical removal of macro algae that is impacting the coral formations. Once this has been done on the reef, continuing macro algae removal will not be a difficult task, and will no longer be necessary when *Diadema* populations are mature.

8. Coral disease is the major cause of the rapid loss of coral formations. The presence of macro algae may aid the development of coral disease and seems to prevent the renewal of coral tissue in areas destroyed by coral disease. There are techniques to remove diseased coral tissue and help prevent the spread of disease and destruction of coral tissue on large coral heads. A team trained in the physical removal of diseased coral tissue can visit the site frequently and monitor the occurrence and type of coral disease and physically remove the onset of coral disease. This can save many coral formations from death and destruction.

9. The loss of large numbers of mature spiny lobsters on the reefs (large lobsters are essentially ecologically extinct on Florida reefs, as are the *Diadema* urchins) These large lobsters in the numbers that they historically occurred on the reefs performed the important ecological function of controlling populations of coralivorous organisms, snails and other invertebrates, which destroy coral tissue and place the entire formation at risk through introduction of disease. An ecologically trained restoration dive team can identify the presence of these organisms and physically remove coral eating snails and other macro organisms that impact coral growth.

10. *Diadema* urchins also have many predators on the reefs. Historically, however, the vast reproductive capacity of this species (one female may produce between 10 and 20 million eggs per spawn) provided the great recruitment of juveniles needed to maintain their populations despite the great losses to predators. The ecological restoration team can physically remove *Diadema* predators when necessary and possible, thus making maintenance of urchin populations a bit easier.

11. All the reefs of the Keys are impacted by storms and careless divers. An ecological restoration team can care for corals after storms and other disturbances by uprighting turned corals, cleaning of sediments from coral tissue and replacing injured and lost corals with hatchery produce juveniles.

12. As an integral part of the ecological restoration efforts, a trained dive team can support and extend coral growth on the these reefs through establishment of healthy, farmed coral fragments on the reef area as necessary.

13. A very important of part of a volunteer effort such as this is the recognition and appreciation of the efforts of the volunteers. An annual meeting of all Reef Mentors and team members will be a time for reports on the accomplishments of the previous year, planning for future efforts, community recognition, and input from professional coral reef biologists.

What would be the results of such a program?

There are many expected results from a successful Reef Mentors program. They include, but are no means limited to the following.

1. Establishment and maintenance of numerous small areas of healthy reefs.

2. Establishment of reef areas where coral larvae can settle and grow. Currently many if not most reef areas are covered with algae and sediment and even if a large coral spawn occurs, there is limited success in settlement and establishment of new colonies. Even small areas of clean reefs will promote better coral survival.

3. Establishment of areas where coral colonies can remain healthy over time and spawn actively. A coral colony stressed from the results of algae competition and overgrowth, bleaching, global warming, disease, pollution, and predation will not spawn as successfully as a healthy formation. Maintenance of the best possible condition for a coral formation will greatly aid the production of coral larvae and juveniles along the Florida reef tract.

4. The presence of *Diadema* populations is essential to the ecological health of the reefs. Establishment of areas where *Diadema* can survive and form a nexus for spawning colonies will not only assure the health of the ecologically restored reef, but the successful spawning of the maintained *Diadema* populations will aid the return of this keystone herbivore to the entire Florida reef tract.

5. Eventually, as the program expands and more and more individual reef areas are restored with healthy coral growth and ecologically functional *Diadema* populations, it is expected that healthy reef areas will develop and expand along the entire reef tract as the increased survival and presence of coral juvenile corals and *Diadema* colonize new reef areas.

6. Although the residents and visitors of the Florida Keys are aware of the decline of our reefs and are greatly concerned and desperately want to do what is possible to reverse the this decline, there is little public knowledge and information on what can be done. This or

a similar program will serve to increase public awareness and active participation in coral reef restoration.

7. Publication and promotion of the program will draw attention to the coral reefs of the Keys, serve an important function as an education, outreach, and stewardship initiative, promote ecotourism diving through the opportunity to help in coral reef restoration and maintenance, and provide long term opportunities for scientific research and comparison between algae dominated and coral dominated coral reefs.

Of course implementation of such a program will require funding, direction, and commitment. I think it is important that scientists and managers at least consider the potential and possibilities of developing a carefully managed and directed volunteer program for ecological coral reef restoration. **The alternative is to continue to monitor and document the ecological decline of our coral reefs.**