GLOBAL CORAL REEF ALLIANCE

A non-profit organization for protection and sustainable management of coral reefs

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INDIGENOUS/ENDOGENOUS SEA PEOPLES: CLIMATE CHANGE ADAPTATION AND ENVIRONMENTAL REGENERATION

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ABSTRACT

Indigenous and Endogenous subsistence Sea Peoples are suffering deeply from loss of traditional coastal resources due to global climate change and pollution that they did not cause, as well as from exploitation by outsiders, and need to develop strategies to regenerate their coastal resources before they lose them. Global climate change impacts on local community marine resources of 22 different coastal fishing communities around the world, and the range of their responses to new environmental challenges to their survival, are analyzed, based on long-term first-hand involvement with local marine ecosystem regeneration needs of each group, and evaluating possibilities of locally managed Biorock technology solutions to resolve them. Most communities have basically four alternatives: extinction, assimilation, forced migration from their lands, or ecosystem regeneration using state of the art methods. Of these options, ecosystem regeneration with Biorock can help preserve their marine cultures, biodiversity, biomass, and ecosystem services, and provide a disproportionately large contribution to reverse global climate change. Each of these groups faces declining natural resources for different reasons but each can learn new methods to regenerate their marine ecosystems, and the planet's climate, if the will, funding, and training can be found in time to avert their collapse.

INTRODUCTION

Indigenous peoples have lived from their natural resources around the world since the dawn of humanity, have "managed" them with varying effectiveness, are guardians of most of the world's cultural traditions (Witzel, 2012) and protect a major part of the world's biomass, biodiversity, and ecosystem functions that are immediately threatened by habitat destruction from "development" and global climate change (Ereira, 1990; Colchester, 1994). A third of the remaining carbon in biomass and peat that must be left undisturbed if Earth is not to warm irreversibly are in Indigenous Lands (Noon et al., 2021).

By Indigenous Sea People we mean the historically oldest surviving human coastal communities, the "Original" or "First People" (also sometimes confusingly called the "Fourth World", an afterthought indicating their sub-3d World status). The same problems are also happening to the marine resources of traditional subsistence coastal fishing communities of ALL origins, who have past histories of migration from elsewhere but who have adapted to their new homes for so long they personally, historically, and mythologically remember no other. Here we refer to them as Endogenous Sea People, mostly marginalized subsistence fishers. Note that the Endogenous group as defined here includes neither recent greedy invaders taking all they possibly can steal, nor waves of needy refugees forced from their own homes and taking all they must in order to survive, nor the subsidized industrial open ocean fishing fleets employed to fish for money, not their own community's food.

Indigenous people, historically threatened with cultural if not physical extermination by their own governments, are now the first and worst victims of climate change they did not cause and are powerless to prevent, except by saving Nature. Their lands, waters, and resources are being stolen and their ancient cultures destroyed for fast but ephemeral profit by more powerful invaders or by waves of foreign immigrants, both lacking historic roots in local ecosystems. Outsider groups with no sustained tradition of local marine resource use severely overharvest essential renewable resources, driving them to local extinction. Those grabbing all they can as fast as possible have caused world-wide environmental problems, which are now inflicted on those who have had to live in balance with nature to survive since the dawn of time.

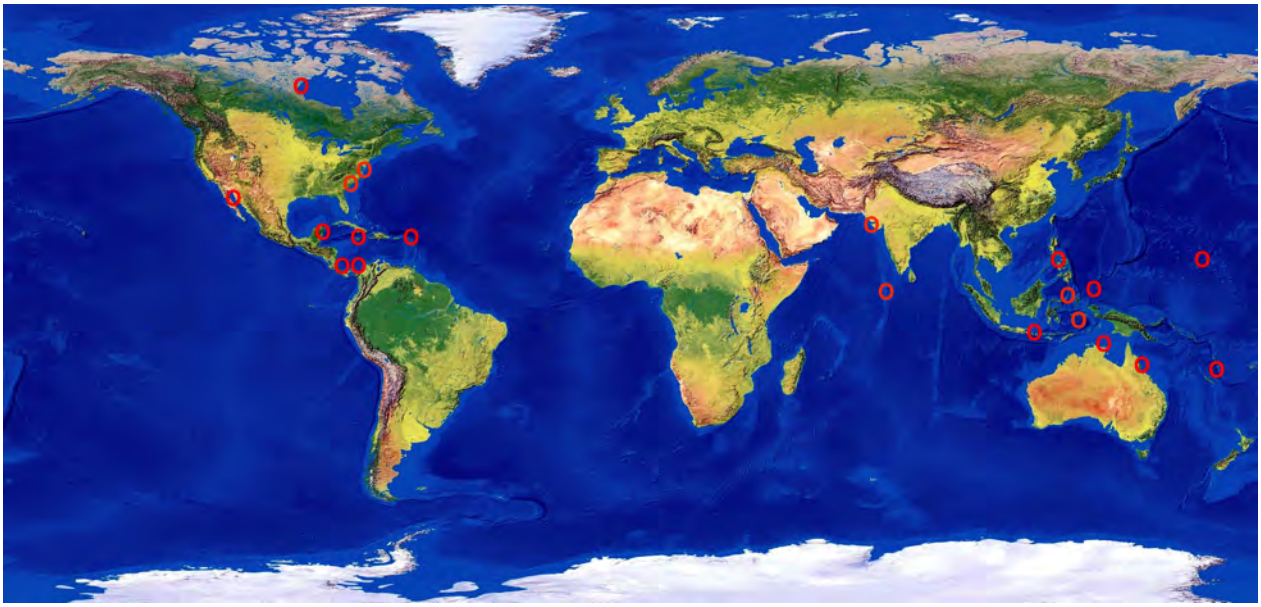
Indigenous people are almost everywhere viewed by their own governments as threats to political sovereignty, and are last to receive financial aid for climate adaptation, if any. These marginalized communities are the first victims of resource destruction, but are usually blamed by outsiders because they lack the political and economic connections of those destroying the resources. For example, 98.9% of land in the USA that was legally deeded by Treaty to Indigenous People was later stolen based on claims that they did not know how to use it (Farrell et al., 2021). Brazil's Bolsonaro still says the Amazon Jungle must be cut down for outsiders' profit because the "natives" don't manage it properly by maintaining the permanent source of their livelihood instead of destroying it for cash that rapidly vanishes!

Many countries hope to get carbon credits by taking control of forested lands away from Indigenous communities through proposed global carbon credit trading schemes. Because Indigenous People largely live in the most remote, wild, high-biomass, and high-

biodiversity habitats, empowering Indigenous cultures to regenerate their biomass, biodiversity, ecosystem services, and nutrient recycling is the most effective path for preserving prime habitat to reverse global climate change. There is an especially critical need for funding for Indigenous & Endogenous Sea People training to restore endangered coastal ecosystems around the world as the most cost-effective way to reverse climate change by storing Blue Carbon, and maintain endangered cultures and ecosystems against accelerating threats of global cultural homogenization and loss of crucial habitats from climate change. Coastal peoples were the first to impacted by outsiders, and their ecosystems are the most damaged, most of the world's coral reefs, mangroves, sea grass, and salt marsh have now been destroyed or severely degraded through degradative mismanagement by those who conquered them. Much of what survives is on Indigenous Lands.

The Global Coral Reef Alliance (GCRA), a non-profit research organization focusing on innovative methods of ecosystem regeneration to reverse climate change, places top priority on working closely with Indigenous and Endogenous Sea People cultures around the world, especially those living near coral reefs. We help them access state-of-the-art methods for restoring their own local species and ecosystem services, empowering them to adapt to global climate change on their own cultural terms, while preserving and adapting their ancient experience-derived knowledge. GCRA works for little or no money but expenses to help Sea Peoples acquire the best methods to restore and defend their lands, waters, and cultures. Working with marginalized Indigenous and Endogenous cultures is more rewarding to us than helping rich countries who could afford climate change adaptation measures if they chose to.

Subsistence fishing communities are among the poorest of the poor everywhere, and have been repeatedly displaced from their ancestral fishing grounds in the name of "economic development" whose financial rewards flow to outside investors, while degrading or destroying marine resources local fishermen rely on to survive. This chapter describes specific global climate change effects on 22 traditional Sea Peoples that the author (TG) has worked with. While far from complete or scholarly, they are based on personal experience, mostly over decades or generations. They include a wide range of marginalized Indigenous and Endogenous cultures spanning three oceans and three continents, from Equatorial to Polar habitats, and focus largely on regenerating coral reef and coastal ecosystems and fisheries habitat.



Locations of Sea Peoples discussed in this article. Some symbols represent 2 nearby islands. They range over a wide range of habitats, mostly coral reefs, in three oceans and three continents.

CASE HISTORIES

JAMAICA

When Columbus first found Jamaica, his ships were out of water, having barely survived hurricanes near Cuba, and he was desperate to find a river or spring to fill their barrels. He sailed into a perfect bay, but the coral reef that grew across the mouth nearly to the surface almost ripped the bottom of his boats out. To his disgust there was no river and they could find no water at all, not knowing that here the rivers ran in caves underground, and they had another terrifying crossing of the reef on the way out. Columbus called it Puerto Seco (Dry Harbour), but Jamaicans know it as Discovery Bay. He not only missed the subsurface freshwater springs the author (TG) swam in as a child, he missed the ancient sea level caves which are the world's best record of the sensitivity of global sea level and temperature to carbon dioxide. These should be the first UNESCO World Heritage Site for Global Climate Change, but despite its National Protected status, the Jamaican Government has issued a permit for this unique natural masterpiece to be dynamited and exported as white powder, a crime against nature and future generations in Jamaica and around the world.

Columbus finally found a river in the next bay, which he called Rio Bueno (Good River), where he filled his barrels. There he found a large town of Taino, the Indigenous Jamaicans, who had the largest boats, carved out of huge logs of silk cotton trees (*Ceiba pentandra*), and the finest cotton cloth he had seen. After filling his water barrels, he tortured and killed Taino demanding gold they did not have, which he was certain they were hiding from him with the help of the devil. Despite lack of gold, Columbus was so enchanted with Jamaica's lush beauty, "the fairest isle eyes ever saw", he insisted the King of Spain give it to him as his personal property. Sadly, Jamaica's once incredible coral reefs that terrified Columbus are now the classic case history of reef degradation (Goreau,

1992).

The Indigenous inhabitants of Jamaica, the Taino or Arawak (Columbus called them Indians, landing on the wrong continent after being lost at sea), had migrated from Amazonia thousands of years before. Their fishery was based on vast populations of Caribbean Monk Seals (Europeans over-hunted them to extinction, the last one was seen in 1918 on Jamaica's Pedro Bank), turtles (now nearly extinct, following European over-harvesting), and fishes (now so depleted by habitat loss of coral reefs they can't reproduce locally and are dependent on larvae carried in by currents from Cuba). The major Indigenous towns were near the sea, where they caught fishes with nets, traps, and lines made from fine local cotton, using dugout canoes made from fire-hollowed entire Silk Cotton trees (*Ceiba pentandra*).

The Taino people were driven to extinction by Spanish diseases brought by Columbus and they killed themselves with poison rather than be enslaved. But before they vanished, they taught their fisheries methods to Portuguese Jews fleeing the Inquisition, who settled Jamaica in Spanish times, who in turn passed them on to Africans brought by English to work on sugar plantations. After the English seized Jamaica in 1655 Indigenous fishing methods remained unchanged for 300 years, yet they had little impact on the abundant fisheries. The first descriptions of Jamaican natural history (Sloane, 1687) by Sir Hans Sloane, founder of the British Museum, mentions the largest Caribbean Grouper, the Jewfish (*Epinephelus itajara*), so called because it was the most common food fish and widely eaten by the Jamaican Jewish population. This predatory grouper was the focus of Jamaican fisheries for over 300 years, but was hard to catch because it lives at the bottom of the reef and if the grouper is not hungry, it won't take the bait, so enough survived that their populations were not depleted.

TG spent the first20 years of his life diving all around Jamaica with his father (the world's first diving marine scientist) and his brothers, the last to remember how magnificent the reefs were, and is curator of the world's largest collection of underwater reef photographs from the 1940s, 1950s, and 1960s. These were mostly taken by his grandfather (inventor of macro close-up photography, who took the first high quality underwater photographs in the Bahamas and the Great Barrier Reef), and his father, largely in Jamaica. TG has spent decades removing algae in Discovery Bay smothering corals, some that were growing there when Columbus briefly passed through.

In the early 1950s his father, Professor Thomas F. Goreau of the Medicine Faculty at the University of the West Indies and the world's first diving marine scientist, was appointed to the Beach Control Authority, which spent years meeting fishermen all around Jamaica officially designating all Fishing Beaches. This was necessary because although all beaches are open to the public by Jamaican Law, tourist interests were buying land behind beaches and blocking public access. Beaches that had been used for fishing for hundreds of years suddenly became "white people beaches" and the local public was banned, causing great resentment. A native Jamaican patois speaker, TG worked with fishermen all around Jamaica to develop the first whole-watershed and coastal zone nutrient management plans, widely copied elsewhere under the term "ridge to reef" or "hilltop to ocean", but unfortunately never implemented in Jamaica.

In the early 1950s, when Prof. Tom Goreau pioneered scientific diving, and dived alone, Jewfish were abundant on reefs all around Jamaica, including near Kingston. At the base of every reef, he would find huge territorial Jewfish, up to 200 kilograms or more. They were curious, friendly, and always at the same spots. In 1958 Tom Goreau set up the first diving club in the tropics, The Jamaica Sub Aqua Club, to train other people to dive and help his research to preserve coral reefs. The “sport” divers went back with spearguns, and in just a couple of years we never saw a large Jewfish again. A rich, ancient, sustainable fishery was totally exterminated in a few years.

Intensive line, trap, and net fishing in Jamaica for centuries had failed to deplete the fisheries, but as soon as fishermen acquired masks, fins, spearguns, and tanks they proceeded to wipe out Jamaica’s fish species in order of desirability. Fishermen could now see the fishes, and teams of spearfishermen could surround and kill them all, whether the fish were hungry or not. The Jewfish was the first to vanish, but species after species that we saw in huge schools in the 1950s were gone in the late 1960s. At the same time Jamaica developed a tourism economy, and people migrated from inland farms to coastal areas, seeking jobs. All the sewage went into the sea. Starting in Kingston Harbour in the 1950s, massive weedy algae, over-fertilized by sewage and agricultural fertilizers, smothered and killed coral reefs. This pattern spread around the island as almost the entire coast was developed for tourism, with reefs near Kingston dying in the 1960s, followed by those of Montego Bay, Ocho Rios, Runaway Bay, and finally Negril, the last major tourism area, developed only in the early 1990s (Goreau, 1992). Kingston Harbour was so overwhelmed that it turned into the first Dead Zone in the world whose formation was documented, by Jamaican marine biologist Barry Wade (Tom Goreau’s student). As is typical of work done by Caribbean and developing country scientists, his pioneering work was never acknowledged abroad.

The collapse of Jamaican reef ecosystems from pollution and then from high temperature coral bleaching and diseases was followed by biodiversity collapse, most fish species and invertebrates that had been abundant disappeared, and only when we would see them in remote parts of the Caribbean again would we remember that we used to have them in Jamaica too, but hadn’t seen any for so many years! As fishes and invertebrates vanished, food chains collapsed until only algae eaters remain, because now that is the only food left. Algae eating fish had been rare before, since there had been little algae for them to eat. Now algae-eating fish are intensively pursued by large groups of fishermen, in December 2020 TG saw up to 50 spearfishermen a day pass by one of the most isolated parts of the Jamaican coast. Prey species have little or no chance to survive, and the catch is almost entirely juvenile fish too young to breed (“babies” in comparison to the size they used to be). Because fish are caught before they can breed, reproductive populations have been eliminated, so the catch is dependent on new larvae washed onto Jamaican reefs by currents from Cuba.

The fishermen were the first to notice algae smothering the reef and destroying fisheries habitat, and to realize it was caused by sewage. Instead of listening to fishermen, people blamed the algae overgrowth on fishermen, saying it was because they were eating all the algae-eating fish. This false claim, widely circulated by foreign scientists who knew nothing about the history of Jamaican fishing, got the story entirely backward! Algae-eating fishes were rare when TG was a boy because there was no weedy algae food for them on the

reef, but now algae is the only food and the fishes are almost entirely algae eaters. Foreign "scientists" who blamed the fishermen also claimed that sewage was not the cause of algae growth, and therefore should not be treated, contributing directly to reef destruction through the unsound policies their bad "science" promoted: telling governments to stop fishermen and their families from eating, instead of cleaning up the pollution.

Today Jamaican fisheries has essentially collapsed, and even stopping all fishing will not bring it back because the coral reef fisheries habitat is essentially gone. Cleaning up coastal waters through sewage treatment and direct regeneration of vanished coral reef fisheries habitat are needed to resurrect the fisheries. We have cleaned up several bays in Jamaica by cleaning up land-based nutrient inputs, and the reefs recovered (https://www.globalcoral.org/covid-ends-dolphin-pollution-in-discovery-bay-jamaica/).

Biorock electric coral reef restoration technology was invented and developed in Jamaica by the late Wolf Hilbertz and TG in the 1980s (Goreau & Hilbertz, 2012), but sadly there are now no major Biorock projects in Jamaica because every effort to get funding was prevented by local corruption. We still seek funding to implement coral reef fisheries restoration projects in Jamaican fishing villages where fisheries have collapsed due to loss of coral reefs, with a particular focus on Little Bay in Westmoreland and Portland Bight in Clarendon and St. Catherine, Jamaica's largest and last remaining fish, conch, and lobster nursery habitat. We also seek funds to scan, archive, and post on the web the most important historical collection of old coral reef photographs in the world, most from Jamaica.

GCRA recently installed the first new Biorock reef in Jamaica in 25 years in a small remote bay. This project aims to restore the elkhorn coral forest that once covered the bottom, and which has nearly disappeared. Results were very promising (http://www.globalcoral.org/elkhorn-reef-restoration-westender-jamaica-after-1- month/, https://www.globalcoral.org/biorock-heals-hurricane-damaged-jamaican-corals/). The last previous Biorock project in Jamaica nearly 25 years ago had been nearby. A Biorock reef had been made of conch shells sandwiched between steel mats powered by a solar panel in a fisherman's back yard, designed as juvenile lobster habitat. Corals quickly grew all over the structure, and dozens of young lobsters and fishes crowded in. Local fishermen reported that it did beautifully until the Biorock reef, solar panel, and the local houses were destroyed by Hurricane Ivan on September 11-12, 2004.

GCRA hopes to find funding to work with the Little Bay Fishermen's Cooperative and the Jamaica Department of Fisheries to get Little Bay, Homer's Cove, and Old Wife Cove demarcated as Fish Sanctuaries under local community-based management, zoned for coral reef and fisheries restoration, and to establish Biorock training programs and pilot projects in every Jamaican Fish Sanctuary to start regenerating Jamaica's fisheries using technology invented in Jamaica.

Author diving at Ocho Rios, Jamaica, 1957, photos by Thomas F. Goreau. This reef was already mostly recovered from a severe hurricane 6 years before that blew the roof off our house.

Author diving in Discovery Bay, Jamaica, 2019, photo by Iain Robinson

NGABE

The Ngabe (Guaymi) Indians are the largest and poorest First Nation in Panama. When the Ngabe discovered Columbus, giving him refuge to repair his sinking worm-riddled ships, they called their land Veraguas. Columbus had finally found the source of the gold he had tortured and killed his way across the Caribbean to seize, with very little result. The Ngabe allowed Columbus to carry all the gold his men could mine in a river in two days, but his unacceptable behavior as a guest, trying to force them into slavery to mine gold and follow his religious superstitions, was just too much, so the Ngabe Quibian told Columbus to leave immediately and never come back. They nearly killed him when he still demanded more gold before leaving, Columbus was lucky to escape when a severe storm washed away the sandbar that had trapped his ships. He then ran his last ship aground in Jamaica just before it sank, spending more than a miserable year shipwrecked on his grounded boat, not daring to go ashore because the Jamaican Taino were waiting to kill him for killing and torturing people demanding gold they did not have on his first Jamaican vacation. Columbus himself died in Spain before he could return to Veraguas to enslave the Ngabe and steal their gold. But he demanded the King of Spain give him Veraguas as his personal hereditary family colony, along with Jamaica for its beauty. Columbus' brother and son bought African Mandingo slaves to mine Veraguas gold. The Mandingo immediately ran away into the jungle and became the first free black Maroons in the Americas around 1510, and the Columbus family had to abandon their colonization plans in both Panama and Jamaica.

Panama's Ngabe National Hero, Uraca, led the fight against the invaders. The Ngabe response to the Spanish invasion was to retreat to the jungles, and to this day they largely avoid outsiders and reject education as a trick to destroy their culture, in strong contrast to the Gunas, who have the confidence to accept the best outside knowledge on their own terms.

The Spanish found the Indios Bravos (Wild Indians) impossible to conquer, but as long as they had a secure corridor across the narrowest part of Panama to ship gold stolen from Peru from the Pacific to the Atlantic in order to enrich the Spanish Monarchy, they were happy to leave the natives alone on either side. More than 500 years after Columbus, the Ngabe people still won't allow gold mining, viewing it as an unspeakable violation of their sacred land. Every time Panamanian Governments are bribed by the world's largest mining companies to seize Ngabe lands for mining, they peacefully block the main roads and bridges in Panama, and most people support them, despite the inconvenience.

TG, whose family roots are in Veraguas (his mother was the first Panamanian marine scientist, https://www.globalcoral.org/memoriam-dr-nora-goreau-april-25-1921-december-18-2016/) is of Ngabe and Mandingo descent. He has lived and dived on Escudo de Veraguas, the tiny offshore island that is the main Ngabe fisheries resource. This very small island has a unique species of dwarf sloth, which lives only in a single tiny patch of mangroves, whose leaves they eat. There may be only one or two dozen in the world. There is hardly any living coral left around their island, with the result that the lobster fisheries are very poor. GCRA aims to work with Ngabe fishermen to restore their fisheries habitat, and with Ngabe farmers on soil fertility restoration projects, using new basalt rock powder methods we have developed in Panama (Goreau et al, 2014), with ancient biochar methods invented by the Amazonian Indigenous People of Brazil thousands of years ago.

Unlike the Guna, who avoided large-scale deforestation by not allowing cattle on their territory, the Ngabe adopted cattle ranching from the Spanish, promoting deforestation for pasture on easily eroded mountain slopes that receive up to 4 meters of rain per year. The opening of roads across the previously impassable mountains to connect the Atlantic coasts of Bocas del Toro and Veraguas to the Pacific have resulted in a flood of cattle ranching immigrants from Azuero on the Pacific coast, where soils are dry, exhausted, and over-grazed. Immigrants from the deforested Pacific side of Panama are now deforesting the much rainier Atlantic jungle slopes on former Ngabe lands. The Ngabe produce most of Panama's valued chocolate as small farmers selling to their own Cooperative, but the entire industry is threatened by the Witches Broom fungal disease that has destroyed almost all the Guna's cacao in Eastern Panama, but which has not yet reached Western Panama. If the spores spread along the country, Ngabe cacao farming could collapse, and they would be forced back into migrant labor picking coffee in Panama and Costa Rica or the banana plantations, the most poorly paid work.

Increased turbidity from soil erosion had blocked light and caused death of coral reefs inside the Laguna de Chiriqui when we surveyed coral reef health and water quality around Bocas del Toro (Goreau et al., 1997). There has been massive tourism development and immigration in the following 25 years. Most surprisingly, my 1997 study found that most outer reefs on the open Caribbean side of Bocas del Toro were also in very poor condition, with few live corals and many old dead corals overgrown by algae. High algae were attributed to increased nutrients from sewage, cattle manure, decay of cut down vegetation, and soil erosion, especially from banana plantations on both sides of the Panama-Costa Rica border. Those areas have been planted to massive banana farms since the late 1800s using Ngabe and Caribbean labor, and are up-current from Bocas del

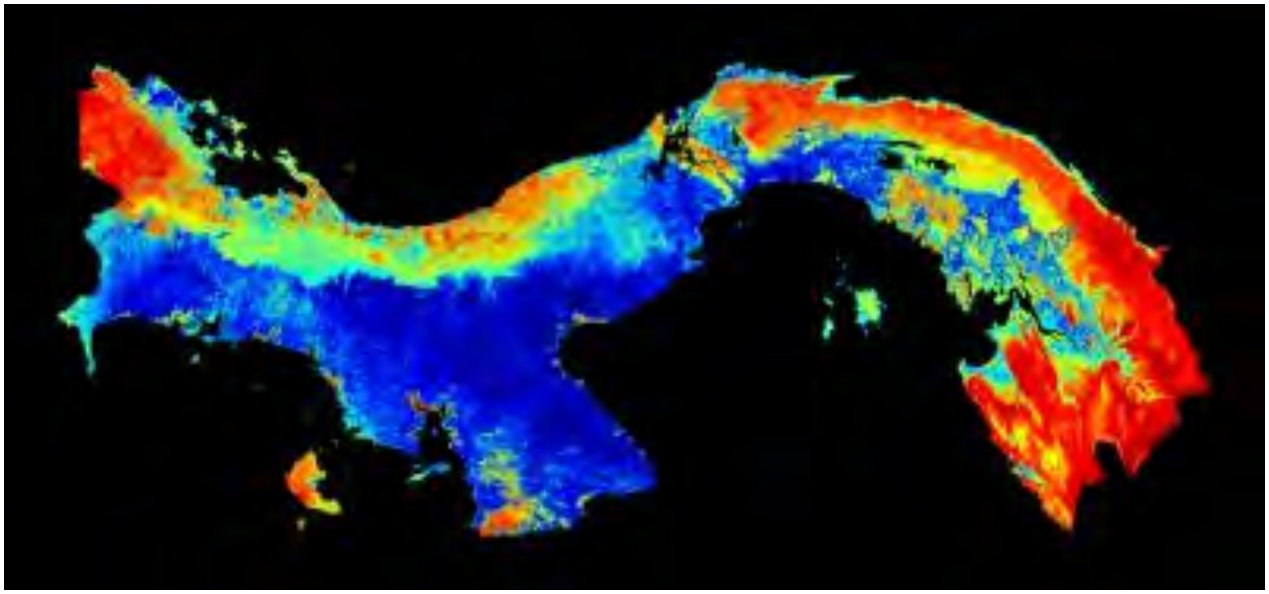
Toro. Death of these corals many decades ago was likely due to runoff of herbicides and pesticides in soil eroded from the banana plantations. Surprisingly low coral cover and massive old dead corals were found as far away as the remote offshore island of Escudo de Veraguas, more than 100 kilometers down-current (Goreau et al., 1997). Impacts of global climate change are visible all around the Laguna de Chiriqui wherever (non-mangrove) forest grows down to the sea, a row of dead trees lines the immediate seashore, killed by saltwater intrusion from rising global sea levels.

Bocas del Toro is slated for massive ecotourism development, but it has inadequate sewage treatment facilities. More concerning are plans for a superhighway along the Caribbean coast of Panama linking luxury tourist resorts, a new Cancun. The highway would stretch from the edge of the Guna Comarca (Autonomous Region) to the edge of the Ngabe Comarca. Indigenous Communities have indicated that they will not allow the road to pass through their lands, but it will bring massive development to all the areas between them, where the population is largely Ngabe or of African descent, an area including Panama's most pristine jungles, coastlines, and coral reefs (http://pulitzercenter.shorthand.com/atlanticconquest/index.html). There is an urgent need to assess the living carbon resources, both terrestrial and marine, of all the Indigenous Comarcas, and the areas between, before they are affected, as the basis for future scientifically-sound carbon management. It is hoped that a 2021 agreement by the Panamanian Government to manage their carbon resources will allow this, and that Biorock mariculture projects can be developed with Ngabe Comarca communities, if they are as open to new ideas as the Gunas at the other end of Panama.

Panama's Minister of Education Berta Arango de Urriola (top, TG's aunt), trained the first Indigenous schoolteachers. This started an educational transformation in Guna Yala, a culture that greatly valued knowledge. Our own people, the Ngabe, saw education as more of a threat than a benefit.

GUNA

The Guna (Kuna, Cuna) Indians at the other end of Panama are an Indigenous Caribbean fishing and diving people who also never lost their independence to the Spanish, and have maintained their cultural and political institutions intact (Howe, 1998). They successfully preserved their independence and traditions by deliberate isolation, never allowing outsiders to cut down their jungles, bring in cattle, own anything in their lands, or even to invest in them (Mauri, 2011). For example, when the Panamanian Government announced that the US would build a military base on the Colombian border, the Guna rejected it, saying no foreign troops are allowed on Guna land, and if the Panamanian Government wanted them, they should put them on their own lands, and the Government backed down. The Guna expelled the long-established Smithsonian Tropical Research Institution Laboratory because they took corals without permission, did not share knowledge, and treated Gunas as intellectual inferiors. The Guna rejected the UN Climate Change Convention (UNCCC) REDD (Reducing Emissions from Deforestation and forest Degradation in developing countries) proposals as a ploy by the Government to gain carbon credits from the forests the Guna have preserved, selling carbon offsets that allow CO2 pollution and global warming to continue.



Remote sensing biomass map of Panama, red is highest, blue lowest. Most Panamanian Biomass carbon stocks are in Indigenous Territories, due to massive deforestation by Latinos. From Asner et al., 2013).

Guna society is remarkably egalitarian, without hereditary rulers. Leaders are elected by universal voting to terms of office based on their knowledge and wisdom. Jamaican pirate reports (Wafer, 1695) of a culture with no hereditary kings or aristocracy, where anyone could rise to the top based on their ability, were so astonishing and revolutionary in feudal Europe that they were translated into every major European language in the early 1700s. The direct source of Rousseau's concept of "natural democracy" that led to the French Revolution's cry "Liberte, Egalite, Fraternite", and the European enlightenment demand for full participatory democracy was the Gunas, not ancient Athens, where slaves outnumbered free citizens.

Because the Gunas are confident in their culture and feel they are (at least) as good as anyone else, Panamanian officials regard them as "uppity" Indians who don't know their place. Refusal to be subservient offends Panamanian politicians, so they are politically and economically marginalized and receive little and grossly insufficient funding for essential needs. Most Gunas die from drinking contaminated river water, even hospitals and clinics don't have clean water for infant formula, sterilizing surgical equipment, or drinking water unless they boil it themselves. A recent foreign aid program gave every Guna family a solar panel so the Government could boast of 100% rural electrification, but the cheap batteries (unaffordable to the Gunas) soon burned out, so now every house is dark again, despite the solar panel in front.

The Gunas live on 50 tiny islands in the sea, small sandbanks on top of coral reefs which they have systematically built up by mining corals over centuries. The Gunas are free divers for lobster, and produce around 80% of Panama's marine exports by value, although almost all the money goes to middlemen who export their catch and not to Gunas. SCUBA diving is completely banned in Guna waters in order to preserve lobsters, with a special exemption for the GCRA team, because they know we don't catch or eat lobsters and are helping them grow back reefs and islands.

Lobster populations in Guna Yala have severely declined due to over-harvesting and loss of reef habitat to sewage pollution around inhabited islands. This has pushed Guna fishermen into deeper more remote waters and outside their traditional fishing grounds into other parts of Panama, on both Atlantic and Pacific coasts. Because Guna fishermen dive with masks and spearguns they are able to exploit many species more intensively than non-diving local traditional fishermen using nets and lines from boats, resulting in social conflicts over resource exploitation, which can turn deadly.

The Guna are now abandoning a quarter of all of their island villages because flooding by global sea level rise is making them uninhabitable, they are already climate change refugees. They have desperately mined living coral from their reefs to pile up around flooding islands. Killing corals on a large scale to protect their islands was not a problem when there were many corals and few Gunas, but now it is the opposite! As living corals are mined to build islands, wave protection against erosion in the windy season (November to May) is destroyed. Guna communities keep throwing their garbage in the sea in the hope it breaks the waves before their houses flood. Sea level rise makes this increasingly futile, so they are moving off flooding islands to the mainland, where sewage pollution of rivers they drink from will become much more of a public health problem than when it all went into the sea, killing the coral reefs around inhabited islands. Yet coral reefs around remote uninhabited Guna Yala islands are still among the very best in the Caribbean, with large amounts of elkhorn and staghorn corals that are now critically endangered throughout the Caribbean. The Congreso General Guna, the council of all the elected Chiefs, have asked GCRA since 1994 to train them to use Biorock Technology to protect their islands from erosion, to restore their coral reef fisheries, and to restore their over-harvested lobster populations, but we have never been able to find funding.

TG's oldest aunt, Berta Arango de Urriola, was the Panamanian Minister of Education who established the schools in the Indigenous regions in the 1950s, personally trained the first generation of teachers, who became life-long friends, and was made an honorary Guna chief (Sahila) in gratitude. Today the Gunas have the highest participation in education of any group in Panama, because their culture is uniquely based on sharing of knowledge. Many Gunas gain scholarships abroad and then return to share what they have learned. Traditional Guna respect for knowledge and a high concentration of educated people make them unusually capable of assimilating useful new ideas on their own terms.

The Congreso General Guna authorized Biorock projects in 1994, and we have built Biorock projects at three sites in Guna Yala since 1996, which were successful as long as they were maintained (https://youtu.be/i0VS98q8Iwk), but sadly, no funding could be found from outside to maintain and expand the projects on the scale needed for a quarter century. In 2022 GCRA plans to hold a Guna Yala Biorock technology training workshops, teaching local communities to design, build, install, maintain, monitor, and repair Biorock reefs which are designed specifically for many different uses. These include growing shore protection reefs that match sea level rise, growing artificial and floating islands, regenerating fisheries habitat, increasing lobster populations by growing suitable Biorock habitat in each of the lobster's mangrove, seagrass, and reef life cycle phases, developing oyster, crab, algae, fish and sea cucumber mariculture, growing new sand for their beaches and ecotourism, and using solar energy to grow Biorock building materials from

the sea (Goreau et al., 2014). We are also developing projects to restore their holy plant, Cacao (chocolate), which has almost been exterminated by Witches Broom fungal diseases, using the ancient Amazonian Indigenous Terra da Preta technology (biochar), and basalt rock powder and which we have shown to greatly improve soil fertility on poor Panamanian soils (Goreau et al. 2014). With Biorock we hope the Guna can preserve their islands, lobsters, coral reefs, and unique culture.

Living corals are mined from the sea to protect the shores of inhabited islands from being washed away by rising sea level. Photo by T. Goreau

Guna children at Uggupseni about to dive on their reefs with masks for the first time. They could not see the marine life around them until Marina Goreau of the Global Coral Reef Alliance brought children's masks for them, a project she began when she was 7 years old. Guna environmental advisor Rogeliano Solis at back left, TG back right. Photo by Marina Goreau.

Guna children snorkeling on a Biorock reef to see the corals and fishes, their first opportunity to use the donated masks. Photo by Marina Goreau.

MAYA

The ancient Mayans were a highly advanced, literate civilization whose boats traded cacao, cotton, jade, and much more along the Central American coast. They had deep knowledge of the sciences of astronomy and their environment, whose hydrology they transformed (https://eos.org/articles/ancient-maya-made-widespread-changes-to-wetland-landscape). The Spanish priests destroyed Maya libraries with thousands of ancient Maya books (De Landa, 1566), De Landa describes how the Maya stood crying as all their knowledge and history was destroyed forever by ignorant fanatics, while he boasted of burning the "works of the devil". The Maya suffered repeated devastating epidemics from European diseases (Clendinnen, 1987), and enslaved Maya were shackled and shipped to Cuba late into the 1800s (https://www.inah.gob.mx/boletines/9413-inah-identifies-the-first-wreck-of-a-ship-trading-to-trade-mayans-slaves-in-mexican-waters). The Maya people of Quintana Roo, the Caribbean coast of the Yucatan Peninsula, successfully revolted in the 1800s against Spanish and Mexican rule, living in jungle isolation for around a century, with Mexican control limited to offshore islands, Isla Mujeres and Cozumel, and a military garrison in Puerto Morelos (Reed, 1964). Abundant lobsters, turtles, conch, and fish on the coral reefs were the major source of protein for the coastal Maya, caught with nets, lines, and traps. The coral reefs and fisheries were intact until the 1960s, as shown by the photographs and films of Ramon Bravo, Mexico's first underwater photographer and film maker. Thanks to his widow, Maria Bravo, TG looked through all of his photographs in his home in Isla Mujeres after his tragic death. Soon afterwards the entire collection was destroyed by water damage from leaking traditional Maya palm leaf roofs that there was no money to

repair. Today there is almost no trace left of the magnificent elkhorn reefs that lined the shores, nor the huge fishes he photographed his friends spearing, nor any of Ramon Bravo's historical photographs of that lost world.

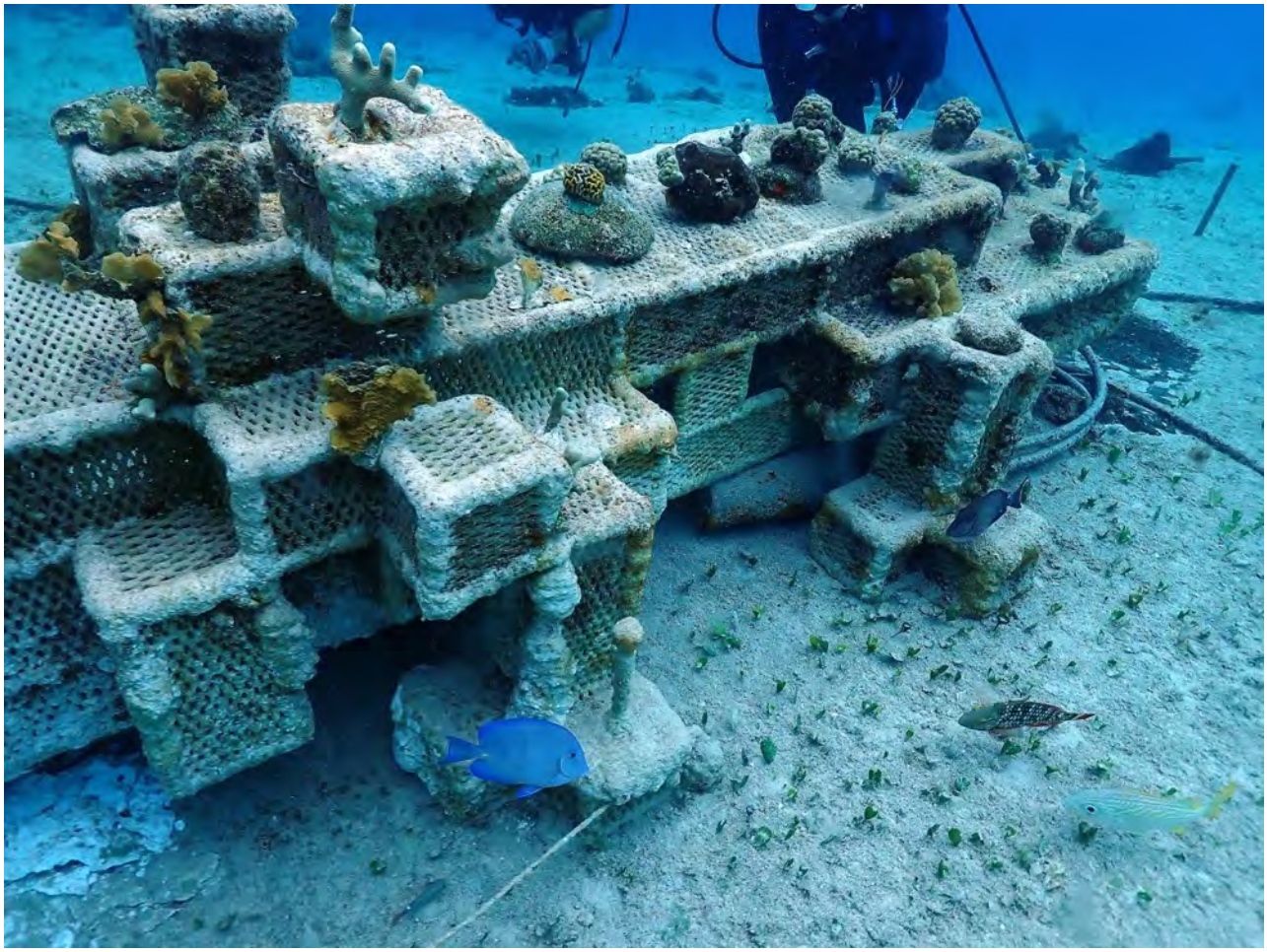
Sudden development of mass tourism began in Cancun in the 1970s, and has now spread along all the coast except for uninhabitable swamps and wetlands. The hotels are owned by the Mexico City elite or rich foreign hotel chains. Most of the Maya now depend on tourism for menial labor income, making around 7US$ per day as maids, janitors, gardeners, streetsweepers, or street vendors. Cancun was the first major resort area whose infrastructure was planned in advance, by a sagacious promoter, Sigrido Paz Paredes, who sold the concept to the Mexican Government. The sewage collection system and treatment plant were built first, before the hotels, a revolutionary reversal of normal development practices. The sewer system was designed for a much larger population than was expected, for 200,000 people. There are now a million people living there, so only about 20% of the sewage receives any treatment, and this is inadequate to remove the nutrients. Effectively all sewage nutrients flow into the sea, where they have caused massive algae growth to smother and kill the coral reefs that built their tourism economy: (https://www.youtube.com/watch?v=xDT_q1LwGmA&t=7s; http://www.angelazulthemovie.com/). Death of the reef that used to protect the beach and provide new sand has caused massive beach erosion, compensated by spending millions of dollars on regular sand dredging and pumping, almost all of which is washed away by the end of the tourist season. With coral reefs dead or dying, fisheries have collapsed.

Because of fortunes made by the original Cancun hotel developers, similar tourism developments spread all along the Mexican Caribbean coast except for inaccessible swamp areas. These later developments did not bother with sewage plants at all, they dump raw sewage into mangrove swamps behind the beach or into sinkholes (cenotes) in the limestone rock (which Maya use for drinking water), where it flows straight out to sea through underground caves. All reef areas down-current from tourist areas are devastated by harmful algae blooms, whose massive growth is due to land-based nutrient pollution. Because the lobsters are largely gone, fishermen now hunt them using laundry bleach squeeze packets, which they squirt into holes in the dead reef. Hundreds of thousands of plastic bleach packets are piled up on the beaches. More recently algae overgrowth from sewage has been compounded by huge blooms of floating *Sargassum* algae from the Atlantic Ocean, over-fertilized by nutrients from deforestation of the Amazon, Congo, and Orinoco River basins. So much algae rot on the beaches that oxygen is stripped from the water, hydrogen sulfide causes massive kills of fishes and marine life, and people breathing it can collapse.

TG has worked with the diving community in Cozumel, the world's largest dive destination, to document deterioration of the corals and replacement by harmful algae blooms fueled by sewage since the 1960s. GCRA worked with local divers and the National Marine Parks to start Biorock reef regeneration projects in Isla Mujeres and Cozumel in 1997. These projects had spectacular coral growth, fish populations, and dense schools of lobsters as long as they were maintained. But some were killed by pollution from new captive dolphin pens, whose wastes caused massive growth of toxic bacterial slime-smothering corals. Now sewage nutrients from poorly planned tourism causes harmful algae blooms and diseases killing the corals from both ends of the island. Biorock projects are among

thousands of corals being grown by the Cozumel Coral Reef Restoration Project (https://www.ccrrp.org/), an oasis of life in a coral desert killed by disease and pollution. Yet now they are threatened with complete physical destruction so Cozumel can build yet another cruise ship pier, right on top of their most effective reef regeneration project! Diving created Cozumel tourism, so this amounts to killing the goose that laid the golden egg.

GCRA, working with Naturalia, one of Mexico's oldest and largest environmental conservation groups, is planning Biorock lobster habitat regeneration projects with local Maya fishing cooperatives near Tulum and Mahahual. Biorock projects designed as lobster habitat in Jamaica and in Isla Mujeres had dozens to hundreds of lobsters crowded into a couple of square meters. Because Biorock not only creates shelter, but also grows clams and the marine life lobsters eat, the lobster populations, and sustainable catches, can be greatly increased by training local fishermen to build suitably sized habitat for lobsters at all stages of their life cycle in mangroves, seagrass beds, and coral reefs. If Cancun wanted a permanent beach, growing a Biorock reef to grow new sand and protect the beach from waves would cost far less than dredging and pumping sand that soon washes away, and make the tourism industry environmentally sustainable.



Biorock reef in Cozumel. Thousands of corals are being grown here by the Cozumel Coral Reef Restoration Program (https://www.ccrrp.org/). They are now threatened by a proposed cruise ship port right on top of them. Photograph by Dr. German Mendez.

COMCAAC

The Comcaac (Seri) are the smallest and most independent Indigenous culture in Mexico, speaking a language completely unrelated to any other (Marlett, 2014) They are also genetically unique (Moreno-Estrada et al., 2014) and may be descendants of the first coastal settlers of the Americas some 20,000 years ago. They live in the driest part of North America, the Sonoran Desert, were never conquered, and survived repeated Spanish and Mexican efforts at genocide by hiding for nearly 300 years on desert islands in the Sea of Cortes where no one else could survive due to lack of water, living on fish, turtles, and cactus, using their intimate knowledge of the life cycle of all the plants and animals around them (Felger & Moser, 1985; Marlett, 2014). Their secret survival food was seagrass seeds, which the Comcaac are the only people to eat. Biorock methods could allow them to grow and harvest it much more quickly, and sell as a highly nutritious specialty grain.

Comcaac lands lie along the world's most active plate tectonic spreading center, which runs the length of the Sea of Cortes. It is an area of intense submarine volcanism and crustal spreading, which causes severe, episodic, and unpredictable earthquakes. Because of deep, steep slopes of the Sea of Cortes, earthquakes are often accompanied by submarine landslides and tsunamis, and there are clear signs of a huge tsunami that shaped the entire Comcaac coast. This has not been dated, but took place sometime in the last 8,000 years, after sea level had reached its present level. The Comca'ac have clear traditional memories of this flood, which washed up the mountains, and killed many people.

The Comcaac fisheries resources are based on several unique endemic species, including two of the world's most valuable and rapidly growing bivalves, and an endemic fish that has been driven to near extinction due to the value of its organs in China. Comcaac waters have the largest seagrass beds and Green Turtle populations on the Pacific coast of the Americas, but turtles and sharks have been severely overharvested for sale to outsiders. The region is also the northern limit of corals in the Eastern Pacific, the only coral reef in the world made up of loose corals rolling around on the bottom, made up of single species, *Porites panamensis*, that elsewhere grows attached. The Infiernillo Channel is lined with highly productive mangrove estuaries, the last pristine estuaries in the Sea of Cortes. Traditionally fish were caught by spearing from reed rafts, and mollusks were collected at low tide, but around 1970 the high value of their endemic shellfish, and overharvesting of accessible intertidal zones, led to diving using hookah hoses to breathe air pumped by compressors on boats. Most of the male population that are physically capable are diving, as this has become the most significant source of income. The compressors are designed for inflating tires or spraying paint, and not designed for diving. They have no filters and use toxic lubricants, so divers are being crippled or dying from grease and oil-contaminated air they breathe while diving from unsuitable compressors on their boats.

Although the Comcaac have incredibly rich marine resources in Infiernillo Strait between Tiburon Island and coastal Sonora, they are among the poorest people in Mexico (https://www.globalcoral.org/un-oceans-regenerating-the-sea-of-cortes/). Rapid tidal currents flowing through the strait make it one of the world's great tidal energy resources. TG is a scientific advisor to Tiburon Agua y Electricidad, a group partnering with the Comcaac to develop proposals to use their marine currents as a source of low-cost renewable energy to produce fresh water from sea water for the Comcaac and the Yaqui

peoples in northwestern Mexico. It is hoped to include the Tohono O'odham (Papago) people of Arizona, whose ancient farming lands were abandoned after the US pumped their rivers and ground waters dry. Surplus water would be available for farmers in Mexico, to regenerate the rich wetlands that died when the Colorado River that flowed into them was sucked dry on the US side before flowing into Mexico, and for sale to Arizona and Southern California. Brine wastes from desalination, normally dumped into the ocean, would be used as for mineral extraction using Biorock Technology, invented by the late Wolf Hilbertz and TG in Jamaica, to produce harder and lower cost building materials than concrete, which removes CO2 from the atmosphere instead of adding it as cement manufacture does. If these projects go through, and if the Comcaac maintain control of their lands, they could become energy and water rich in a land with little of either. This could allow them to earn much more by selling frozen seafood, instead of having to rush it immediately to market and sell at a low price before it spoils. They will have to decide if they want to go this development route, as opposed to going back to the past, and if they can remain in control of their unique lands, waters, and culture without being overwhelmed by outside forces, investors, developers who would turn their lands into golf courses for rich outsiders, or drug smugglers. To do so they will have to upgrade their education system like the Gunas have, only a handful of Comcaac have had the opportunity to pursue higher education.

GCRA helps the Comcaac community develop sustainable management plans for their marine resources (http://comcaacnativeaquaculture.blogspot.com/). TG dived in Infiernillo with Comcaac fishermen and showed them how they could grow their valuable mollusk species much faster using Biorock stimulation of valuable shellfish growing in suspended bags powered by floating solar panels, avoiding all health risks of unsafe diving. Research and development projects have been started to find the fastest and most effective way to bring these species into valuable mariculture using Biorock Technology. Not only will the electrical trickle charge greatly speed up their growth, they will have much more suspended food supply hanging in the flow than on the bottom. Preliminary results were very promising, and a proposal has been developed with Naturalia AC, one of Mexico's largest and oldest environmental conservation groups and the National Fisheries Agency (INAPESCA) for funding to greatly increase training and valuable mariculture productions, while safeguarding fishermen's health. If funding can be found similar methods will be developed for oysters, snails, sea cucumbers, corals, sea grasses, algae, and other economically valuable species, while protecting the environment for sustainable use. With Biorock the Comca'ac can keep outsiders from destroying the austere and pristine beauty of their deserts and their incredibly fertile waters, by enhancing their natural biodiversity and energy resources with their ancient cultural knowledge.

Biorock mariculture rafts in the Sea of Cortes, in front of the Comcaac village Punta Chueca, growing endemic bivalves with Biorock. Photo by Gerardo Carreon.

AHIARMIUT

The Ahiarmiut were the only Inuit (Eskimo) who lived inland, all the rest lived from the sea. The Ahiarmiut lived in the tundra Barrenlands from caribou and fresh water fish (Karetak, Tester, & Tagalik, 2017). The European fur trade brought in guns, which allowed over-hunting of caribou. When the fur trade suddenly collapsed, so did the supply of bullets, and their ancient stone-age hunting skills had become rusty, so most Ahiarmiut starved to death. The handful of survivors were forcibly evacuated to Arviat on the Hudson Bay coast by the Canadian government, where they died of “broken hearts” (Tester & Kulchyski, 1994).

After a few years of exile, the Ahiarmiut decided to abandon the coast and go back to their native tundra to try to resume their traditional life in 1954. They were accompanied by TG's grandfather, who photographed their traditional cultural practices. Unfortunately, there were too few caribou left to survive, and they were forced back into exile from their lands, which are now melting away due to global warming. The surviving People of the Caribou were forced to become Sea People.

The land has dramatically changed since those photographs. Because global warming in the tundra is the highest in the world, the climate has changed, the vegetation is taller, and exotic new plants, insects, and animals are moving in from the south and displacing the old ones. Because this area was the thickest part of the North American Ice Cap during the last Ice Age 18,000 years ago, kilometers of Ice pushed the earth's crust down, and after the Ice melted the land is rebounding, rising at the fastest rate of any place on Earth. When the Ahiarmiut go to sea to hunt seals and whales, their boats run aground and propellers are broken on rocks that used to be deep below the surface last year, beaches are getting wider and expanding seaward year by year, new islands are emerging in Hudson Bay, while old islands become part of the mainland. When they take their kayaks up river to hunt caribou, the boats run aground because rapidly rising land makes rivers and ponds dry up, and dried-out peat bogs and ponds are pumping greenhouse gases into the atmosphere.

Our goal is to scan the old photographs and make them available to the Ahiarmiut community on Hudson Bay as a tool to preserve their culture and history and document the changes in their environment. When TG brought the old photographs to Arviat in 2018 there were only two survivors left from the group, they could identify all the people, and what they were doing. They were thrilled to see their native homeland again, and for all their descendants to see it for the first time (shown in the Canadian Broadcasting Corporation documentary film *Coral Ghosts*). When the Canadian Government apologized to the Ahiarmiut for their forced exile some 7 decades later, large posters of these photographs were chosen by the Ahiarmiut as the backdrop for the reconciliation and reparations ceremony.

The oldest survivor of the Barrenlands Ahiarmiut, in front of her 1954 photograph, with the Canadian Government Minister who led the reconciliation ceremony, photo 2019, by Shirley Tagalik (https://www.canada.ca/en/crown-indigenous-relations-northern-affairs/news/2019/01/canada-advances-reconciliation-with-historic-apology-to-the-ahiarmiut.html).

NANSEMOND

The Nansemond Indian Nation harvested oysters along the banks of the Nansemond River, the last estuary entering near the mouth of Chesapeake Bay, Virginia, USA, for thousands of years, without depleting the sizes of oysters harvested in prolific ancient middens (Rick et al, 2016). In 1607 uninvited English immigrants moved in across the river, and after all their imported crop seeds died, unable to survive local conditions, John Smith (regarded a national hero in the USA) stole all the corn the Nansemond had harvested and stored to survive the winter, and then returned to burn down their homes and sacred lodges (https://en.wikipedia.org/wiki/Nansemond) Fortunately, he could not steal all their oysters, as the bay was choked with them, much larger than are now found in ancient piles of shells left behind by prehistoric Nansemond (Jansen, 2018).

The Nansemond people are still there, they lost their language but not their cultural traditions. But now their oyster reefs are dead or toxic, their forests have become cities, farms, factories, and military bases, pumping out industrial pollution, urban sewage, fertilizer, and manure runoff that has poisoned their waters (Kilch & Nielsen, 1977) and makes oysters toxic to eat. In the old days oysters filtered all the water in Chesapeake Bay every couple of days, keeping the water clear, but after European immigrants wiped out the seemingly inexhaustible oyster populations, it now takes months for the water to clear,

instead of just days (Loosanoff, 1965). Clear waters became dark and turbid, little light penetrates, so the algae on the bottom died, and then the formerly huge population of the iconic Chesapeake Blue Crabs that fed upon them. The microscopic diatom phytoplankton that oysters feed on were replaced by harmful cyanobacterial algae blooms, which they won't eat, and which can be toxic to estuary life and humans.

Now there are efforts to regenerate oysters, even if unsafe to eat, to filter out organic matter and sediment that have fouled the waters, in order to improve the water quality. Millions of dollars have been spent shoveling dead oyster shells into the water in the hope that oysters will settle on them, and gluing oysters onto cement and other exotic materials. Although there are periodic claims of success, most of these are temporary, and there is little evidence of long-term regeneration of oyster populations or ecosystem services due to deteriorating water quality (Carey, 2021).

Solar powered Biorock projects at a SuperFund toxic waste site in New York City grew oysters at phenomenal rates with extraordinary survival, and the oysters grew all winter long without going dormant, while controls almost all died, and dormant survivors shrank in size as their shells dissolved. Biorock saltmarsh showed much higher growth both above ground and below ground, and expanded into deeper water than it could normally grow in, at a site where sea level rise is eroding salt marshes (Cervino et al., 2012). Mussel growth around the base of the saltmarsh grass raised the level of the bottom about 10 centimeters, and built a new beach that was undamaged by Hurricane Sandy. Use of Biorock could expand the salt marshes now steadily washing away due to sea level rise.

Sea level rise in Chesapeake Bay is accentuated by rapid downward subsidence of the US East Coast, causing massive coastal erosion problems. In a minor act of symbolic restitution for the 98.9% of Native American Lands that were stolen following treaty protection with the Government (Farrell et al., 2021; https://www.science.org/doi/10.1126/science.abe4943), the Nansemond Indian Nation has recently regained control over some of their ancestral sites, and started an oyster farming project (https://chesapeakebaymagazine.com/nansemond-indian-nation-joins-oyster-alliance/). GCRA hopes to work with them to regenerate their oyster reefs and salt marshes with Biorock to protect their shores from washing away. These methods could be used for other indigenous coastal communities on rapidly eroding shores in Louisiana and Georgia, as well as the surrounding public descended from immigrants who swarmed uninvited like locusts, blighted the land, fouled the waters, and declared it was divinely ordained.

GULLAH

The Gullah people live in the offshore coastal marsh islands of Georgia and South Carolina where they grew rice and harvested crabs, oysters, shrimps, and fishes for centuries. Their ancestors were brought from West Africa as slaves to rice plantations along the coast. The marsh lands were full of malaria, so there was a very high death rate of Europeans, but many Africans whose ancestors came from the malarial swamplands around Guinea and Sierra Leone had inherited evolved resistance to malaria from the sickle cell gene, and survived where others died. Many also came from regions where West African rice had been traditionally grown for centuries. The Gullah people (also known as the Geechee)

developed their own speech which uses mainly English words with West African grammar, very similar to Jamaican patois, Sierra Leone Krio, and Nigerian pidgin languages, and largely mutually intelligible although some different African words have been preserved in each. The Gullah came to develop a completely distinctive culture in relative isolation, since white people avoided the unhealthy coast as a graveyard. In the US Civil War, the Gullah were the first black people to be freed from slavery and became farmers growing rice on their own lands.

Their long isolation ended when wealthy people saw their remote and beautiful islands, with huge spreading Southern Live Oak (*Quercus virginiana*) trees covered with hanging bromeliads, (*Tilandsia usneoides*, "Spanish moss" or "old man's beard"), along beautiful coastal beaches, as the perfect place for luxury mansions and golf courses. The coastal islands became favorite beach resorts for the ultra-rich, driving up land prices so local people could no longer afford them. This forced many Gullah to reluctantly migrate from their islands, losing both their lands and their culture. In addition, their estuaries face severe pollution from upstream sewage, fertilizer, and manure dumped into the rivers, plus nuclear waste from the Savannah River nuclear bomb plant, which has had repeated unacknowledged radioactive leaks.

Now the major threat to the Gullah way of life comes from global climate change, increasing sea level and increasing strength of hurricanes is battering and eroding their islands, which are washing away. There is little hope to save them unless they use methods that greatly increase the growth and survival of oysters, mussels, and saltmarsh, to regrow living shoreline protection, as Biorock has been shown to do (Cervino et al., 2012). Biorock shore protection can grow back eroded beaches, regenerate shellfish, grow crab and shrimp habitat, and extend now eroding salt marsh seawards due to enhanced root growth. GCRA hopes to work with Gullah communities regenerating their ecosystems, food, and natural shore protection against the challenges to come.

https://www.theguardian.com/environment/2019/oct/23/gullah-geechee-distinct-us-culture-risks-losing-island-home-to-climate-crisis

https://www.pewtrusts.org/en/research-and-analysis/articles/2021/07/12/african-descendants-have-stake-in-saving-us-southeast-salt-marshes

https://gullahgeecheenation.com/gullahgeechee-sea-island-coalition/

BARBUDA & SAINT BARTHELEMY

These two islands are discussed together because they are close neighbors yet have very contrasting geographies and histories. The Indigenous people of both islands, whose archaeological remains are found, had vanished before European colonization. The new people on these islands found no rivers, few wells, and soils too dry to grow plantation crops or even much food. They became the master fishermen of the Eastern Caribbean, living from the sea, largely using fishing methods, such as fish traps, copied from traditional Indigenous designs. Both islands were surrounded by reefs and shallow banks rich in fish, lobster, and conch, which they caught and exported to wetter and richer islands in exchange for food and supplies. Whenever there was prolonged drought, the few wells became salty, and the entire population was forced to leave in their boats and beg for

water from higher, wetter islands.

The soil and geology of the islands are very different. Barbuda is entirely limestone, mostly very flat low ancient beach sand dunes, with a small area of higher limestone. There are no streams or fresh ponds, and much of the groundwater is brackish. The soil is thin and poor with little nutrients or capacity to hold water. Saint Barthelemy on the other hand is extremely steep and rugged with little flat land except along coastal salt ponds. Unlike high islands, the islands are too small for the hills to cause much rain, so there are no streams, just normally dry gullies that flood in rains. The rocks of Saint Barthelemy are the oldest in the Eastern Caribbean, but unlike the fertile basalt soils on high, wet volcanic islands, Saint Barthelemy is mostly ancient, highly weathered volcanic ash deposits which have largely been leached of nutrients, so soils are poor.

The two islands followed very different historic paths. Barbuda was occupied by the English, and assigned to the Codrington family of Barbados, who brought African slaves to grow cotton. When the Codringtons found cotton couldn't grow on so dry and infertile soil, they abandoned the population to subsist from the sea, which they did with remarkable success, catching scanty rain from their roofs to survive. Uniquely in the Caribbean the whole island is owned in common by all the traditional inhabitants, who were deeded the entire island after Emancipation. Saint Barthelemy, in contrast, has always been French speaking, even though for a brief interlude it was administered, in name only, by Sweden (as a symbolic royal family dowry gift). Since there was no flat land, plantation slavery was never possible, and the island was settled by French fishermen, many of Breton or Norman origin. The Saint Barthelemy people speak three different dialects of French on their tiny island, Creole similar to that of Guadeloupe, Martinique, and Haiti, Patois similar to Normandy-influenced Quebec French, and Parisian French, as well as English for tourists. The Barbuda people speak Caribbean English with an accent similar to that of Antigua and Jamaica, distinct from other Eastern Caribbean English accents. As a result of these different colonial histories, the Barbuda population is the most African of any Caribbean Island, and Saint Barthelemy is the most European, there are few brown people on either island. There is almost no communication between the two islands, even though they are nearby neighbors with the same environmental problems.

Neither island has an international airport, one must enter from larger tourist islands, Antigua for Barbuda, and Saint Martin for Saint Barthelemy, and transfer by boat or very small planes holding a few passengers. Despite this, Saint Barthelemy has become the ultimate high-end luxury Caribbean resort for the ultra-wealthy, making food and accommodations impossibly expensive for local residents, many who still live from the sea. But most have had to become tourism service providers, maids, waiters, cleaning, staff, etc. Coastal lagoons are now largely polluted and stagnant (septic tanks drain into them), and coastal waters of major beaches are polluted with sewage runoff, stimulating algae overgrowth of coral reefs that used to form and protect the beaches, resulting in severe beach erosion. Barbuda, on the other hand, has resisted tourism, since the inhabitants own the whole island and would rather live from a healthy sea than become maids and gardeners for foreign tourists and risk pollution and economic marginalization on their home island, as happened to nearby Antigua, Saint Barthelemy, and Saint Martin. Barbudans have rejected schemes for mass or luxury tourism on their magnificent beaches, because they prefer small-scale tourism under local ownership than what they

see on Antigua, where most tourism jobs are menial, profits flow mostly to foreign owners or politicians, and the population dissatisfied by inequality of economic opportunities.

All these islands were devastated by Hurricane Irma, the worst in their history, a category 5 hurricane that arose with no warning and whose eye hit first Barbuda and then Saint Barthelemy. On Barbuda almost every house was destroyed, and the entire population of the island was forcibly evacuated to Antigua, where they had to stay for over a year until basic infrastructure could be restored. The hurricane ripped a huge hole through the barrier beach that contains Codrington Lagoon, the largest and most pristine salt water lagoon in the Eastern Caribbean, critical nursery grounds for the fish, lobsters, and conch Barbudans catch in surrounding coral reefs, mangroves, and sea grasses, and home to the largest Frigate Bird nesting colony in the Caribbean. Previous hurricanes had opened the lagoon to the sea, but the gap always soon closed naturally. This time it has continued to expand, and is now nearly one and half kilometers wide, allowing lagoon waters to flow into the sea and altering water quality of critical habitat for the island's fisheries.

On Saint Barthelemy all houses and hotels along the shore were devastated, but as the island is part of Metropolitan France, aid for rebuilding was generous and rapid to arrive. On Barbuda it was delayed for political reasons, the Government of Antigua used removal of the entire population to try to revoke traditional common legal ownership of the entire island by its people, declaring that the land belonged to the Government, and arranged to sell off beach front land to rich foreign developers who proposed to dredge the Codrington Lagoon for mega-yacht marinas and build hotels and golf courses whose sewage would destroy the pristine water quality of the lagoon and its fish and shellfish nursery habitat (https://www.globalcoral.org/palmetto-point-development-potential-impacts-on-barbudas-fisheries/). The nearby island of Saint Martin had a similar lagoon to that of Barbuda, Simpson's Bay Lagoon. Uncontrolled development has turned this into a stinking mess devoid of life other than slime (Duijndam et al., 2020). This would happen to Barbuda too, if these environmentally irresponsible plans are forced on them by those who seek to profit from exclusive foreign-owned tourism.

GCRA has worked with the diving and fish communities on both islands for years. In 1996 TG did the major study of reef health around Barbuda and Antigua, and has repeatedly visited the island to advise the Barbuda Council, the island's elected government, on various environmental protection, fisheries, and development issues. He worked with the island government, fishermen, and school to review environmentally damaging proposals made and to develop funding proposals to use Biorock technology to close the hurricane gap to save the Lagoon, restore water quality, increase coral, seagrass, and mangrove growth, improve the fisheries nursery habitats, and develop more productive sustainable mariculture methods, to put the island under a sustainable development path according to the wishes of its inhabitants. GCRA and the High School on Barbuda have set up extremely successful projects to improve soil fertility with volcanic ash from the nearby island of Montserrat, allowing many vegetables to be grown successfully on Barbuda for the first time (https://www.remineralize.org/2020/06/barbuda-limestone-soil-crop-growth-stimulated-by-montserrat-volcanic-ash/).

On Saint Barthelemy, GCRA has trained two local teams to do Biorock projects. To our amazement Biorock reefs in one meter water depth on top of the reef crest, where waves

around 10 meters or more broke, were totally undamaged by the huge hurricane waves that destroyed all hotels and houses on the shore behind it (https://www.globalcoral.org/biorock-electric-coral-reefs-survive-severe-hurricanes-little-no-damage/)! The Biorock reef, and even the cable that powered it, were undamaged, and most astonishingly, there was no damage to rich elkhorn and staghorn coral growth on it, an oasis of life in the middle of a vast barren desert of dead coral reef. The main tourist beach on Saint Barthelemy, which lies behind this dead reef, suffered severe erosion after the coral died. Millions of dollars have been repeatedly spent pumping sand onto the beach, all of which is washed away in a year or so. Local environmental groups propose using Biorock to regenerate reefs so the beaches their tourism depends on will grow back naturally, and their fisheries regenerated. Funding is being sought to do so.

Volcanic ash remineralizes Barbuda soil. The plot on the left had a 20 Kg bag of volcanic ash added about 10 years ago, and has much more pumpkin and sweet potato growth than the control plot on the right. Photo by T. Goreau

GUJARAT

India is third in the world in fisheries catches after China and Indonesia. Fisheries employ 14.5 million people, with around 55% of the catch coming from fresh water ponds. The marine catch focuses on netting small schooling fishes in turbid waters, then on bottom fish, but many species caught spend part of their life in coral reefs, which have been strongly degraded from human impacts. The coral reefs along the coasts of Gujarat are the most exceptionally stressed by extreme ranges of temperature, salinity, mud, large Monsoon waves, and very strong tidal currents, as well as runoff of sewage and agricultural fertilizers from a densely populated land. Traditional fishing boats target offshore schools of fish in turbid waters with nets and lines, not reef fish, because nets and lines would be entangled, torn, and lost on coral reefs. The reefs appear to have changed greatly in the thousands of years people have lived next to them. A unique feature of Gujarat coral reefs is the complete absence of the most common coral genus, Acropora (Satyanarayana, 2009), whose fast-growing branching corals dominate coral reefs across the Indian Ocean and Pacific, and are the most important corals for protecting beaches from waves and fish habitat. Yet the beaches of Gujarat are covered with very old, long-dead, broken Acropora coral skeletons, showing that a dramatic ecological shift thousands of years ago caused them to disappear (Chowdula Satynarayana, pers. comm.). This may have resulted from the original deforestation of Gujarat for agriculture in Prehistoric times.

Gujarat was a major node of marine trading networks that spanned the Indian Ocean four thousand years ago (Abulafia, 2019; Joseph, 2018), bringing plants like sugar cane, bananas and taro from Indonesia to India and Africa, African millets to India, Pigeon Peas (*Cajanus cajan*) from India to Africa, Chinese millets and marijuana to Africa in ancient times (Fuller & Boivin, 2009). Exchange of many economically valuable plants like pigeon peas (*Cajanus cajan*) happened so long ago that it is uncertain whether these crops were originally developed in India or Africa. The collapse of Indian ancient civilization from drought in prehistoric times left behind only archaeological remnants of trade items like Money Cowries (*Cypraea moneta*) from the Maldives and distinctive trade beads made in India found in Maldives, the Near East, and Africa (Heyerdahl, 1986). Drowned remnants of ancient cities in front of Dwarka, Bet Dwarka, Lothal and other parts of Gujarat are only starting to be excavated (Rao, 1987). Dwarka, home of the God Krishna, has been one of the four most sacred pilgrimage sites in India for thousands of years, built on top of more ancient cities whose trade once crossed the seas. Until the still undecipherable ancient Pre-Vedic Indian scripts can be interpreted, their history will only be accessible by archaeology.

In 2020 the first new Biorock coral projects in the Indian Ocean in decades were started by the Zoological Survey of India near Mithapur, Gujarat (https://www.globalcoral.org/first-biorock-projects-in-india/). The projects are near Bet Dwarka, an ancient port from which ships sailed to and from the Maldives and much of the Indian Ocean 4 or 5 thousand years ago (Rao, 1987). The Biorock reefs are powered by floating solar panel buoys, and soon after installation survived extreme monsoon waves, high mud, strong tidal currents, and a high temperature coral bleaching event. The projects were installed just before the Covid outbreak by a large team of Zoological Survey of India marine biology experts led by Dr. Chowdula Satyanarayana and Dr. Chandran Retnaraj, with help from the author. Due to Covid lockdowns it has been very difficult to monitor since installation but the projects

resulted in rapid coral growth that survived bleaching, immediate increases in fishes, and in sand producing algae on the bottom around the Biorock reefs. The Zoological Survey of India team includes India's top coral reef species experts (taxonomists), so important work on biodiversity enhancement will result. One goal of the project is to bring Acropora corals back to Gujarat reefs after thousands of years absence, because they are the most effective corals for shore protection and fisheries habitat, due to their open branching and exceptionally rapid growth.

The coral reefs that line the Gujarat coast are difficult to dive on because of high currents and turbidity, so very few people will ever see or appreciate their ecological services. The Gulf of Kachchh in Gujarat is more protected, but has extremely high tides, currents, turbidity, the world's largest oil refineries and petrochemical plants, and much of India's heavy industry, so corals are limited to very shallow water due to lack of light. They reach their greatest development in unique shallow tide pools in which water is trapped at low tide, whose bottoms are covered with corals despite being only a few tens of centimeters deep. The Gujarat Forestry Department, which manages the marine parks, has built low stone walls at Poshitra to greatly increase the area of shallow tide pools, which has resulted in a stunning expansion of corals in shallow pools which can easily be seen by the public, a unique opportunity to walk and look at a reef without having to swim or even getting wet. We hope to use solar panels so tide pool coral reefs can be greatly expanded with Biorock and appreciated by the entire Indian public!

Bringing back corals in Gujarat is only the first step (https://www.globalcoral.org/first-biorock-projects-in-india/). Coral reefs in Tamil Nadu, South India are far more impacted by human use, mining of corals, bleaching and net damage, and although reefs in the remote Lakshadweep, Andaman, and Nicobar areas have less human damage, they have suffered greatly from bleaching. Reefs that were once rich sources of food for coastal populations are collapsing, and reef regeneration that works in places as extremely stressed as Gujarat would work even better there, and allow India's coastal fishing populations to be more productive and less destructive with Biorock mariculture. Biorock could regenerate coastal reefs and protect severely eroding shores along the mainland.

MALDIVES

The Maldives, an archipelago of 1200 spectacular Atoll islands in the Indian Ocean, more than 500 kilometers offshore from South India, were settled in prehistoric times and became a major part of the maritime trade of the ancient Indian civilizations centered on the Indus Valley and Gujarat. Maldivian Money Cowrie shells were used as currency for thousands of years in Asia and Africa, and beads from ancient Indus Valley cultures are found in the Maldives, along with a rich and ancient archaeological record, much of which has been destroyed by later immigrant cultures (Heyerdahl, 1986). The cowries, so common in the Maldives and treasured elsewhere, were cultured for export, harvested from coconut palm leaf mats hanging in the sea, the snail grazed algae growing on the leaves, making the Maldives the country that exported money grown on trees!

The Maldivians were master boatbuilders, despite having only coconut wood on their low islands, most only about a meter above sea level, sewing the coconut planks of their dhoni boats together with coconut fibers. They developed intensively productive and sustainable

tuna fisheries, catching small bait fish by hand-thrown nets in shallow water, then hooking tuna one by one in open water from baited fishing lines thrown from dhonis. Tuna and coconuts fed Maldivians and provided rich exports along with the Money Cowrie, traded for rice.

Coconuts are now the only thing they can grow, because rising salty ground water tables caused by global sea level rise has killed mango and fruit trees. Nobody really needs money cowries any more except as knick-knack souvenirs. And even though Maldivians, using traditional hand line fishing, are the only people in the world managing their tuna fisheries sustainably, as soon as tunas wander out of the Maldivian Exclusive Economic Zone they are pounced upon by insatiable industrial fishing fleets using long lines, drift nets, and satellite sensors to catch entire schools, steadily destroying the resources Maldivians have managed sustainably for thousands of years.

Although every island in the Maldives was built by corals, and the coral reefs swarmed with spectacular fishes, Maldivians did not eat reef fish. Tuna IS food in the Maldives, and is eaten in every meal. Reef fish are starvation food to be eaten only if the weather was too bad to go out into the open ocean for tuna. The spectacular and untouched reef fish populations were the basis of tourism that transformed the Maldivian economy starting in the 1970s. All 200 inhabited islands and 1000 uninhabited islands have accelerating erosion. The Maldives lies on the Equator and is outside the Hurricane belt, but it has a unique double Monsoon, blowing half the year from the east and half from the west. This moves sand from one end of each island to the other twice a year so the beaches wax and wane, but with global sea level rise, they mostly wane. As a result, there are few natural beaches at resorts, most are protected behind sea walls made of dead coral rock mined from living reefs. These walls shift and collapse in storms, so resorts began to cover them with steel fencing material, which rusts and falls off in about a year, and then with more expensive fencing with plastic coating that cracks in the strong sun with the same slightly more delayed result. Some resorts, feeling that rock walls are ugly and uncomfortable for tourists to climb over or lie on, prefer to pump sand into bags, which they shift from one end of the island to the other seasonally. This is about as expensive as rock walls, and after the first big storm the sand is lost and plastic shreds litter the beach.

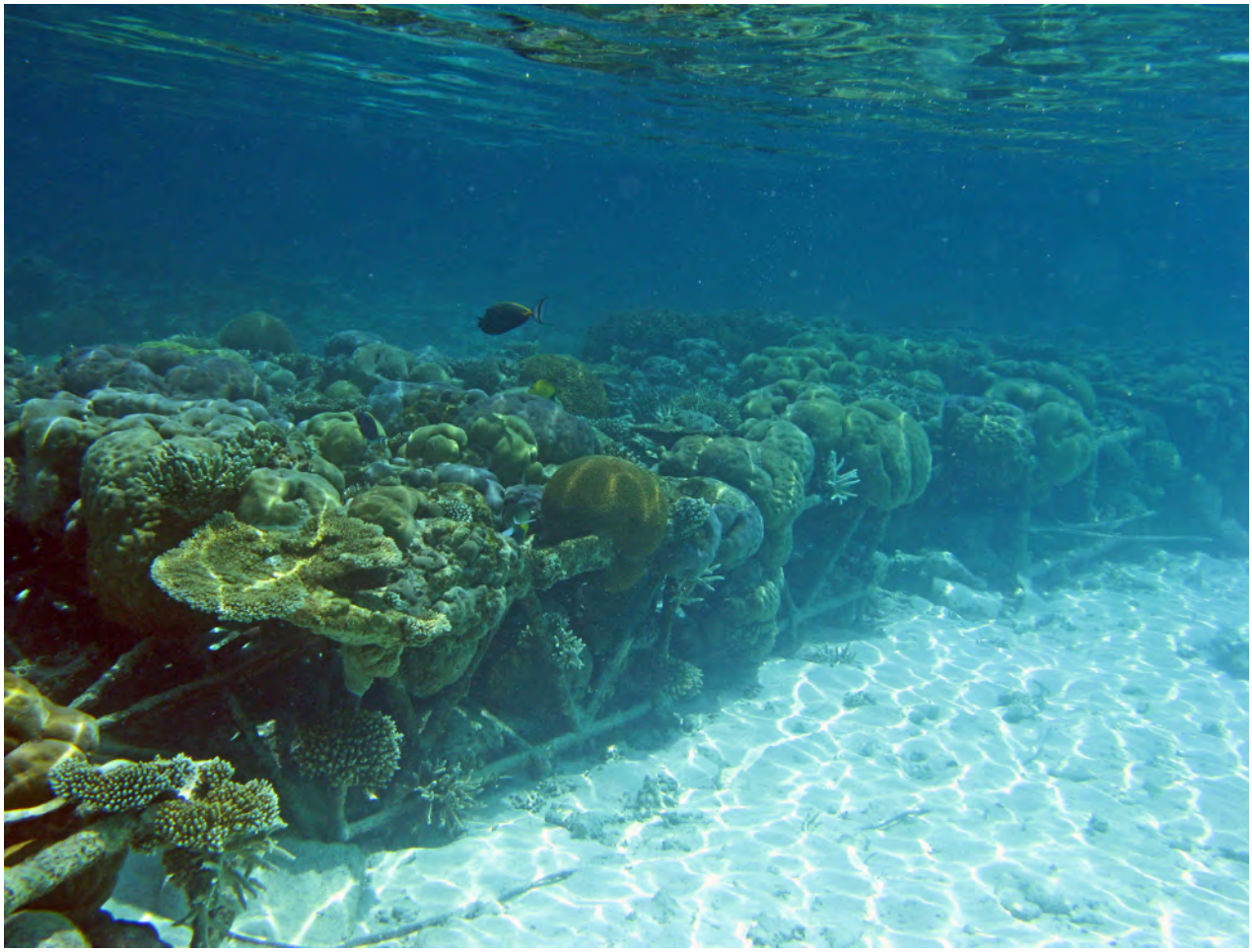
The only building stone that Maldivians had was mining live corals from the reef. The killed corals were cemented together with quicklime, made from burning corals. When Maldivians were few and corals many, it had limited impact, but as population grew and people migrated to the capital in search of jobs, education, and medical care, all the reefs around the capital were mined out for building material, then further afield, destroying the natural protection against storm waves. By the 1980s waves from remote storms in the Indian Ocean or the Antarctic Ocean flooded the capital, contaminated the ground water wells, killed fruit trees, and caused cholera epidemics. The Government of Japan built a sea wall around Male, made of giant cast concrete tetrapods shipped from Japan, at a cost of around $13 million per kilometer. The other 199 inhabited Maldivian islands did not get any.

The British Overseas Aid agency funded the University of Newcastle upon Tyne to do coral reef restoration projects near Male. They shipped 360 tons of concrete from Newcastle upon Tyne, most in the form of huge superhighway bridge overpass slabs, and dumped

them over 4 hectares of mined-out dead coral reef. They then went to a living reef further away, broke off the corals, cemented them to the concrete, and quickly published scientific papers claiming complete success of the world's best coral reef restoration project. When TG filmed it a few years later, all the transplanted corals had died, but a few baby corals of weedy species had settled on the undersides of the huge concrete slabs, which looked like a barren parking lot. The corals died from poor water quality because they were near the capital city's sewage marine discharge pipes, long before the first major bleaching event in 1998.

In 1996 the founder and Director of the Maldives Marine Research Institute of the Ministry of Fisheries, Maizan Hassan Manniku, heard about Biorock reef restoration results in Jamaica and invited GCRA to the Maldives to help. We began projects at Ihuru Island in North Male Atoll, working with Azeez Hakeem, former Director of Agriculture. Azeez had grown huge coral gardens around the resort by transplanting corals and cementing them to concrete. He had incredible success, he was at the time probably the master coral gardener in the world. TG filmed all his coral gardens to compare their growth against Biorock. Coral growth and fish populations on the Biorock reefs quickly outstripped both the planted coral gardens and even the natural reef itself: large populations of fishes schooled in the structure in the day and fed at night, or vice versa. The resort had a serious erosion problem, the beach on the south side of the island had washed away, there was a 2 meter high cliff in the sand and trees were collapsing in the sea, with buildings about to follow. They were desperately piling sand bags in front of the restaurant that overlooked the water, and the owner of the resort told us they would have to tear the building down because there was no way to save it.

In 1997 we grew a Biorock reef in front of the vanished beach, and transplanted corals on top. In short order sand piled up under the structure, the beach grew back naturally, the building was saved, and a huge vibrant reef full of stunningly colorful corals and fishes appeared where there had only been bare rock, right in front of our newly grown beach. In 1998 the worst high temperature bleaching event in the history of the Maldives too place, and in weeks 95-99% of the corals on the natural reefs died, along with 100% of the corals in the transplanted coral gardens, but most of the Biorock corals survived the extreme water temperatures. After bleaching, all the fish moved out of the dead reefs into the Biorock reef, and for around a decade, tourists at other resorts would pay to come and snorkel at Ihuru, because the house reefs at their resorts were dead, and only Ihuru had a reef full of bright live corals and fish right in front of a natural beach. This had been achieved using about 3 air conditioners worth of electricity, in a resort with hundreds.



This Biorock reef in the Maldives, built in 1997, survived the severe bleaching event of 1998 and the 2004 Tsunami, and grew back a severely eroded beach, photo 2010 by Azeez Hakeem. Reefs like this can grow to match sea level rise and protect Atoll islands from erosion, as well as grow islands, food, and construction materials.

Following the bleaching, the resort was sold to a foreign operator, who shut the power off, and refused to allow the project to be repaired, monitored, or documented. In 2004 the Asian Boxing Day Tsunami flooded the island, and swept Azeez Hakeem out to sea (luckily, he managed to swim back), but there was no damage to the new beach, reef, or corals. The Maldives was very fortunate to have no major bleaching events for 18 years, and in that time the reefs slowly recovered, but in 2016, most of the corals died from bleaching. Those we had saved in 1998 were no longer protected by electricity due to the resort's refusal to maintain the Biorock project. As a consequence of their pulling the plug on the project, progress in Maldivian reef restoration was delayed for a quarter of a century (Goreau, 2022). European, Australian, and American consultants, hired at high cost, told the Maldivian government that Biorock did not work and that they should not take a 15 minute speedboat ride from the capital to see the projects for themselves. Instead, they recommended, and funded, fragmentation methods like the Newcastle project that fail as soon as the water gets too hot (Foo & Asner, 2020), muddy, polluted, diseased, or rough, instead of using superior methods developed in Jamaica and the Maldives, yet another example of systemic racism Island scientists face from rich countries consultants and funding agencies.

In early 2022, some 25 years after the last Biorock project there, the Maldivian Government Blue Economy advisors requested more information about Biorock, especially to protect large dredge-fill islands now being constructed. GCRA has indicated readiness to train young Maldivians and set up pilot Biorock projects to for reefs that grow to protect eroding islands from sea level rise, save corals from bleaching in Biorock Coral Arks, regenerate eroding tourist beaches, develop sustainable mariculture, produce local carbon negative building material that is cheaper and harder than coral rock or expensive imported Portland Cement (each ton of which releases a ton of CO2 into the atmosphere), and grow floating reefs to produce food for tuna and maintain Maldivian tuna stocks in their own Exclusive Economic Zone, so the tuna stock can be sustainably managed without being stolen by foreign industrial fishing fleets. Biorock can grow faster than sea level rise, so it can also grow islands on shallow banks, and help the Maldives be the first Atoll country to grow their way out of the climate emergency instead of being drowned.

INDONESIA: BALI, LOMBOK, SULAWESI, AMBON

Indonesia is the world's largest island nation, with more than 17,000 islands and the fourth largest population in the world, and the second largest fish catch in the world, after China. It has at least 300 distinct Indigenous Peoples, most relying on the sea for all or most of their protein. Indonesia has the world's largest areas and highest biodiversities of coral reefs, seagrasses, and mangroves, nearly all next to traditional Indigenous lands. Around half the mangroves have been destroyed for shrimp farming, the seagrasses are largely gone, buried by soil eroded after deforestation for agriculture, and more than 90% of the coral reefs have been severely damaged or destroyed, mostly by use of explosives and poisons for fishing, soil erosion, sewage, diseases, dredging, anchor damage, and global warming. Indonesian marine environments are extraordinarily diverse and dynamic, with strong ocean and tidal currents, affected unpredictably by the most active plate tectonic subduction zone in the world. This causes the most violent volcanic eruptions, earthquakes, and tsunamis of any country. Extreme spatial variability of habitats, impacted by severe episodic disruptions, fuels intensive evolutionary selection and genetic exchange between local populations, making Indonesia the global center of marine biodiversity.

TG and the late Wolf Hilbertz have worked with Indonesian divers, scientists, environmentalists, and fishing communities for more than 20 years, and our Indonesian students have built more than 600 Biorock coral reef restoration projects on many islands, around three quarters of all such projects in the entire world (http://www.biorock-indonesia.com/; https://giliecotrust.com/). Biorock has been shown to be the only method that saves corals from dying from coral bleaching (Goreau, 2022), and so is the only hope for maintaining these ecosystems and their priceless economic services, fisheries, biodiversity, shore protection, and ecotourism, in the future.

The major regeneration sites have been in Pemuteran (Bali) and Gili Trawangan (Lombok). When we began after the catastrophic 1998 bleaching event there was only around 1% live coral cover on the reef, and the fisheries had collapsed. In 5-10 years GCRA-trained teams had restored their reefs to around 99% live coral cover, and built up huge and diverse fish populations that restored fisheries of surrounding reefs. These projects have become international ecotourism attractions that drive economies of entire villages, which had been the poorest on their islands, creating a boom in hotels, dive shops, tourism services, and

jobs (Goreau, 2010). Biorock Indonesia teams have built many more Biorock projects in Sulawesi, Java, Flores, Sumbawa, and Ambon, and are developing new projects and training local teams in Halmahera and West Papua.

Biorock reef in Pemuteran, Bali, with author for scale. Photograph 2000 by Wolf Hilbertz.

Same reef in October 2021. Photo by Komang Astika

One of our local partners, Yayasan Karang Lestari (Protected Coral Foundation), received many international awards, including the United Nations Equator Award for Community Based Development, and the Special United Nations Development Programme Award for Oceans and Coastal Management. Despite international accolades, we have never had funding from governments or international agencies (except for UNDP funding described in the next section), and the projects and local staff are minimally supported by small donations from tourists.

Pemuteran villagers are very proud of how they restored their fisheries, and want every other fishing village in Indonesia, a nation of 250 million people on more than 17,000 islands, where 80% of the protein comes from the sea, to do the same. Only 5% of Indonesia's coral reefs, the largest and most biologically diverse in the world, remain in good condition. In recent years many reefs were devastated by severe storms, massive outbreaks of coral-eating starfish and snails, mud from floods, sewage from humans, wastes from fish farms, and global warming-caused bleaching that was worse than that which killed most of the corals in the Great Barrier Reef in early 2016 (which needless to say, got all the publicity).

In 2016 more than 95% of the corals on the best reefs in Bali died from heat shock, but Biorock reefs had almost complete coral survival (see videos at www.globalcoral.org). Growth and settlement of new marine life all around them has made the biodiversity

constantly increase, exceeding that before (Goreau, 2010). Biorock reefs grew back severely eroded beaches naturally in a few months, and could be used worldwide to restore vanishing shorelines (Goreau & Prong, 2017). This astonishingly fast regeneration of beaches is due to two factors: the Biorock reef absorbs wave energy and reduces wave erosion at the shore, and produces large amounts of new coralline algae sand, which builds up under the reefs and along the shore, even where the beach had been progressively eroding.

Biorock Indonesia is seeking funds to renovate and expand these projects, not only in Pemuteran, but all across Indonesia, and train the many remote fishing communities that are asking for help, but who have no tourists who can donate small sums to help maintain them. Biorock Indonesia works with communities across the archipelago, here we discuss only four islands: Bali, Lombok, Sulawesi, and Ambon.

The Balinese people preserve intact traditions of the ancient Hindu high culture of Indonesia. They are traditionally rice farmers and not a Sea People, in fact the ocean is feared as the home of evil spirits and most Balinese are afraid to swim in the sea. Balinese developed the Subak system of rice farming, regarded as the most advanced system ever developed to recycle water, soil, and nutrients at the highest possible efficiency (Lansing, 1991; 2006). Much fishing was traditionally done by fishermen from the island of Madura, where dynamite fishing destroyed the reefs in the 1980s, causing many to move on to Bali, where most of the reefs were then dynamited in the 1990s.

Pemuteran in Buleleng province of Northwest Bali had the largest area of reefs in Bali, and the lowest currents, making it the center of diving ecotourism on the island. The population of Pemuteran originally came from the opposite end of the island, Karangasem, where they farmed the slopes of Gunung Agung, the highest and holiest volcano in Bali. The violent 1963 eruption destroyed large areas of farmland and forced the population to flee. Some refugees were resettled in Pemuteran, empty because it was too dry to grow rice, forcing the people to turn to the sea to survive. Pemuteran was documented at that time as the poorest village in Bali, people slept on dirt floors with their animals.

The development of tourism, based on Pemuteran's beautiful reefs, transformed the economy, but in 1998 massive dynamiting of reefs, use of cyanide poisons, and a devastating high temperature bleaching event killed almost all the corals and caused fisheries and diving ecotourism to collapse. In 2000 Biorock reef projects began, and around 150 Biorock reefs, sponsored by locally owned hotels and dive shops, revived local tourism, beaches, diving, and fisheries. This created massive employment as copycat hotels and dive shops moved in. Surveys show tourists come from all over the world to see the Biorock projects in Pemuteran, and most said that was specifically why they had come. Word of mouth, not advertising, spread the message. By 2015 Pemuteran had become one of the richest villages on the island, from having been the poorest. Immigration into the village by people seeking jobs is now stressing housing and water resources, causing local sewage pollution and harmful algae to spread on the reef. Decline of tourism caused by Covid has been a blessing in terms of water quality improvements, and the Biorock reefs continue to grow beautifully (see recent photographs and video at www.globalcoral.org & http://www.biorock-indonesia.com/).

Biorock projects began a few years later at Gili Trawangan, Lombok with the Gili Eco Trust. Like Pemuteran, diving resorts began because of spectacular coral reefs and fishes, but collapsed when almost all corals died from dynamite, cyanide, or bleaching in 1998. Working with the Gili Eco Trust, some 150 Biorock reefs were installed. Diving on Biorock reefs has become the basis of the economy of Gili Trawangan. Negative pollution consequences started due to uncontrolled expansion and lack of sewage treatment. Covid has stopped tourism, and many immigrants have left the islands, so the waters are clear again and the coral growth is absolutely spectacular (see (https://giliecotrust.com/).

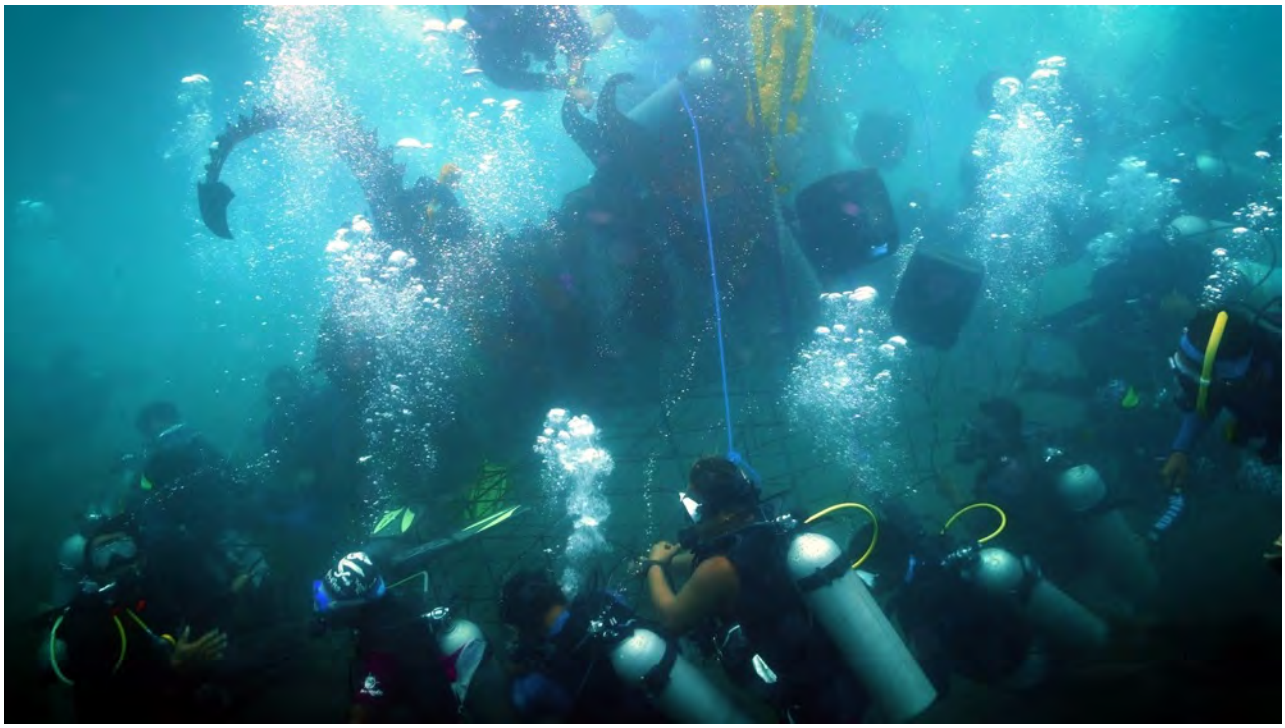
The fishing community on Gili Trawangan are Bajau Peoples, so-called "Sea Gypsies", an extraordinary diving people who live entirely from the sea, usually in floating villages, and have migrated across Indonesia from South Sulawesi. The Bajau people are exceptional divers, and have unique genetic mutations that greatly increase their ability to hold their breath and dive deep, some of which may have come from extinct Denisovan ancestors (Ilardo et al., 2018). Bajau communities are often accused of overexploiting marine resources (TG was once nearly killed by a bomb thrown by a Bajau fisherman while filming a "Protected no-fishing reef" in Sulawesi). In Gili Trawangan they clearly see that a live fish is worth much more than a dead one; they make much less money catching and eating or selling a fish once than they do by selling the same fish over and over again to watching tourists. Migrating Bajau communities have been widely blamed for reef destruction and overfishing by local communities across Indonesia, but if they turn to being reef growers like in Gili Trawangan, their incredible mastery of the waters makes them ideal to regenerate Indonesia's priceless marine resources, the richest and most productive in the world.

In North Sulawesi we grew back severely eroded beaches with Biorock next to a Minahasan fishing village on the island of Pulau Gangga, whose beach had washed away after unwise sea wall construction (Goreau & Prong, 2017). We revived coral reefs, seagrass beds, and fisheries. The village now would prefer to regenerate their coastal resources rather than build expensive concrete walls that keep falling down.

In Ambon we are growing back the last corals in Ambon Bay, where the spectacular coral gardens were first made famous to science in the 1600s by the great naturalist Georg Eberhard Rumpf (Rumphius), who described hundreds of species from fishermens' nets by touch, since he was completely blind (Rumpf & Beekman, 1999), and by Alfred Russel Wallace in the 1800s. Deforestation to grow clove spices for colonial export by the Dutch caused most of the rich soil to wash into the bay and smother the corals, while untreated sewage causes harmful algae blooms. Biorock Indonesia is regenerating Ambon reefs, and to symbolize the peace pact that ended undeclared civil war between Christians and Muslims, built Biorock reefs shaped like a church and a mosque next to each other (http://www.biorock-indonesia.com/biorock-brings-coral-back-in-ambon/).

Indonesia, with the world's largest and most biodiverse coral reefs, mangroves, and seagrasses, is the center of our global marine ecosystem regeneration efforts, because most of these ecosystems in Indonesia have already been badly degraded or destroyed. If Indonesian fishing communities have the tools to regenerate them with Biorock Technology, Indonesia could become the world's largest, and most cost-effective, Blue Carbon sink, and collapsing livelihoods and customs of its hundreds of Sea People

cultures would be rejuvenated.



Biorock Indonesia team installing new Biorock reef in Pemuteran, Bali. The structure represents Balinese Mythological figures.

YOLNGU

The Yolngu people of Arnhem Land, Northern Australia, were the only Aboriginals who never lost their land to forcibly exiled British criminals who committed continental-scale genocide and then declared their god had given them an empty land. The Yolngu fiercely fought invaders trespassing on their lands. White Australians finally decided to leave them alone because they had nothing worth stealing, until rich uranium, manganese, and aluminum mines were discovered on their lands, which were then seized ("bought" with a case of beer, the Aboriginal owners of the land say). The Yolngu have a remarkable society, composed of two separate cultures, the Dhuwa and the Yirritja, with different languages and traditions (Berndt & Berndt, 1954). Each person must marry someone of the other group, and has ritual obligations to both. This is almost unique in human history, two separate cultures who chose to merge as equals and preserve both cultures rather than trying to exterminate the other.

The Dhuwa Yolngu may have the oldest creation story in the world (Witzel, 2012), going back around 60,000 years, remembering the island they came to Australia from and the names and locations of all the places where they lived that were drowned by the sea at the end of the last Ice Age (Mudrooroo, 1994). Their journey across the drowned lands are remembered in secret chants, songs, and bark paintings, strictly limited to the clan authorized to know (Caruana & Lendon, 1997). These oral histories are thought to be the oldest human memories of climate change (Nunn, 2018). The Yolngu of Arnhemland are regarded as the source area of most Australian languages, the Rainbow Serpent Dreamtime myth, bark painting, and the Yidaki musical instrument (called Didgeridoo outside Arnhemland).

Because the area was so remote, and so lacking in any resources white people wanted,

the Yolngu were left alone, regarded as naked black savages. Whenever white cattle ranchers or Japanese pearl divers would try to steal their women, the Yolngu would spear them. After such an incident in the late 1930s the police authorities decided to go in with guns and exterminate them all “to teach the niggers a lesson”. At the last minute, they were convinced by anthropologist Donald Thomson to let him go to talk to the Yolngu to find out if they could be “tamed” instead of slaughtered. Thomson headed alone into the bush and returned years later, having learned Yolngu languages and cultures, and reported that these were perfectly fine people who only wanted to be left alone, and should be given their own designated area to live in (Thomson, 1983). As a result of his advice being heeded, they were the only Aboriginals not to lose their land. However, the Australian government insisted they be forced out of the bush into “civilized” towns, “supervised” by white people, and were sent an “administrator” who was also the missionary to force them to abandon their culture and become Christians, as well as the policeman, judge, jury, the shop keeper who passed out their government dole and took it all back selling them imported white junk food that devastated their health with diabetes, and jailer locking them up if they ran off to the bush for traditional ceremonies. While they were allowed to keep their traditional land rights to hunt game, they were denied their traditional Sea Rights. Until the 1960s the Aboriginal had no legal rights and were classified under the Wildlife Act along with kangaroos and goanna lizards.

The Yolngu prefer to avoid modern society and education as a threat to their culture, but the lean fierce warriors who TG’s grandfather photographed in 1950 are now dying from diabetes caused by white man’s food: white sugar, white flour, white bread, white rice, and white lard, dumped on them by the welfare system. Many wish the white people would just vanish, so they can return to the ways of their ancestors. But most have lost hunting skills their ancestors perfected, and are weakened by dependency on white food or alcohol when they go to the nearest white Australian town, Darwin, where they are routinely abused. Yolngu communities are “dry”, alcohol is banned, which has resulted massive use of an exotic recently introduced Pacific drug, Kava. This has become addictive, whole towns stay up all night drinking kava, night after night.

The Dhuwa bark paintings, describing in secret encoded symbols the lands and the waters they lived in over the past 60,000 years, have been recognized by the Australian Supreme Court as proof of their ownership of their lands. Nevertheless, they have been denied rights to their seas, even though the bark paintings describe all their submerged lands that were drowned by the sea. In 1950 TG’s grandfather, who photographed traditional Yolngu cultural practices in the Crocodile Islands, was adopted as brother to the clan leader of the Dhuwa Yolngu clan whose duty is to preserve these secret ancient histories. They recognize that status as hereditary: TG’s family are custodians of the clan’s oldest, most sacred, and complete bark paintings, and are routinely asked to return for important secret traditional ceremonies that no outsiders have witnessed.

The Yolngu had migrated up the coast as sea level rose since the peak of the last Ice Age, 18,000 years ago. They speared barramundi fish from boats, but avoided diving on coral reefs because of fierce tidal currents, muddy waters, and swarms of deadly box jellyfish, irukandji. Sharks are sacred and if found dead on the shore, are ceremonially buried as ancestors. Now their waters are rented out by the Australian Government to commercial fishermen from outside and the Yolngu are trespassers. Theft of Aboriginal sea rights was

“justified” in Australian law by the Magna Carta, which states that any lands or waters, which somebody does not have a paper deed proving their ownership of, belongs to the Kings of England, despite Aboriginal bark painting documentation of continuous territorial possession going back tens of thousands of years. The Magna Carta states that a fish belongs to no one until it is caught, and then it belongs to the person who caught it. The King’s successor, the Australian Government, sells rights to Aboriginal waters to local and foreign fishing fleets, while denying them to natives of the land. GCRA’s goal is to help the Yolngu regain their sea rights, whose possession is clearly indicated in the bark paintings, songs, and chants, and to scan our family photograph collection of their grandparents’ traditions so they are available to current and future generations of the people who remember their environmental past the longest of any First Peoples on Earth.

TG (back) watches his Yolngu cousin Ronnie prepare a painting with symbols showing ancient events in their history. Photo taken in Millingimbi, Crocodile Islands, Arnhem Land, by Dr. Peter Goreau.

KUKU YULANJI

The Kuku Yulanji Aboriginal community of Mossman's Gorge and the Daintree Rainforest, Queensland, Australia, own offshore islands, including Low Isle, where the Lighthouse and Marine Protected Area is jointly managed by the Kuku Yulanji, the Shire of Port Douglas (the mainland town), and national and state agencies. The Kuku Yulanji were overwhelmed and forced from most of their land by European and Chinese gold miners in the 1800s, then sugar plantations moved in. The sugar plantations used quasi-enslaved labor from Vanuatu, the Solomon Islands and New Caledonia, "kanakas" captured or sold, often at gunpoint, by white "blackbirders", transported to Australia and indentured for years of labor to plantations (https://www.douglashistory.org.au/local-stories/commerce.html). Many were unable to save money to return to their islands, their meager wages consumed by debt for white flour, sugar, lard, and alcohol. Their descendants mixed into local Aboriginal Black communities in sugar plantation areas.

The sugar plantations were established by deforesting tropical jungle on all accessible flat lands, mostly coastal plains and river flood plains. With the forest roots that had held the soil gone, soil rapidly washed away in heavy summer rains, largely driven by cyclones (hurricanes), smothering the inshore fringing reefs which used to line the entire Queensland coast except for river mouths. The Kuku Yulanji used to wade at low tide onto the coastal fringing reef, which provided most of their food, since they had few boats to reach remote offshore island reefs. These coastal reefs that fed them are now dead, suffocated by eroded soil that blocked the light corals need to grow and buried them in mud. Bottom mud resuspended by intensive bottom trawling offshore for shrimp has dealt the coastal fringing reef a doubly mortal blow from both directions. The Great Barrier Reef Marine Park Authority claims these reefs were always dead from natural causes, not human damage, and so is not their responsibility, but the Kuku Yulanji and coastal Aboriginal communities remember when these reefs were a never-failing source of food, vibrant and alive, full of corals, fishes, and beautiful bright blue starfish.

TG visited these smothered reefs at low tide with a Kuku Yulanji family who recalled the vanished living coral reef and all its marvelous life fondly (https://www.kycht.com.au/). The reef was completely buried under mud and sand washed from sugar fields down the nearest river, only at the very edge of the reef where it began to drop off into deeper water could a few dead coral skeletons be found with only their tips poking out of the mud. We went up the river to the sugar fields where the soil came from. The fields had been ploughed right up to the river banks, and were baked entirely barren of life. It was the hottest day in their history, and near the end of the worst drought they had recorded. The hard baked and cracked soil would wash into the river with the first heavy rain.

In the midst of this biological desert stood Andre and Julia Leu's organic fruit farm. They mulch their leaves and compost back into the ground, so their soil has around 10 times higher organic carbon content and holds vastly more water than surrounding sugar cane fields. Their fruit trees were green and the soil was still moist (https://www.remineralize.org/2019/01/a-visit-to-andre-leus-regenerative-organic-fruit-farm-in-queensland/). Andre Leu took a handful of his soil and of nearby sugar cane field soil and shook them up in jars of water. Half an hour later his soil had all settled to the bottom in nice lumps and the water was clear. The sugar field soil jar looked just as opaque

as when he had first shaken it, all the clay in suspension would be washed away in rains. If all their neighbors managed their land as they did, the problem would be solved. Reforesting river banks to hold soil, carbon, and nutrients where they are needed would improve coastal water quality so the Great Barrier Reef can recover.

The reefs of Low Isle are the unfortunate setting of many news reports about the catastrophic death of Great Barrier Reef corals due to global warming in recent years. GCRA has a unique historical record of these devastated reefs, we have photos from Low Isle taken by Sir Maurice Yonge, the leader of the 1927 Cambridge University Great Barrier Reef Expedition, by Fritz Goreau in 1950 (the first underwater photos of the GBR), by Thomas F. Goreau in 1967, when he and Sir Maurice Yonge checked the old sites, in 1998 when Thomas J. F. Goreau (TG) filmed reefs on all sides of Low Isle, and again in 2019. GCRA plans to provide this documentation of their reefs to the Kuku Yulanji community, and is working with the Low Isle Preservation Society (https://www.facebook.com/LIPSinPort/) to initiate Biorock coral reef restoration projects under local community-based management. Our goal is to train Aboriginal Coastal Rangers to manage and regenerate the reefs that the Australian Government has not only failed to protect, it has been complicit in destruction through mismanagement.

ATI

The Ati (Aeta) are the aboriginal people of the Philippines, and have lived there for at least 30,000 years. Called Negritos (little black people) by the Spanish, they have been forced into remote islands or mountains, overwhelmed or marginalized when the ancestors of the modern Filipinos migrated from Taiwan around 5,000 years ago. Only one generation ago, the Ati were the only people on the island of Boracay, where they lived by fishing and hunting (https://en.wikipedia.org/wiki/Ati_people). When it was realized that Boracay had the finest white sand beaches in the Philippines, all their land was taken from them. The Ati still survive in one small village, can't get jobs, have almost no educational opportunities, and survive by sending their small children begging on the streets with blank eyed stares and hands out in the hope someone drops a few coins in them so their families can eat that day.

Their ancient traditional village lands are being claimed by a rich Filipino businessman who is trying to throw them out of their last refuge so he can build a luxury hotel on their beach. His gunmen openly murdered the only educated Ati leader and no case was filed against him. The Philippines Government is now offering the Ati 7.8 hectares, less than 1% of the 1032 hectare island they once exclusively owned (https://www.rappler.com/nation/214985-only-8-hectares-boracay-land-to-be-distributed-to-ati-tribe/)

Boracay has become a mass tourism destination with all the worst features of greed and over-development, crowded slums, prostitution, and whenever it rains people have to wade through raw sewage in the streets. The coral reefs are almost entirely dead from sewage, which also causes skin, nose, throat, and ear infections to divers, swimmers, and kite surfers. GCRA researchers did the two most detailed water quality and reef health studies all around the island in 1997 and in 2007, but none of our recommendations to the Government to clean up the water and restore the reefs were followed.

We have been trying for decades to get back to Boracay with funding to work with the Ati

community to grow back the coral reefs in front of the last Ati village on Boracay, so that they can manage it as an ecotourism snorkeling reserve and set up mariculture projects. They are eager to do so, if there is still time, funding, and government support for their First People rights. Almost all Philippines reefs have collapsed ecologically, and if they are not regenerated he country will lose most of its coastal resources.

VANUATU

The Vanuatu people have developed 113 separate languages and cultures over thousands of years on their archipelago of 83 islands. Vanuatu is one of the poorest countries in the Pacific, its people survived two near genocides, first from European diseases, and then from European and Australian slavers, so-called "blackbirders" who carried islanders off to labor on sugar cane fields in Australia and coconut plantations in the Pacific. Nevertheless, the Ni-Vanuatu people have been rated happiest in the world by international surveys, because the islands are lush, beautiful, and people generous to each other in order to live in harmony. TG has a special bond with young Vanuatu people because they greatly admire Jamaican culture, and he was the first Jamaican they met.

Vanuatu coastal villages fish coral reefs for food, and even though reefs are still among the best in the world, local fishermen were so deeply concerned about decline of their reefs from coral bleaching that they tried all conventional methods of coral transplantation, but found all failed when water became too hot or muddy (conditions that Biorock-grown corals survive). In June, 2016, the United Nations Development Programme funded the Vanuatu Fisheries Department to hold a Biorock coral reef fisheries restoration training workshop. This was attended by more than 100 people, who built and installed Biorock reefs at three sites near Tanoliu, whose coral reefs were dredged and destroyed by the US military in 1943 as landfill for an airport runway, and never recovered (https://www.globalcoral.org/vanuatu-biorock-workshop-june-9-18-2016/). These villagers wanted to greatly expand the projects and start Biorock giant clam farms, and around a dozen other coastal villages requested similar projects.

GCRA feels that Vanuatu is one of the most promising places in the world for reef restoration due to the eagerness of the people, and especially the youth, to restore their resources. Unfortunately, we have not been able to find any funds to continue. We are seeking support to greatly expand training in Biorock coral reef restoration and mariculture methods to fishing communities across Vanuatu, to set up village cooperatives for giant clam and fish cultivation, and as a base to train people from other Pacific Island nations in reef restoration, in particular atoll islanders.

Adults and children at Tanoliu got very involved in the Biorock project. Photos by Robert Lee.

HOTSARARIE

Hotsararie (Helen Reef) is an extremely isolated atoll that belongs to the Hatahobei (Tobi) People of Palau. Hatahobei is one of the very remote Southwest Islands, closer to New Guinea, Indonesia, and Philippines than to Palau, whose people speak a completely different language than Palauan. Their islands have no lagoons, no safe anchorages, and hence very little fish resources, so most of the population has been forced to migrate to Palau, where they form an isolated community, feeling discriminated against by their neighbors.

The Hatahobei peoples' only fisheries resource is Hotsararie, a huge remote atoll 80 kilometers away across the richest tuna fisheries in the Pacific, which the Palau government leases out to foreign commercial fleets. Hotsararie, one of the world's greatest seabird and turtle nesting sites, has only a single tiny sand bar above water at high tide, uninhabitable because there is no fresh water. Hotsararie means "Reef of the Giant Clams" in the Hatahobei language, because it had the most abundant giant clams in the Pacific, and has the highest coral, fish, and invertebrate diversity of any Pacific reef. Hatahobei people could not live there permanently to protect their resources, since they had to sail from Hatahobei to fish and could stay only as long as their water lasted. While they were on their home island, almost all the giant clams were stolen by foreign industrial fishing

fleets, many from Taiwan, leaving the reef barren.

The only dry land on Hotsararie, the sand bar, moves sideways 15 meters a year across the reef flat due to rapid erosion on the west and deposition of sand on the east. A coconut tree planted on the east shore of the island will collapse into the sea on the west shore before it is old enough to bear nuts! The remains of a concrete platform built on the island by Japanese troops in the 1940s sits underwater nearly a kilometer away. If the Hatahobei people lose this sand bar, they will lose control of their entire atoll and its coastal waters.

Hatahobei Governor Sabino Sackarias asked GCRA to grow a solar powered Biorock coral reef to protect Hotsararie from washing away, because they heard of our work growing back beaches naturally and quickly in the Maldives and Indonesia. It took many years to find funding to get there, then we had to wait nearly a year because their only supply boat to carry food from Palau to Hatahobei was broken and in dry dock in the Philippines, so Hatahobei islanders had no supplies at all for this period, living only from coconuts and fish. When the boat was finally repaired, we first had to deliver the rice and betel nuts they were desperate for before going to Hotsararie, where we built a 32 solar panel rack and a Biorock shore protection reef 200 meters long. We were trapped in the lagoon by a Super-typhoon, and when we finally could leave, we were down to the last bag of rice.

Building a solar powered Biorock reef with Hatahobei young people at low tide to protect Hotsararie from washing away. Notice the huge flocks of sea birds over the island. The dark sky is from a forming Super Typhoon. Photo 2004, Wolf Hilbertz.

Unfortunately, we did not have enough time, money, people, or equipment to finish the job properly. Since we had no electricity, we could not weld, so the structure was wired together by hand, and this was not enough to withstand huge logs smashing across the reef, coming from New Guinea, Indonesia, the Philippines, and even from Canada on the opposite side of the Pacific, logs of Douglas Fir with characteristic rocks from British Columbia wedged between the roots. Our solar panels are stored on Hotsararie, but we have no funds to get back there with the materials we need to finish the job, so the island continues to wash away. If we can raise funds, we will go back to help the Hatahobei people save Hotsararie.

TG has lived in every single atoll nation: Maldives, Tuvalu, Kiribati, and Marshall Islands, and all their islands are washing away. Millions of dollars have been spent by foreign aid agencies building sea walls, and every single one has collapsed, many before they finished building them, or soon will. Biorock beach restoration projects at Pulau Ganga, Sulawesi, Indonesia, grew back a 300 meter long beach in months, increasing the height of the beach by about 1.5 meters and the width by about 10 meters (Goreau & Prong, 2017). It is the last hope for atoll countries to save themselves from global sea level rise, nothing else works (https://www.globalcoral.org/climate-proofing-coastlines-with-biorock-technology/). We hope Hotsararie and Hatohobei will be among them.

BIKINI ATOLL

Bikini Atoll has been inhabited for some 3,500 years by the master mariners of the Pacific, people whose boats staggered Europeans not only because of their incredible speed, sailing circles around the fastest European boats, but because they could go just as fast backwards. The Bikini people, despite their remoteness, were not isolated because they could sail wherever they wished. They were essentially untouched by colonialism. A couple times a century Spanish or Germans would show up and demand they all work to produce copra for them, then they would sail away. World War I, when German rule was replaced by Japanese, and World War II, when Americans replaced Japanese, hardly affected them. But in 1946, a US Military Task Force suddenly showed up and told them to leave as fast as they could pack, their Atoll had been selected in Washington DC for nuclear bomb testing, precisely because of its isolation (Kiste, 1974; Niedenthal, 2001).

The Bikinians packed all they could carry onto landing craft that would carry them away from their homeland forever. The entire population of 167, against their will, abandoned their houses, their chickens, and their crops behind, trusting American promises that they would “soon be back”. In short order, they were replaced by 42,000 American men, living on hundreds of naval warships and a whole tent city built on top of their abandoned village, complete with (all-male) bars, movie theatres, bowling alleys, and unlimited food and beer.

The huge lagoon of Bikini Atoll was full of huge corals that rose vertically 200 feet from the bottom and grew right up to the surface. These reefs were immediately dynamited so warships could anchor in the center of the lagoon to be bombed, and not sink on the reefs first. No documentation was ever made of 200 foot tall coral reefs before they were blasted into oblivion, along with thousands of years of environmental records their coral skeletons contained, just a quick practice run for the REALLY big bombs to come, the biggest the world had ever known.

Like rich boys with unlimited toys, they proceeded to blow up a series of nuclear bombs, in the air, in the water, deep underground, just to see what would happen if their own troops were exposed to sufficient nuclear radiation. They quickly found out that they would die, and in doing so made Bikini uninhabitable with nuclear radioactivity for up to a quarter of a million years, until the plutonium decays away. They irradiated themselves first, but most terribly, they even managed to irradiate the exiled Bikinians too on the remote barren desert island where they abandoned them to starve.

For thousands of years Bikinians had one of the largest atoll lagoons, full of corals and fish, at their disposal, suddenly they were dumped on Rongerik, a tiny uninhabitable barren island with no fresh water, no lagoon at all, no reef to fish in, and soon their water and then food was gone. They weren't too worried then, they expected to go back home to Bikini in weeks as soon as the Americans went away. A passing Navy plane accidentally passed by and found them starving, and arranged for a small airdrop of water and food, soon exhausted. They had been put on an uninhabitable island up wind from Bikini, so they would not be affected by nuclear radiation fallout, but when the time came for the boys to blow up their big toys the wind was blowing the wrong way, in the reverse direction to normal. The boys were not willing to wait for their fun, they blew it up anyway even though they were warned that was against the guidelines and would contaminate innocent people. The radioactive cloud hit the US task force first, it blew in most concentrated form right over the American barrack cities on Bikini and Enyu islands where the troops were based, and then continued out to sea, passing right over the island where the Bikinians were starving.

Radioactive white powder flakes fell from the sky, the children thought it was the snow they had seen only in pictures, they rushed out to play and dance in it, rubbing it on their hair and skin, which soon began to fall off in large patches. Months later women gave birth to "jellyfish babies" transparent embryos you could see through, with no bones. Many later died of various cancers.

The survivors of this horrific treatment were then forcibly evacuated again, not home to Bikini as they pleaded, but to tents along the side of the air force base runway at Kwajalein atoll! After some further delays, Ujelang, an uninhabited atoll was found for them, but they rejected it, it too was uninhabitable because of lack of water, and anyway it had already been given to the nuclear exiles from Enewetak Atoll, the US alternate nuclear bomb target. Finally, another uninhabitable island, Kili, was found for them that was further south, and there they were dumped again. This island, although much wetter than Bikini, was uninhabited because it had no lagoon at all, only a narrow fringing reef with no landing beach (their only supply boat was soon wrecked), and waters so rough that most of the year they couldn't even get into the water to chase the few fish. They became entirely reliant on food aid, if it came. There on Kili around two thirds of the Bikinians remain, essentially isolated from the rest of the world except for occasional flights bringing white rice, white flour, and frozen chicken necks and backs from Arkansas. As there is little employment or services on Kili, about a third of the Bikinians migrated to the capital atoll Majuro, where they are isolated on Ejit, a tiny islet on top of the reef flat, which they have to wait for low tide to wade across three tidal passes to get to.

Starting around 15 years ago, Kili and Ejit began to flood with sea water during unusually high “King” tides. Most of the islands are now inundated with sea water once or twice a year. This floods homes, contaminates wells with salt water, and kills fruit trees like mangoes, bananas, and breadfruit. Even coconut trees are dying in the worst flooded areas. Year by year it gets worse, and soon the islands will be uninhabitable unless they can regenerate their natural coral reef coastal defenses (https://www.globalcoral.org/climate-proofing-coastlines-with-biorock-technology/).

Our work in Bikini began in 1946 when TGs grandfather was Official Photographer of the Operation Crossroads Task Force, documenting the effects of the first nuclear bomb tests on ships, people, experimental animals, birds, coconut crabs, and marine life. He photographed the homes the Bikinians had abandoned, their chickens still searching for food, the birds, the mangroves, the coral reefs, the fishes, and he showed how their bones and organs were so radioactive they could take their own photographs. These photographs are the best record of how Bikini was before, and immediately after, and most have never been shown, except by TG to the Bikini community in 2019, 73 years later. In 1947 a massive scientific study was done of the impacts, the Bikini Scientific Resurvey, supervised by Dr. Roger Revelle. TG’s father was Revelle’s graduate researcher, and measured the Carbon Dioxide, Oxygen, and acidity of the waters and air to determine how quickly Carbon Dioxide was exchanged between atmosphere and oceans, and quantify the metabolism of the entire ocean ecosystem, the photosynthesis, respiration, and calcification of the reef through tidal and day/night cycles. If repeated at the same locations, they would provide the world’s longest record of coral reef response to ocean acidification. He was the diver who collected rare specimens for radioactive measurement, including the first poisonous coral-eating Crown of Thorns starfish collected alive, they hid deep in submarine caves in the day and came out only at night to feed. He died of acute Bikini radiation-caused cancer at the age of 45.

Bikini Atoll is a UNESCO World Heritage Site, marking the “Dawn of the Nuclear Age”. Luxury dive cruise ships are the only visitors, diving on the sunken fleet bombed to the bottom in 1946 and the big sharks around them. But there is no plan for its management. Radioactive wastes on Bikini and Enyu islands were bulldozed flat and buried under dynamited dredged up coral reef fill. Then coconuts were planted on top. These are the most sickly-looking coconuts TG has ever seen, and the juice of one exceeds your annual radiation limit. Bikinians used to eat a dozen a day since they often had no fresh water in their wells! The devastated islands of Bikini and Enyu are overrun with imported invasive weed plants, rats, cats, and cockroaches, and have no native nesting birds. The uninhabited islands not blasted into oblivion have natural vegetation and are some of the world’s most important sea bird nesting sites. These would be wiped out if rats and cats arrived from the two big ruined islands on the atoll, which are on the up-current side of all the natural islands, so it may just be a matter of time, since there is no management plan at all.

In 2019 TG looked at the condition of the coral reefs around Kili, Ejit, and Bikini. He found that almost all the corals had died from a bleaching event a few years before, and he found more bleaching was underway among the few surviving corals. He also found clear signs on Bikini atoll showing that sea level has risen over decades, but had suffered a smaller but very recent drop, killing coral that was now exposed to air. This recent drop reflects not

long-term global sea level rise, about 3-4 millimeters per year, but instead short-term weather patterns. Sea level in the Central Pacific can vary by tens of centimeters from year to year, depending on how atmospheric pressure changes during El Niño Southern Oscillation (ENSO) cycles, which are unfortunately not predictable.

The Bikini people, having been expelled from their homeland, starved, irradiated, and abandoned, are now losing their coral reefs to global warming and their islands to global sea level rise. Either they will be forced to abandon their exile islands and their ancient way of life, and leave forever, or they can grow solar powered Biorock reefs, which can grow up to 10 times faster than current sea level rise, regenerate beaches, fisheries, coral reefs, sea grass, and mangroves, and provide new opportunities for highly productive mariculture. A pilot Biorock project was built in front of the flooding school on Ejit. GCRA is looking for funding to grow reefs to protect all of Ejit (https://youtu.be/cv2h8Uv-MEs?t=1116), Kili, and other atoll islands (https://www.globalcoral.org/shore-protection-in-the-republic-of-the-marshall-islands-pilot-project-report/).

The US Government has absolved itself of all further responsibility from cleaning up the toxic wastes they left behind on Bikini and Enewetak Atolls. Biorock should also be used to seal in the highly radioactive wastes that the US military buried under concrete on Enewetak Atoll. That allegedly “impermeable seal” was supposed to last 250,000 years, until Plutonium decays to safe levels, but it is now cracking open, and global sea level rise is flooding it, releasing radioactive wastes to the rising tides. As always, the polluter should pay!

Waves break through the fence and flood the Ejit school during King Tides. 2019 low tide photo by T. Goreau

Bikinian schoolchildren at Ejit Island, 2019. TG has just shown them photographs of how Bikini Island looked in 1946, and built a small Biorock project to protect their school from flooding.

CONCLUSIONS: EXTINCTION, MIGRATION, ASSIMILATION, OR REGENERATION?
Each of these cultures now faces environmental changes and economic pressures that demand adaptations beyond their past experience. Some are well placed to adapt, others may find it impossible, or even undesirable. Indigenous cultures face four fundamental alternatives: extinction, migration, assimilation, or regeneration.

Physical extinction by outright extermination, has historically been most common. Cultural extinction, often by enforced migration to areas impossible to survive in, or assimilation, where the language and culture is completely destroyed and replaced by that of their conquerors, even though the people themselves were not killed, but become a slave underclass or caste, has been next most common. Forced migration removes them from the very land itself, and usually results in loss of culture and assimilation unless they are lucky enough to find an empty land and preserve their language. Some Indigenous environmental knowledge and practices, particularly with regard to plant crop cultivation and processing and fishing methods, were preserved as “folk culture”, as in Caribbean islands, but often such knowledge was deliberately destroyed by Christian or Muslim missionaries as “works of the devil”, suppressed in order to ensure complete subjugation to dogmatic religious and cultural obsessions of the conquerors. Indigenous People have usually been forced to disappear into the invaders’ culture as slaves or at best a subservient lower class, usually losing their language in the process, with their original separate cultural identity often denied outright (“they really don’t have any language or culture of their own, they just speak our language, but badly”).

The last alternative, regeneration, can take two very different trajectories: a purist “back to the past” approach that rejects all external innovations, or a hybrid that preserves past wisdom, but also learns and adapts the best of outside knowledge to local ends. The first is an extreme conservative reaction, which some groups strongly favor, the second is a new and radical step by cultures that are secure in their cultural heritage, confident in their traditions, and willing to embrace useful new ideas on their own terms, rather than feeling threatened by them. Because the changes we face will far exceed anything our past traditions prepare us for, only in this last regeneration scenario are biological and cultural diversity, biomass, and ecosystem services likely to be preserved.

Difficult choices lie ahead for all people that can no longer be avoided. The challenges of climate change in coming years and decades lie well beyond the traditionally documented experience of any society. Because the old skills and adaptations will mostly no longer work, going back to the past may no longer be possible when everything has changed everywhere. New technologies, new skills, and new concepts will be needed to meet them. Habitual business as usual will only cause intensified degeneration of the habitats and resources of each of the 22 Sea Peoples examined here unless dramatic changes are made by each of them to learn new approaches to regenerate their own habitats for the long-term benefit of their descendants, wherever or whoever they are. To seize this crisis as an opportunity, Indigenous and Endogenous Sea Peoples need to blend the best of modern scientific knowledge with traditional experience of climate change within greatly strengthened capacity to defend, regenerate, and sustainably manage their own natural resources. Some are better prepared for future challenges than others. Those failing to learn new Biorock methods to grow up faster than sea level rise will eventually see their natural and cultural resources wither and vanish, they must sink or swim. Sea Peoples should play a critical role by regenerating their living shorelines with new technology to become carbon sinks that adapt to, and help reverse, climate change.

RECOMMENDATIONS:

Regenerating tropical Green Carbon (Land Biomass), Blue Carbon (Ocean Biomass), and Brown Carbon (Soils, especially marine peat soils, the most carbon rich of all) are key to growing our planet out of the Climate and Extinction Crises about to really hit hard this century. Regeneration of Indigenous and Endogenous managed ecosystems by conservation and active regeneration is the most beneficial tool to maintain our planetary life support systems, the quality of the air we breathe, the water we drink, the food we eat, and the satisfaction of living sustainably. We call for full recognition of Sea Rights to traditional Indigenous and Endogenous Sea Peoples, along with designated long-term environmental management responsibilities, exclusion of industrial offshore fishing fleets from their waters, an end to all subsidies to offshore fleets and the funding transferred to support community-run regenerative coastal fisheries management. Let us hope the rest of the world allows Sea Peoples to save themselves and the planet!

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gratefully acknowledged. I specially thank Marina Goreau for review and critical comments.

DEDICATION

This chapter is dedicated to my close friend, the late Rogeliano Solis. Environment Advisor to the Congreso General Guna. He was a brilliant marine biologist who studied in Panama, Spain, and the US, fluent in Dule, Spanish, and English. His dream was to use Biorock to establish sustainable lobster mariculture and grow islands in Guna Yala, but his life was tragically cut short by cancer. TG worked closely with him for 18 years to help his people restore their fisheries and coral reefs and save their islands and unique culture from being lost to global warming and sea level rise. We continue to seek support to develop his mission of Guna sustainable development through restoring their natural resources.

https://www.globalcoral.org/rogeliano-solis-in-memoriam-panama-indigenous-environmental-leader/

Rogeliano Solis, d. February 19 2014

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