GLOBAL CORAL REEF ALLIANCE
A non-profit organization for protection and sustainable management of coral reefs

Global Coral Reef Alliance, 37 Pleasant Street, Cambridge, MA 02139, USA
Telephone: 617-864-4226 617-864-0433
E-mail: goreau@bestweb.net Web site: http://www.globalcoral.org

TOURISM AND SUSTAINABLE CORAL REEFS

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GLOBAL CORAL REEF ALLIANCE WHITE PAPER

Thomas J. Goreau[abc*]
[a]President, Global Coral Reef Alliance, Cambridge, MA, USA
[b]Scientific Advisor, Yayasan Karang Lestari, Pemuteran, Bali, Indonesia
[c]Scientific Advisor, Gili Eco Trust, Gili Trawangan, Lombok, Indonesia
[*]Email: goreau@bestweb.net

ABSTRACT

Environmentally unsustainable tourism has been a major, although localized, contributor to coral reef destruction and degradation, severely impacting ecotourism quality, beach sand supplies, protection of coastlines from erosion, fisheries, and marine biodiversity. Nevertheless, hotels and dive shops could readily apply modern coral reef restoration methods to grow back reefs, providing high quality ecotourism in front of resorts, growing back sandy beaches naturally, restoring fisheries habitat, and preserving marine species from global warming extinction. A large-scale effort by the tourism industry is proposed to make tourism part of the solution, rather than part of the problem. National and international policies are needed to encourage this.

KEYWORDS

Tourism, ecotourism, coral reefs, environmental impacts, restoration, sewage, beach erosion, dredging, community-based management

INTRODUCTION: THE NATURE OF THE PROBLEM

All tropical coastal regions have staked their economic future on tourism, focused on warm, clear waters and white sand beaches. Every grain of sand on a white sand beach is a remnant of the limestone skeletons of coral reef organisms, and the growth of the beach is intimately dependent on healthy coral reefs in front of them. Nevertheless, tourism and coral reefs have been on a historical collision course, with coral reefs the invariable losers. Most tropical beach hotels have a

largely dead reef in front of them, so they have to take tourists hours by boat to see corals and fish, and they usually face social conflicts with local fishermen over these resources. That is because expanding coastal tourism has killed coral reefs through fossil fuel emissions, land clearance and erosion, dredging, anchors, trampling, and inadequately treated sewage.

The tourism development process typically begins with a beautiful forested site behind a white sand beach, with a healthy reef full of corals and fish in front of it. The developers cut down the vegetation for construction, later followed by planting ornamental vegetation. Soil is rapidly eroded from bare land in the rainy season, turning the water brown and killing corals by sedimentation. Often dredging takes place for landfill, construction of dock facilities, and to make boat channels. When diving tourism began in Bonaire there was a dense forest of fringing reef reaching to the water line, so hotels dynamited the reef to create swimming areas or channels so divers could get to deeper water. Now almost no trace of the original shallow coastal fringing reef remains. Dredging causes more turbidity, killing corals as far down-current as turbid sediment plumes are carried by extreme storm waves and currents. Destructive activities are typically ignored or downplayed by paid environmental consultants, who say that damage will only be “temporary”, and that coral reefs are “resilient” and will quickly recover (Sullivan-Sealey & Cushion, 2009).

Obvious physical damage to reefs from sedimentation is followed by an invisible, but far more insidious and long lasting threat: dissolved nitrogen and phosphorus from sewage released directly into coastal waters or indirectly into groundwater, where it soaks into the ocean. Coral reefs are the most nutrient-sensitive of ecosystems, being adapted to extremely nutrient poor waters, and the slightest traces of nitrogen and phosphorus trigger prolific blooms of weedy algae that smother and kill corals (Bell, 1992; Lapointe et al., 1993; Goreau & Thacker, 1994). Almost no place, with the exception of a tiny handful of resorts that voluntarily use advanced wastewater treatment systems followed by recycling sewage wastewaters on land, treats their sewage to a level adequate to protect coral reefs. The Turks and Caicos Islands are the only country in the world that require every resort to treat their sewage and recycle all their waste water on their own property as irrigation for ornamental plants and lawns, thereby absorbing the nutrients and preventing damage to the reefs.

The effectiveness of these methods is demonstrated in the only reef in the world known to have been overgrown by weedy algae that were permanently eliminated. The coral reefs of Dragon Bay in Jamaica were being smothered on one side by red algae, over-fertilized by nitrogen-rich sewage treatment plant effluents, while the other side was being smothered by green algae, over-fertilized by phosphorus-rich laundry detergents. The hotel eliminated both sources of nutrients by putting the laundry effluents into the sewage plant, removing the sewage pipe onto the reef, and using the treated waste waters for irrigation of the gardens and lawns. Within weeks the weedy algae killing the

corals began to die back, and two months later had vanished (Goreau, 2003). The site still remains free of weedy algae 13 years later, and endangered elkhorn corals are now growing back inside the bay (Edwards and Goreau, in preparation). There are no other sites in the world known where permanent elimination of weedy algae has taken place, although this approach is clearly replicable anywhere that ALL anthropogenic nutrient sources to coastal waters are diverted and absorbed on land. But this must be both complete and sustained. Kaneohe Bay reefs in Hawaii was smothered by weedy algae, recovered when the sewage effluents were diverted, and has once again become smothered with algae because population growth caused nutrients from uncontrollable “non-point sources” like golf courses, lawns, and road runoff that does not go into the sewer system. The Dragon Bay example is unusual because this bay had only a single polluter who had to change, but in most places there are many nutrient sources (Goreau, 2003). In Akumal, Quintana Roo, Mexico, all hotels have advanced biological wastewater treatment with plant uptake, but this has failed to eliminate weedy algae on the reef because communities on either side have not taken the same steps.

Tropical coastal tourism development is only rarely based on isolated hotels that can control all nutrient inputs. More commonly the success of the first hotel spawns a flock of imitators who move in next door, until the entire shoreline is covered with hotels. The result of this kind of massive strip development is that algae overgrowth of reefs expanded in concentric rings around the original nutrient point sources until these rings coalesce, and the individual nutrient sources are no longer visible. In Jamaica, this process took place across the island over a 40 year period, following local tourism development in every place (Goreau, 1992). Pollution from hotel sewage is vastly compounded by mass in-migration of people seeking jobs in hotels or tourism services, usually living in slums with minimal sewage treatment. Local inhabitants release sewage 365 days a year, while most tourists are only there from 1 to 2 weeks. So even if all hotels treat all their own sewage, the vast bulk of pollution, coming from local populations, remans untreated. This contributed to the demise of the reefs in Negril, Jamaica, where the sewage collection system only collected from the hotels and villas on the shore, leaving sources from the vast bulk of local inhabitants untreated, and where the sewage treatment was inadequate to remove the nutrients (Goreau, 1992; Lapointe & Thacker, 2002). The resulting death of corals from algae overgrowth has removed most of the shore protection that the growing reef used to provide, causing severe beach erosion, just as had been predicted (Goreau, 1992).

Finally, the reefs are impacted by physical impacts of anchors, snorkelers, and divers. Most work on human impact on reefs has focused on diver damage, and sought to determine the “carrying capacity” of divers. But by and large, diver damage is minor in comparison to other sources of damage to reefs, and takes place after the worst damage has already been done. Tourism damages are highly localized in reef areas in front of and down-current from resorts, where it

can be the major cause of reef destruction, but overall on a global scale these damages are small compared to those caused by global warming, new coral diseases, sewage releases from cities, and massive erosion from land deforested for agriculture. But the existence of these other sources of damage do not absolve the tourism industry from doing all it can to mitigate the damage it has caused. The practical result: most hotels that used to have good snorkeling reef right in front of their beach must now take guests hours by boat to decent snorkeling sites where they can see a few corals and fishes, and their beaches are washing away, requiring costly seawalls, groynes, and sand pumping and dredging to replace. Yet few in the tourism industry seem to realize that their damaged coral reefs can be quickly restored.

METHODS

Most methods of coral reef restoration rely on attaching corals with cement or glue to hard structures. These techniques only work well in areas of excellent water quality, and wherever the water has become too polluted or too hot, the corals invariably die. Only one method is known that greatly accelerates coral growth and resistance to high temperatures and poor water quality.

Biorock® Technology uses safe low voltage direct current applied to steel frameworks to grow limestone structures of any size or shape in the sea (Hilbertz, 1979; Hilbertz & Goreau, 1998). The steel is completely protected from rusting, and Biorock is the only marine construction material that gets stronger with age, while all others deteriorate. Biorock materials are self-repairing: damaged areas grow back preferentially. Power can be supplied by solar panels, windmills, tidal current turbines, wave generators, or land-based transformers.

Corals and other marine organisms on Biorock typically grow 2-6 times faster than normal, and have 16-50 times higher survival after severe high temperature episodes. Rates of spontaneous colonization of Biorock structures by corals, attached marine organisms, and fishes are extraordinarily high. As a result Biorock technology can be used to keep coral reefs alive when they would die, and restore coral reefs in a few years where little or no natural recovery is taking place (Goreau & Hilbertz, 2005, 2007, 2008). Biorock coral reefs, by absorbing wave energy, cause waves reaching the shore to deposit sand instead of washing it away. They turned a severely eroding beach in front of a resort in the Maldives that was desperately piling sandbags to prevent buildings falling into the sea, into 15 meters (50 feet) of beach growth in a few years, which survived intact the tsunami that swept over the island (Goreau, Hilbertz and Hakeem, 2004).

RESULTS

Hundreds of Biorock projects have been built in the last 20 years in more than 20 countries across the Caribbean, Pacific, Indian Ocean, and South East Asia.

Coral reefs covered with bright corals and swarming with fish are quickly grown in front of beaches (www.globalcoral.org), and have turned severely eroding beaches into growing ones in a few years (Goreau, Hilbertz, & Hakeem, 2004). Tourists come from all over the world to see them, come back again and again to watch their evolution, and tell their friends. Besides their ecotourism value, these projects also play a crucial roles for saving coral reefs from global warming and coastlines from global sea level rise and increasing storm strength, while restoring fisheries, maintaining biodiversity, and educating the public about the need for environmental restoration.

Indonesia is the world's leader in coral reef restoration, with the Karang Lestari ("Protected Coral" in Indonesian) Project in Pemuteran, northwest Bali, and the Gili Trawangan reef restoration projects in northwest Lombok, which are thought to be the two largest coral reef restoration projects in the world. Some examples of the tourism benefits of such projects are described below.

1. Pemuteran, located near the furthest point on Bali from the mass-market tourist resorts of the south, specializes in "green" ecotourism. Low rise, low density resorts surrounded by lush gardens in a beautiful and remote setting attract people who seek peaceful surroundings far from the hustle and bustle of the major resort areas. Formerly one of the poorest parts of the island, the area is too dry for traditional Balinese rice agriculture, so the people were forced to live from the sea, exploiting some of the richest reefs in Bali. These reefs attracted divers, and the area was fortunate to be developed from the start in an environmentally conscious way, reflecting traditional Balinese Hindu concepts of harmony with nature. The development of tourism provided new jobs and income, transforming the standard of living of the community.

All hotels and dive shops in Pemuteran contribute a percentage of their earnings to an environmental and development fund administered by the village government. This has been used to restore temples, upgrade school facilities, and develop a village environmental management plan. The village used traditional law to establish their own marine protected areas in front of the beaches. Enforcement of village laws against use of bombs and cyanide are enforced by the Pecalang Laut, or "sea guardians", a village police force that monitors and enforces village marine protected areas and bans on unsustainable fishery practices. Violators are first warned, and if they persist their boats and all their gear are seized, they are arrested, and the Indonesian police prosecute them. Because traditional Balinese village law is respected by national law enforcement agencies, villagers were able to declare their own marine protected areas without requiring any permission from central government authorities. Unfortunately such purely local initiatives are now rarely possible in most places outside of Bali and the more traditional islands of Melanesia.

Despite these progressive steps, the coral reefs were very badly damaged in 1998, when high temperatures killed around half the corals, and when the South

East Asian economic crisis forced displaced workers and farmers to the sea, causing mass destruction of fishery habitat. Corals on the outer bank reefs of Pemuteran, the major fishing grounds, were almost entirely destroyed by bombers, most coming from other islands, and diving became unsafe because of the risk of injury from shock waves due to bomb fishing blasts.

Realizing that their food supply and income from tourism were threatened, Pemuteran began to fully enforce their laws against destructive fishing, and began large-scale Biorock reef restoration efforts in 2000. These have become the largest in the world, with around 60 separate Biorock reefs and a total length of around half a kilometer. These have been supported purely by locally raised funds, and transformed formerly barren areas into spectacular coral gardens full of fish right in front of the beach (photographs and articles about these projects are at www.globalcoral.org). A recent survey showed that 40% of tourists visiting Pemuteran were aware of the Karang Lestari project and came from around the world to snorkel and dive on it (Jamison, 2009, to be submitted to the Journal of Sustainable Tourism). The villagers are very proud of the many national and international awards that this project has received. Fishermen, seeing the large numbers of fish in the protected restoration projects, have requested similar projects to restore fisheries habitat in the devastated outer bank reefs (Goreau, in press).

Pemuteran has established several unique local programs to ensure sustainability of their coral reef based ecotourism and fisheries. A Biorock Centre has been set up on the beach (Figure 1), from which village employees monitor and maintain the Karang Lestari reef restoration projects, and provide educational materials and information to visitors. Their dedicated efforts have made this the best managed Biorock project in the world. They are partly supported by a voluntary program by which dive shops sell diver tags whose proceeds support village environmental programs, and by voluntary coral sponsorship programs in which tourists pay a small fee to have a coral grown with their name growing in Biorock limestone next to it, and get periodic photographs of their coral (Figures 2 and 3). These can be enjoyed by divers, snorkelers, and by glass bottom boat (Figure 4).

Another unique program is the Reef Gardeners Program. Employment in the tourism sector requires education and speaking ability in English, the international language of tourism, marginalizing those who lack the educational and language skills needed. The village set up training programs for youths, teaching them diving, English, and basic business skills, and hiring them to manage the village's coral reef resources. Based in the Reef Gardener's Centre, up the beach from the Biorock Centre, the Reef Gardeners have planted Vetiver grass to stabilize the beach and riverbanks from erosion in front of their headquarters (Figure 5). The Reef Gardeners rescue and transplant naturally broken corals, and remove starfish and snail pests that eat corals and damage the reefs. They have built an underwater sculpture diving trail, inspired by

Balinese temple garden, and made several Biorock reefs on offshore banks, shaped like boats or giant turtles, powered by solar panels on a raft that they maintain. Tourists diving on these pay a small fee to help support the program. The Reef Gardeners are highly motivated and proud of making their village reefs a more productive place.

2. Gili Trawangan, Gili Meno, and Gili Air are small low-lying islands off the north west of Lombok. Because they are basically coral limestone islands isolated from the main volcanic island by deep water, the waters are clear and free of sediment, so they were entirely surrounded by luxuriant coral reefs. As they were too dry for agriculture, the local villagers lived from subsistence fishing, until the magnificent coral reefs made them an international attraction for divers. The local community has essentially stopped fishing because preserving fish for tourism is more economically rewarding, generating jobs and income for local families. However, before this consensus was taken by the community, their reefs had been heavily damaged by fishermen using bombs and cyanide. Waves from a remote typhoon destroyed vast fields of fragile lettuce corals, which have barely recovered. In 1998 the surviving corals suffered catastrophic mass mortality from high temperatures, with the result that there were few corals and fish to see in a place whose economy had come to depend almost entirely on diving tourism.

The Gili Islands carefully manage tourism to ensure maximum creation of local jobs. For example, there are no motor vehicles on the islands, not even motorcycles. All transportation is by foot, bicycle, and local horse carts. The community balances Muslim traditions with friendly and tolerant acceptance of tourists, most of whom are young backpackers there to dive and party, a very different clientele than the families who vacation in Pemuteran. Because of concerns that the coral reefs were not properly protected, the community and the local tourism industry formed the Gili Eco Trust (GET) with the specific aim of protecting and restoring the coral reefs. GET visited Pemuteran, and asked for training in Biorock reef restoration methods. Two major Biorock training workshops have been held there, in which nearly 40 Biorock reefs were built on all three islands. Almost every dive shop has one or more projects in front of them, and 15 pilot Biorock shore protection structures have been built, which have already locally halted beach erosion on these low lying and vulnerable islands. These projects have been spectacular successes, converting areas of barren coral rubble and sand into lush coral gardens swarming with fish (url). Coral growth rates up to six times faster than controls have been recorded.

3. Besides these larger projects, which serve as a model for community-based ecotourism restoration and management, there are many smaller Biorock projects around Indonesia. Six Indonesian Biorock Training Workshops have been held, providing intensive training and certification in theory, design, and hands-on construction, monitoring, maintenance, and repair. Hundreds of people have been trained, the majority being Indonesian students who are eager to use

their knowledge and skills in restoring their country's coral reefs, the largest and richest in the world (but around 95% destroyed, damaged, or degraded). Many Indonesian and international students have done scientific research projects on Biorock. Biorock students have set up projects in North, South, West, and East Sulawesi, Java, Flores, and Sumbawa. Biorock projects have been built in more than 20 countries in Southeast Asia, the Caribbean, the Pacific, and the Indian Ocean, and won many prestigious global and national environmental and ecotourism awards. There is constant demand for new projects all over the world, most of them focused on ecotourism or for naturally protecting and growing back eroding beaches.

Biorock reefs use entirely different physical principles to absorb, not reflect, wave energy, so waves reach the shore with less energy and deposit sand instead of washing it away. Hotels around the world are starting to realize that conventional methods of shore protection using concrete or rock walls only increase erosion in front of them, and wave focusing by reflection causes these structures to be ultimately scoured out underneath, collapsing, and needing to be rebuilt again and again. Florida, Cancun, and Negril have severe beach erosion and have spent fortunes pumping sand onto their beaches, only to watch the sand wash away and kill the remaining corals that had formerly built and protected their beaches. Many hotels are starting to recognize that Biorock reefs cost far less than concrete breakwaters and provide vastly greater ecotourism, fisheries, and sand building benefits, and are asking for projects using the new technology as the most cost-effective and beneficial solution to their beach erosion problems, which are rapidly increasing as global sea level rise accelerates.

DISCUSSION: THE NATURE OF THE SOLUTION

Tourism is often in social conflict with traditional fishermen over access to marine resources. In many places fishermen have been displaced from their traditional beaches. The diving industry and the fishermen are competing for the same fish. While tourists seeing fish can in effect "buy" the visual value of the same fish many times over, with much greater net benefits than would be realized by killing and selling the fish, the revenues accrue to different sectors of society, and rarely benefit local fishermen since dive shop operators and dive masters are often foreigners or from metropolitan elites. Since the sea is open access to all, in many tourist areas divers complain of the lack of fish to see. Dive masters who beg local fishermen not to kill the fish are often physically threatened as greedy outsiders stealing food from poor locals. Fishermen are usually the first to notice that environmental degradation from pollution and physical damage caused by tourism development is a major factor in fisheries collapse, but they are often outraged that their overfishing is blamed instead.

This progressive environmental deterioration can be turned around if hotels restore local environmental quality in a way that benefits their own ecotourism while it increases fish habitat, and therefore fish populations on a larger scale.

Fishermen can be convinced that protecting restoration projects in front of hotels from fishing will benefit them if they can see increases in fish populations in surrounding fishing areas. This will not happen by simply declaring protected areas where the habitat is already too damaged to serve as fish sanctuaries: active restoration of already degraded areas will be needed. To do so hotels must gain the confidence of traditional resource users by building collaborative coastal management efforts that genuinely benefit all sectors simultaneously by increasing the total quantity of corals and fish, rather than marking off the few areas left in good condition and making them inaccessible to other users.

Many environmentally conscious hotels do an excellent job of "green management" by reducing their own environmental footprint through appropriate sewage treatment and through active outreach to local communities, for example by arranging garbage recycling programs to reduce floating plastics in front of their own beaches, but they are a small minority. Such steps add real costs to their operations that their competitors do not have to bear, and are only engaged in by those who feel it is the right thing to do, regardless of the price they pay. This largely restricts such programs to high-end resorts with managers of exceptional environmental awareness and a strong ethos of social responsibility. Others who might like to do so feel they cannot afford to. As long as restoration is a purely voluntary activity, most hotels will not follow through with more than symbolic steps. For example, resorts whose dredging and large scale clearing of forests and mangroves for construction, golf courses, and marinas has killed reefs may cement a few corals on concrete and then quickly claim they have restored a fraction of what they destroyed (Sullivan-Sealey & Cushion, 2009) before the corals die from poor water quality, but this does not come close to compensating for what they have killed.

There is increasing pressure on hotels from "green certification" programs, especially from the large European tour booking agencies, but this tends to promote minimum necessary compliance efforts, and to date has had little or no impact on the marine environment. Hotels that spend millions of dollars on ornamental landscaping are generally unwilling to invest in seascaping. Most feel that they do not "own" the foreshore in front of their beaches and that providing marine attractions for their guests is not their responsibility, and should happen "naturally" with no effort on their part. This has been justified by politically motivated claims that coral reefs are "resilient" ecosystems that will spontaneously bounce back from any damage, even though all experienced coral reef observers know this does not happen.

That is why systematic policies are needed from governments, the World Tourism Organization (WTO), and national tourism agencies that mandate, not merely encourage, all of the tourism industry to play a constructive role. WTO has commissioned an excellent study on the impacts of global climate change on tourism, pointing out that tropical coral reef tourism and the ski industry have already felt serious impacts from global warming, making many areas no longer

viable for tourism (WTO, 2007). WTO pointed out the need to control greenhouse gas buildup in the atmosphere to avoid further economic impact to vulnerable components of the tourism industry. But they have not yet backed environmental restoration linked to tropical tourism as part of the solution. Formal policy steps on their part are needed to this end.

CONCLUSIONS

Tropical beach hotels can play a critical role in coastal management if they grew Biorock reefs, creating novel ecotourism opportunities right in front of their beaches, protecting their beaches from erosion, while increasing biodiversity, preserving reefs from global warming, and replenishing fish stocks for neighboring communities. Shorefront hotels should be encouraged, even mandated, to practice seascaping the same way they use landscaping to enhance the beauty and quality of their property. By promoting large-scale coral reef restoration in front of hotels, the tourism industry can be transformed from part of the problem into playing a leading role in the solution, and encouraging local communities to take similar steps. Hotels, national tourism agencies, and the World Tourism Organization should promote tourism as a contributor to large-scale environmental restoration with impacts that extend way beyond the hotels themselves. Hotels doing so will attract higher quality guests who want to stay in "green" resorts and are willing to pay extra to stay in places that are restoring nature. If each hotel were as proud of the coral gardens in front of their beach as the flower gardens behind them, they could be leaders promoting sustainable coral reefs and marine resources.

REFERENCES

P. Bell, 1992, Eutrophication and coral reefs: some examples in the Great Barrier Reef lagoon, Water Research, 26: 553-568

F. Chan, 1992, Coral reefs: Ecology and economics of ecosystem conservation, 203 p., Thesis, Hampshire College, Amherst, Massachusetts

T. Edwards & T. J. Goreau, in preparation, Coral reefs of Eastern Portland: current status and management recommendations, National Environment and Planning Agency, Kingston, Jamaica

T. J. Goreau, 1992, Bleaching and reef community change in Jamaica: 1951-1991, Symposium on Long Term Dynamics of Coral Reefs, American Zoologist, 32: 683-695

T. J. Goreau, 1992, Negril: Environmental threats and recommended actions, P. 9-37 in K. Thacker (Ed.), Protecting Jamaica's Coral Reefs: Water Quality Issues, Negril, Jamaica, http://globalcoral.org/Negril%20Environmental%20Threats%20and%20Recomme

nded%20Actions.htm

T. J. Goreau, 2003, Waste nutrients: Impacts on coral reefs and fisheries and abatement via land recycling, 28 p., United Nations Expert Meeting on Waste Management in Small Island Developing States, Havana, Cuba, http://globalcoral.org/WASTE%20NUTRIENTS%20IMPACTS%20ON%20COASTAL%20CORAL%20REEFS.pdf , http://www.sidsnet.org/workshop/experts_meetings.html http://www.sidsnet.org/docshare/other/20040310124457_case_study_by_Thomas_J_Goreau_on_waste_mgmt_2003.pdf

T. J. Goreau, 2006, Tourism, water quality, and coral reef health, http://www.biorock-thailand.com/tourismwaterquality512.html

T. J. Goreau, in press, Coral reef and fisheries habitat restoration in the Coral Triangle: The key to sustainable coral reef management, Invited Keynote Talk, World Ocean Congress, Manado, Sulawesi, Indonesia http://www.globalcoral.org/Coral%20Reef%20and%20Fisheries%20Habitat%20Restoration%20in%20the%20Coral%20Triangle.htm

T. J. Goreau & W. Hilbertz, 2005, Marine ecosystem restoration: costs and benefits for coral reefs, World Resource Review, 17: 375-409 http://globalcoral.org/WRR%20Goreau%20&%20Hilbertz%202005.pdf

T. J. Goreau and W. Hilbertz, 2007, REEF RESTORATION AS A FISHERIES MANAGEMENT TOOL, in Fisheries and Aquaculture, Ed. Patrick Safran, in ***Encyclopedia of Life Support Systems (EOLSS)***, Developed under the Auspices of the UNESCO, EOLSS Publishers, Oxford ,UK, [http://www.eolss.net] http://globalcoral.org/Reef%20Restoration%20as%20a%20Fisheries%20Management%20Tool.htm

T. J. Goreau & W. Hilbertz, 2008, Bottom-up community-based coral reef and fisheries restoration in Indonesia, Panama, and Palau, p. 143-159 in R. France (Ed.) Handbook Of Regenerative Landscape Design, CRC Press, Boca Raton http://globalcoral.org/Handbook%20of%20Regenerative%20Landscape%20Design.5.pdf

T. J. Goreau, W. Hilbertz, and A. Azeez A. Hakeem, 2004, Maldives shorelines, growing a beach http://globalcoral.org/MALDIVES%20SHORELINES.%20GROWING%20A%20BEACH.htm

T. J. Goreau & K. Thacker, 1994, Coral reefs, sewage, and water quality standards, Proceedings 3d Caribbean Water and Wastewater Association Conference, 3: 98-116, Kingston, Jamaica, http://globalcoral.org/CORAL%20REEFS.%20SEWAGE,%20AND%20WATER%

20QUALITY%20STANDARDS.htm

T. J. Goreau, T. J., L. Daley, S. Ciappara, J. Brown, S. Bourke, & K. Thacker, 1997, Community-based whole-watershed and coastal zone management in Jamaica, Proceedings 8th International Coral Reef Symposium, 2: 2093-2096, Panama http://globalcoral.org/Community-Based%20Whole-Watershed.htm

W. H. Hilbertz, 1979, Electrodeposition of Minerals in Sea Water: Experiments and Applications, IEEE Journal on Oceanic Engineering, Vol. OE-4, No.3, 19p. http://globalcoral.org/electrodeposition_of_minerals_in.htm

W. Hilbertz & T. J. Goreau, 1998, Third generation artificial reefs, Ocean Realm, Summer Issue, 45-48

N. Jamison, 2009, The role of Biorock artificial coral reefs in the sustainable governance of marine protected areas: A case study of Pemuteran, Bali, 60 p., M.Sc Thesis, Sustainability and Management Programme, Department of Geography, Royal Holloway College, University of London

B. E. Lapointe, M. M. Littler, & D. S. Littler, 1993, Modification of benthic community structure by natural eutrophication: The Belize barrier reef, Proceedings of the 7th International Coral Reef Symposium, 1: 323-334, Guam

B. Lapointe & K. Thacker, 2002, Community-based water quality and coral reef monitoring in the Negril Marine Park, Jamaica: Land-based nutrient inputs and their ecological consequences, p. 939-963 in J. W. Porter & K. G. Porter (Eds.) The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook, CRC Press, Boca Raton

K. Sullivan-Sealey & N. Cushion, 2009, Efforts, resources and costs required for long term environmental management of a resort development: the case of Baker's Bay Golf and Ocean Club, the Bahamas, Journal of Sustainable Tourism, 17: 375-395

World Tourism Organization, 2007, Climate change and tourism: Responding to global challenges, 24 p., http://www.unwto.org/climate/support/en/support.php

More information, including photographs, reports, and articles can be found at www.globalcoral.org

FIGURE 1.
The Biorock Centre and Staff in Pemuteran, Bali. Photograph by Rani Morrow-Wuigk.

FIGURE 2.
A sponsored coral growing with the name of the donor also growing in limestone. I Gede Ardika is the former Indonesian Minister of Tourism. Photograph by Rani Morrow-Wuigk.

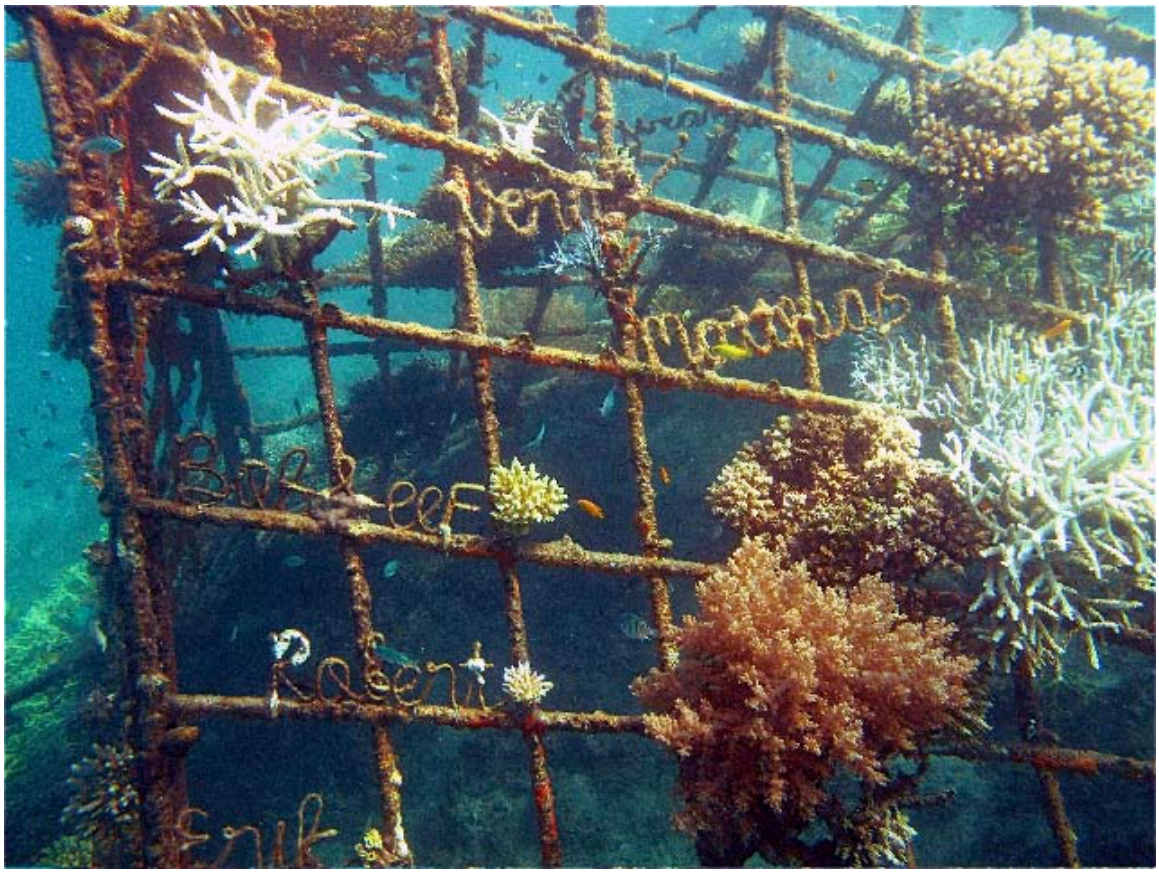

FIGURE 3.
Sponsored corals on the Karang Lestari project, with donor's names growing in limestone. Photograph by Rani Morrow-Wuigk.

FIGURE 4.
Village leaders enjoy the Karang Lestari project from a glass bottom boat. Local education programs are bringing in local school children who don't swim so they can see the projects and learn about the importance of reefs to their community. Photograph by Rani Morrow-Wuigk.

FIGURE 5.
The Reef Gardener's Office and Staff in Pemuteran, Bali. Notice Vetiver and goat's foot vine they have planted in front to reduce beach erosion. Photograph by Rani Morrow-Wuigk.

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NOTES ON CONTRIBUTOR

Dr. Thomas Goreau, President of the Global Coral Reef Alliance, has dived on reefs around the world for more than 50 years. He worked with the late Prof. Wolf Hilbertz in pioneering Biorock reef restoration technology since the mid 1980s. Educated in Jamaican schools, he holds degrees from MIT, Caltech, and Harvard, and was previously Senior Scientific Affairs Officer at the United Nations Centre for Science and Technology for Development in charge of global

climate change and biodiversity issues. His work focuses on coral reef and fisheries restoration to adapt to global warming and sea level rise.