REEF REMINISCENCES

Ratcheting back the shifted baselines concerning what reefs used to be

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Ratcheting Back the Shifted Baselines

Peter F. Sale and Alina M. Szmant

Baselines shift. People take their early experiences and build a vision of what their world is like. This vision is the baseline against which new experiences are compared. This is true for those of us contributing to this booklet. The habit of building baselines anew each generation would serve us well if we lived in a world which changed only suddenly, but it risks us failing to notice slower, long-term changes.

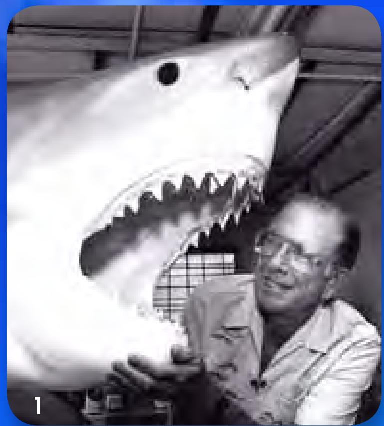
Coral reefs appear to be changing in a number of fundamental and detrimental ways. Many reef scientists, comparing coral reefs to canaries in a coal mine, argue that coral reef deterioration is an early warning of major global environmental disruptions in the coming decades. The tragedy of recent coral reef decline is that too few people actually know what coral reefs are supposed to be like, and too few of those who now study reefs witnessed what coral reefs used to be like decades ago.

To begin with, *in situ* observation of coral reefs is something that barely existed before the 1950s. Technologies for capturing visual records of reefs are all quite recent, although there are impressive photographs of reef flats exposed at low tide from the late 19th century. Deciphering what a coral reef may have been like centuries ago from the writings of early naturalists, or the less technical writings of seafarers, fishermen, and voyagers can be challenging. Geological studies can tell us much about reefs in the distant past, but patterns of change are hard to discern at scales less than 1000 years. Coral reef science is young although its roots go back before Darwin. It struggled until scientists were able to explore reefs the same way they explored other environments, up close and personal. The explosion in reef research that occurred since the 1960s can certainly be tied to Cousteau's invention of the first SCUBA regulator and the prolonged access to deeper reef environments that it provided. The first International Coral Reef Symposium, hosting fifty reef scientists, was held at Mandapam Camp, India in 1969. The 12th International Coral Reef Symposium is being held in Cairns, Australia in July 2012, and about 2500 people from 80 countries are expected.

Coral reef science has changed in many ways: the questions being asked, the approaches used to answer them, the technologies available, and the accessibility of reefs. These changes get forgotten, much as do changes in the reefs themselves, because we quickly shift our baselines as we adopt new technologies. Who dwells on the struggles to do math calculations with slide rules when now we can just whip out our cell phones? Modern scientific writing does not permit lengthy discussion of the logistical difficulties inherent in accessing coral reef systems, but if it did, we would see that while there are still plenty of challenges in our field, it is much easier to study coral reefs today than it was just a few decades back.

This booklet began when a brief exchange of e-mails on Coral-List touched on what reefs were like a few decades ago. It dawned on us that the great majority of new reef scientists are young enough that their baselines were set very recently. They are exploring long-term changes without the benefit of a hindsight that goes back more than a decade or so. It seemed worthwhile to collect some information from the 'early years', bring it together, and make it available. It also seemed desirable to avoid a typical academic approach, since most of our recollections are not quantitative anyway. We invited a number of scientists our age or older to join us, and asked each of them to write a short essay about their earliest coral reef experiences. We particularly asked for comment on what the experience was like, and what it meant to these, then young, scientists. All our contributors were pioneers, three were present at Mandapam Camp, and each has had an impressive career, fledging graduate students who have made their own contributions. We were limited in how many scientists we could invite, and some invitees were unable to join us, but in releasing these stories, we are inviting others to contribute their own for what could become the collective memory of coral reef science. And a warning: we may never know how shifted our own early baselines are from what may have been the 'natural' state of coral reefs a millennia ago, before early human populations settled reef islands and coastlines, and began exploiting them.

It has been delightful working with our contributors to put this booklet together. We now have photographic proof that some of those old guys (women do not age) we see at conferences were actually young once, and even good looking, with hair. These engaging stories capture the flavor of reef science in the 1960s and 70s, and the kinds of reef environment within which we played. The enthusiasm of our participants has been infectious, as is their cautious optimism concerning reefs in the future. But if the future is going to be as dim as some of us fear, our stories will help us truly know what we are losing. Knowing this is an important step in building the will to fight for a brighter future.



1

Reminiscing Reef Encounters

John E. Randall

"The first view as a snorkeler or a diver of the marine life of this zone is a never-to-be forgotten experience"

In the summer of 1946, after being discharged from the U.S. Army, I tried skindiving from the rocky shores of Palos Verdes in southern California. The earliest swim fins were shaped like frog feet, and the facemask was round with a hard narrow rubber edge that had to be carefully cut and sanded to fit one's face. I enjoyed skindiving in the kelp beds but I could not remain in the cold sea (average August temperature, ~20°C). I dipped my U.S. Army longjohn underwear into a washbasin full of latex rubber, hung it up to dry, and may have invented the first wet suit.

After graduating from UCLA in 1950, I sailed a 37-foot ketch to the Hawaiian Islands to enter graduate school in the Department of Zoology of the University of Hawai'i. My first dive was on the Kona coast of the island of Hawai'i. Such a contrast to the shores of California! Warm clear sea, live coral, colorful reef fishes, and my first encounter with a Green Sea Turtle. One year later, I was selected

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to assist invertebrate biologist A.H. Banner at Onotoa Atoll in the Gilbert Islands (now the Tungaru Islands of Kiribati). At low tide on one calm day, I walked across a broad reef flat on the lee side of the atoll to dive the outer coralliferous terrace, which sloped about 3 m for a distance of ~60 m before ending in an abrupt drop-off. The sea was incredibly clear and the substratum almost entirely carpeted with live coral, mostly species of *Acropora* that I had not seen in Hawai'i (of ~325 species of this genus, only 3 are rarely found in Hawai'i). I did recognize a few fish species found in Hawai'i, but was overwhelmed by the number I was seeing for the very first time. I remember writing, "*The first view as a snorkeler or a diver of the marine life of this zone is a never-to-be forgotten experience.*"

Shortly after being hired by the University of Miami in 1957, I obtained a National Science Foundation grant to study the ecology of the coral-reef fishes of the Florida Keys. When a request came from the National Park Service to direct a marine biological survey of the Virgin Islands National Park I was able to transfer the grant and spent the next three years with my family on the island of St. John. My first task was to chart the marine environments of the island. I alternated with a graduate student being towed over the inshore waters while my wife Helen carefully plotted our transects on aerial photographs. A band of bare sand between the fringing reef and seagrass beds showed on the photographs and made the mapping easier. I suspected seagrasses did not grow in this sand zone because of overgrazing by herbivorous fishes that do not venture far from the shelter of the reef. I built a small artificial reef out of concrete blocks in the seagrass and linked it with a corridor of blocks across the bare sand. A halo of bare sand then developed around the blocks in the seagrass. I built a large artificial reef farther out in the seagrass bed and observed its colonization by reef fishes, mostly from recruiting prejuveniles, especially grunts (*Haemulon*) and snappers (*Lutjanus*). Two years and four months later, all the fish were collected. Their total weight was 11x the biomass of comparable collections made from the fringing reef. Grunts and snappers are nocturnal. They range onto adjacent seagrass beds at night to feed and shelter in the reef by day. The productivity of the artificial reef was greatly enhanced by the surrounding seagrass.

Near the end of my stay on St. John, the National Park superintendent asked me to investigate a coral reef off Buck Island near St. Croix. I resisted because I could not imagine that it could be any better than the reefs of St. John. He persisted, adding that he would send over the Park Service launch and provide a helicopter for aerial view. As we flew over, I was surprised to see a well-developed barrier reef surrounding a major part of the islet that I had not seen elsewhere in the Virgin Islands. Inside the reef

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was a clear emerald lagoon with spectacular colonies of Elkhorn Coral (*Acropora palmata*), Brain Coral (*Diploria labyrinthiformis*), and a multitude of colorful reef fishes. I made a motion picture film undersea and from the air. I was told that this documentary was a major factor in the islet being proclaimed Buck Island Reef National Monument by President John Kennedy in 1961. My study of reef fish ecology was completed during four years at the University of Puerto Rico.

I returned to Hawai'i in 1965, and soon thereafter was asked to visit Palau to recommend a site for a marine laboratory. There I found an even higher magnitude of reef diversity. This was unexpected, as Palau is part of Micronesia, and I had already dived at other islands of Micronesia, including the Marshall Islands, Pohnpei, and Guam. The Marshalls have 845 species of reef and shore fishes, whereas Palau has 1,387. I was also astounded by the diversity of marine invertebrate fauna of Palau (estimates of over 300 species of corals and 150 soft corals). A chart of the islands of the western Pacific reveals the answer. Palau is linked by a series of small islands and reefs to Waigeo, near the center of the richest marine faunal area in the world, the Coral Triangle, which includes New Guinea, Indonesia, and the Philippines. An incredible 2,228 species of reef and shore fishes are known from this region, and 605 species of corals!

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The warming of tropical oceans during the summer of 1998, triggered by an El Niño event, led to the greatest increase in sea temperature in modern time. In June of that year, I took my granddaughter Sandra, then 18, to dive at Redang Island off the coast of Malaysia. I was surprised by the many coral colonies that were bleached a ghostly white. Diving later in Fiji, I was depressed when I saw the vast stretches of dead coral that had once been luxuriant shallow coral reefs. There are predictions that reef-building corals will be extinct within 30 to 50 years, along with all the life dependent on corals, if mankind continues with CO_2 emissions at the present rate. Sadly, the rising sea level at atolls and developing nations like Bangladesh barely above sea level, whose CO_2 emissions are negligible, will be the most devastated.

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In addition to the predicted impacts from climate change, the earth is now experiencing the highest extinction rate in recorded history from the degradation of environments, introduction of invasive species, and the overexploitation of biological resources. Over a span of 62 years I have witnessed an alarming reduction in the populations of reef and shore fishes in the Hawaiian Islands. It is estimated that reef and shore fish stocks in Hawai'i are now ¼ of what they were 100 years ago. The attempts to conserve fish stocks, such as quotas, size limits, gear restrictions, and temporary closure of fishing areas, have all failed in the long term. I have been among the proponents for the creation of a system of marine reserves with a minimum of 20% of the Hawaiian Islands coastline. Fishermen have strongly opposed, and none of the proposed reserves has been created. The few marine reserves we do have are very popular with snorkelers and divers; Hanauma Bay on O'ahu has had over a million visitors per year. The campaign for more marine protected areas will continue.

I am most grateful to Sandy Hillis-Starr for his aerial photograph of Buck Island and Dr. Patrick L. Colin for his underwater and aerial photographs of Palau from his book Marine Environments of Palau.

Tiahura Coral Reef Site Moorea, French Polynesia

Bernard Salvat

"...we met in Madapam Camp, India, for the first International Symposium on Coral Reefs (ISCR), with less than 50 participants"

WHEN? My first dives and research paper on coral reefs were in New Caledonia, early in the 60s. It was an impressive first experience for a young biologist (not yet an ecologist -- the word was less used then) ending his doctorate at the Sorbonne on crustaceans of the Atlantic beaches. In the mid 60s I had the opportunity to work on many atolls in the Tuamotu archipelago and coral reef ecosystems in other French Polynesian high islands. In 1967, due to the leadership of David Stoddart we met in Madapam Camp, India, for the first International Symposium on Coral Reefs (ISCR), with less than 50 participants!

WHERE? In 1971, I planned to launch a small research station in the Pacific to develop French coral reef research. I chose French Polynesia because the reefs surrounded small insular systems less complex (at least in terms of biodiversity) than in the west Pacific and also because of the important cultural ties linking reefs and Polynesian communities.

Tahiti was not as developed as today, but Moorea, the sister island of Tahiti was not too far from Papeete, and appeared to be a good compromise between a busy island and a "remote and natural" one. One boat per day, embarking only one car, linked the two islands. I had already had the opportunity to see by plane the wonderful coral reef system surrounding Moorea, so I landed and went all around the island on its three sides, each of about 20 km, partly on coral sand roads or just walking between coconut palms.

HOW WAS THE REEF COMPLEX? On the north-west part of the island I climbed a small hill – some hundred meters altitude – from which I contemplated a magnificent reef system which was later named the "Tiahura site". A natural channel with deep blue water half way out, separated a fringing part from the barrier portion. Except for the channel, coral and algal communities seemed submerged by no more than a few meters. I knew from maps that the entire coral reef belt surrounding the island was less than a kilometre wide, from the white coral sand beaches edged by coconut palms to the forereef facing the ocean. At the Tiahura site, it was about 800 m wide. Waves from the ocean were breaking on the reef front and covering part of the barrier. Off the front, the ocean was as blue as the sky on a sunny day. I realised that this small coral reef ecosystem extending just 800 m from land to ocean would be easier to study than the very large ones I knew in New Caledonia, and very different from reefs bordering atolls (reef flat and reef crest). In a few hundred meters all conditions from rough ocean exposure to calm waters were probably organizing the distribution of all algal and animal species and communities. More than that, to the right of the seascape was a pass through the reef, the Tiahura pass, where waters coming over the reef crest and the barrier reef were thrown back furiously with turbulence to the ocean. I imagined the outer slope with a high coral cover as the constructive part of the system compared to shallow barrier and fringing reefs with patches of corals and sand. Such a site with a laboratory near the beach and not too far from the pass would be excellent. Later in the week, I went back to this north-west part of Moorea to swim from the beach to the reef crest, discovering healthy coral communities and lot of invertebrates and fish. All were arranged in successions from calm to rough waters. Branched corals and algae were dominant on the fringing reef with a lot of holothurians, the channel was sandy and the barrier reef - no more than 2 meters depth - was increasingly dense in massive *Porites* coral heads as we progressed toward the reef crest. There was no need of scuba diving to study the whole ecosystem, except for the outer slope where strong currents in the pass demanded a boat.

"Such a site with a laboratory near the beach and not too far from the pass would be excellent"

The first research facility was established by renting a Polynesian house on the beach just in front of the Tiahura pass. It became the "Antenne Museum EPHE" of Moorea, Tiahura, named to recognize the two French institutions supporting this first implantation. This was our research facility until 1981 when the research station moved to the Bay of Opunohu into new buildings constructed by the local government when we renamed the facility the "Centre de Recherches Insulaires et Observatoire de l'Environnement" (CRIOBE), now being directed by Professor Serge Planes through the "Ecole Pratique des Hautes Etudes" and the "Centre National de la Recherche Scientifique" et "Laboratoire d'Excellence Corail".

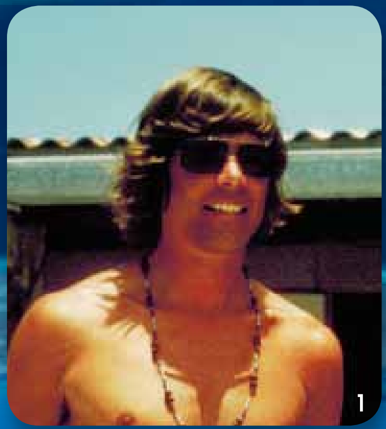
WHAT HAPPENED? Time passed on the Tiahura site, and a lot of degradation occurred due to natural catastrophic events and human activities. Among the most important disturbances were bleaching, Crown-of-Thorns outbreaks, and cyclones. Bleaching with heavy mortality occurred in 1991, 1994 and 2003. Crown-of-Thorns demographic explosions lasting several years commenced in 1971, 1981 and 2006, and drastically reduced the coral cover on the outer slope (to as little as 5%). Cyclones, especially in 1982-83 (5 cyclones) but also in 1997, 1998 and recently in 2010, have all caused damage. All these events caused important damage to the reef ecosystem but their frequency was not sufficient for reefs to not recover. We think that such events were more frequent during the past half century than before but we do not have proof of this for the French Polynesian coral reef ecosystem.

"...a lot of degradation occurred due to natural catastrophic events and human activities"

On the other hand, we are sure that major degradation came from human activities over this same time span as mentioned in hundreds of papers published by scientists since 1971. Sand extraction to provide construction material started in the fringing reef to the east of the Tiahura sector as early as 1975, and we began to fight with authorities for a ban on such practices. In 1991, the construction of a hotel just in front of the Tiahura pass commenced with a lot of digging and construction of artificial islets for bungalows on the lagoon. Inside the Tiahura sector, two large and deep channels were dug from the beach toward the pass across the entire fringing reef. This work has continued to cause increased turbidity and sedimentation on neighbouring habitats and coral reef communities. Another small and very shallow channel dredged along the beach front has completely disturbed the hydrodynamics of the Tiahura fringing reef. Water transported onto the fringing reef by waves and swell from the ocean is immediately collected by this channel without any backwash and the result has been an important drop of the low tide water level all over the fringing reef with an important degradation and change in community structure. Since 1971, Moorea's population has increased threefold and tourism arrivals have exploded. The result has been a lot of nutrient pollution which favoured algal communities in the fringing and barrier zones. Some mollusks such as the giant clam *Tridacna maxima* which are part of the cultural diet for Polynesians have been overexploited and disappeared in the lagoon.

"The whole Tiahura site, from the pass to the lagoon islets in the west, is now fully protected"

There is some good news. Stabilization and restoration efforts have been launched in the context of a general framework for coral reef conservation with protected areas all around Moorea. Across Moorea, collection of shells and corals is banned and tourism activities are regulated. The whole Tiahura site, from the pass to the lagoon islets in the west, is now fully protected. Nevertheless major damage remains on the fringing zone and loss of biodiversity has occurred in the whole lagoon. The outer slope coral communities continue to change from healthy to degraded according to natural catastrophic events, as has long been the case.



1

One Tree Island – a Special Place and a Special Time

Peter F. Sale

"…lots of reefs could provide such experiences even today, but reef scientists now seem too hurried, and field work is never done alone"

When I arrived in Sydney late in 1968, freshly minted PhD in hand, there was only one research facility on the Great Barrier Reef. Soon after arriving I headed north to Heron Island; two days by car to Gladstone, followed by an eternity on the MV Saramoa. As fat and sluggish as her name, Saramoa had been designed to roll deliciously through a 150° corkscrew with, a cute little hiccup on the crest, whenever she faced a beam sea, while diesel fumes made a U-turn at the stern, and wafted gently into the open cabin. The trip from Gladstone to Heron Island was always on a beam sea; tourists arrived at the Heron Island Resort damp, bedraggled, and a greasy shade of green-gray. At Heron Island, I left the tourists, crossing to the down-market side of the island where the Great Barrier Reef Committee maintained the Heron Island Research Station – a group of two houses for staff, a kitchen, a lab building with lots of bench space and zero equipment, and a set of basic sleeping cabins.

"…it was me, lots of fishes, and a reef environment that stretched out for many km in all directions"

Barely 30 m across the beach was a reef that stretched almost 1 km out to a steep slope and a deep channel. If the station was modest, the reef was all I could have asked for. Once out on the reef slope, it was me, lots of fishes, and a reef environment that stretched out for many kilometers in all directions. Heron Island became my field base for 4 years, during which time I struggled with fish whose names were known only to ichthyologists (and they kept changing them), and with corals whose names seemed not to be known at all.

Twenty kilometers east of Heron Island, still further from civilization, lay One Tree Reef and its tiny island. Frank Talbot had 'colonized' One Tree, claiming possession for the Australian Museum, and had built a still more basic field facility, then managed by Ted Chilvers. In August 1974, after discussing it with Ted off and on over several months, I made my first visit to One Tree. By that time I actually had a research assistant, and so Rand Dybdahl and I set off one morning in my 3 m runabout for an overnight visit. Despite the distance, we were only briefly out of sight of land and seldom in deep water. It was one of those magically calm days when the sea is still, and some of the butterflyfishes, damselfishes and wrasses get confused and can be seen swimming about upside down beneath the surface, instead of 15 or 25 m below on the reef where they belong. Our trip was uneventful, and we crossed the shallow sill into the One Tree lagoon with plenty of water under the prop.

I was captivated immediately. The reef itself was nearly as large as Heron Reef and lush with coral. The lagoon, particularly rich in patch reefs, was ponded at low tide. The island was silent, because there was no generator, no tractors, no machinery of any kind rattling away preserving the veneer we call civilization. And it smelled clean and bright, primarily because there were no noddy terns or mutton birds and only three people on it – five when we stepped ashore. The One Tree Island Field Station consisted of three shacks built of corrugated steel over wooden frames, held to the ground like tents by steel cables from eaves to stakes pounded into the rubble ground. They had rubble floors, kerosene fridges, stoves and lanterns, and were comprised of Ted's Hut, the Living Hut, and the Lab Hut. The latter had a rear alcove known as the honeymoon suite (don't ask), as well as about 2 m of lab benches. And 3 m from the Living Hut doorway was the lagoon, and boats waiting to be used. As I lay in my top bunk that evening, listening to the wind whistle through the gaps in the wall, I dreamed about reefs and ocean and solitude. I did not know that One Tree was going to become my primary field site for the next 14 years.

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Later that year, the University of Sydney paid the Australian Museum $1.00 for the facilities and boats, the lease on the island was transferred, and I found myself Ted's new boss. Ted knew way more than I did about his job (keeping boats and machinery running in spite of scientists, while trying to keep us scientists out of trouble), and communication was limited to cables delivered via the Royal Flying Doctor Service short wave system, or by phone if Ted happened to be on Heron Island. So, I governed Ted with the lightest hand possible! We turned One Tree into a place where graduate students could live on a reef, and where there was nothing to do except dive. I spent some wonderful times there with my own students, with students from other labs and other institutions, with other 'fledged' scientists, and with a succession of Teds. The succession of Teds were all unique individuals, very different from each other, yet resourceful and independent as you have to be if living on a 4 ha speck of land 130 km off the coast.

"…One Tree was that Shangri La, a natural environment without any people except for a few scientists"

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One Tree Reef was, and remains a unique place. The island lacks sandy beaches and an easy approach from the open sea – it has to be approached from the lagoon. Difficult access meant the island was seldom visited, although there was some fishing and diving along the outer shelf. Even today, travel to the station is strongly tide dependent, and the pass across the reef can be interesting. We were regularly ordered by Ted to jump overboard and push as he cleared the shallowest spot, motors raised, with the boat shifted over to one gunwale. This was easy; the challenge was jumping back in before the motors started up and the boat prepared to broach the breaking waves just offshore. When the first zoning of the Great Barrier Reef Marine Park came into operation in 1979, One Tree Reef became even less accessible. The entire reef and the waters up to 1 km seaward of the crest became, and remain, a Scientific Zone, access to which requires a permit to do scientific research.

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To me, One Tree was that Shangri La, a natural environment without any people except for a few scientists. It was not pristine, even in 1974, and scientists can be sloppy if not policed, but it was a place where equipment could be left in place in the field with little likelihood of vandalism or theft, where long-term experiments could be run free from the worry that a fishing boat would remove the test subjects, and where a reef scientist could find solitude to reflect on what coral reefs are, and what they might be. Beachcombing along the 500 m sand spit separating two sections of lagoon far from the island, alone with the seabirds and the ocean; or standing on the reef crest at low tide listening to the roar of the breakers crashing down, and watching parrotfishes, tails in the air, striving anxiously to get back onto the rich turfs of the reef flat just as soon as the tide permits; or, best of all, drifting slowly on SCUBA through well-known parts of the lagoon, visiting fishes that I knew, and suspect also knew me, fishes who were there last visit and will likely be living there still the next time I come by – these are heaven to me. I'm sure lots of reefs could provide such experiences even today, but reef scientists now seem too hurried, and field work is never done alone. The opportunity for solitude and reflection while alone on a reef is harder to find.

"…visiting fishes that I knew, and suspect also knew me, fishes who were there last visit and will likely be living there still the next time I come by"

I'd like to believe that One Tree Reef has not changed since I last dove there in late 1987, but I know it has. Like all reefs, it was always changing, and some of the changes in recent years, such as significant bleaching, have not been for the better. Still, I'd like to believe that if I were to get in the lagoon, I would recognize places, and perhaps bump into that old Queensland Grouper, almost as big as a Volkswagen, who persisted in looming out of the gloom just when you least expected her.

1

Intertidal Reefs of Phuket, Thailand

Barbara Brown

"...these seemingly delicate creatures have built up such a formidable array of physiological defences"

My first visit to Phuket, on the west coast of Thailand, marked a switch in my research interests from temperate to tropical marine ecosystems. Up to this point I had been focusing on how heavy metals affect temperate aquatic organisms. But, after reading about the extensive tin dredging that was happening in Thailand and learning that a tin smelter had been built close to the Phuket Marine Biological Center (PMBC), which was adjacent to some well developed fringing reefs, I decided that this would be an ideal place to investigate coral response to localised heavy metal discharge. So in June 1979, I packed my bags and along with a research student set forth to base ourselves at the PMBC for 6 weeks.

"…this would be an ideal place to investigate coral response to localized heavy metal discharge"

It was the first time either of us had worked on Indo-Pacific coral reefs so the experience was a steep learning curve. My earlier work had been in the British Virgin Islands in the Caribbean in the early 70s where reefs were luxuriant with huge stands of branching *Acropora* and other healthy corals interspersed by forests of sea fans and sea whips. Luckily, the reefs near PMBC were easy to reach from the lab and the Thai scientists we encountered

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were always happy to help out. On the negative side I found the coral taxonomy of these reefs a bit challenging and it was often quite difficult to see the corals, even at high tide, because of high sedimentation. I can say that I was surprised to find that unlike many shallow reef flats throughout the Indo-Pacific, these were rich in species and coral cover. Over 30 coral species have been recorded so far and their cover ranges from 0-20% inshore to as much as 60% on the outer reef flats. The reefs are also quite extensive on Thailand's sheltered west coast, in some places extending over 200 m from shore. We later learned that this was quite common throughout the Andaman Sea, with similar reefs being found in the nearby Andamans and Nicobars of India, and the Mergui Archipelago of Myanmar. The contrast of the Caribbean with the reefs of the Andaman was stark with much higher coral diversity in the latter and, in the intertidal areas, relatively small coral colonies battling for survival in a difficult environment.

One of my first thoughts was … how on earth can corals survive in such hostile conditions? These reefs are subject to a diurnal tidal range of over 3 m and are completely exposed to the air for more than 4 hours on spring tides at certain times of the year. The reef communities are dominated by a mixed assemblage of massive corals (poritids and faviids) on the more exposed side of the peninsula and by branching corals on the other. These reefs, both massive and branching-coral dominated, have been subject to rising sea temperatures over the last 50 years, and severe bleaching events in 1991, 1995, 1998 and 2010, yet they only succumbed to major bleaching-induced mortality in 2010. Although they are amazingly resilient, these reefs have shown sensitivity to intermittent, extended periods of sea level depression as caused by an

"One of my first thoughts was... how on earth can corals survive in such hostile conditions?"

atmosphere/ocean interaction known as the Indian Ocean Dipole (IOD). For example, in 1997-98, a marked positive IOD caused the sea level to be depressed by 30 cm over a 10 month period causing extensive coral mortality. Nevertheless, recovery was well underway barely one year later. Such remarkably rapid regeneration involves regrowth of tissue over formerly dead surfaces by live coral remnants, and survival of juvenile corals. Rates of linear

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extension in massive corals here are particularly fast compared to elsewhere in the world. Overall, it is impressive that in this location these seemingly delicate creatures have built up such a formidable array of physiological defences in response to such major environmental challenges.

"…almost all the corals along the west coast of Thailand bleached completely"

The reefs of Phuket have also endured an onslaught of anthropogenic influences over the last 32 years. In the late 70s and early 80s this took the form of run-off from a tin ore washing facility, gleaning by locals for fish, molluscs and octopus, and dredging associated with the construction of a deep-water port. Even though the dredging took a heavy toll, the reefs showed considerable resilience and localised damage was quickly repaired, usually within a year. Regular dredging in a deep water channel seaward of the reefs and hotel development posed additional threats, yet again these reefs have fought back and have shown improvement over the last 15 years. This may be attributed to an increase in sea level over this period, partly due to climate change and also because of downward movement of the mainland following the earthquake that hit Sumatra in 2004.

When I returned to Phuket in early 2010, I found the intertidal reefs to be visibly healthy with over 70% coral cover on the outer reef flats and rapid spreading of branching *Acropora* on reefs formerly dominated by some of the more massive species. But in April 2010, sea temperatures rose to $32^{\circ}C$ and stayed this way for 8 weeks as a result of a delayed SW monsoon onset. Incredibly, almost all the corals along the west coast of Thailand bleached completely and experienced a total loss of established *Acropora* stands and whole colony mortality of many massive species that occurred on the intertidal reef flats. However, the damage to the reef flats was site specific; deeper sites (by as little as 10 cm) showed much less damage than nearby sites with similar reef communities and physical attributes. Now only two years later, recovery from this major bleaching event is steadily taking place, again through the re-growth of remnants and the survival and growth of juveniles and adult colonies. So, despite continuous battles over the last three decades against a host of natural and anthropogenic disturbances, these hardy reefs have survived and even flourished in recent years. The rising sea levels have provided more accommodation space (and less aerial exposure) for the coral framework to grow and, in some cases, resist the most damaging effects of temperature induced bleaching.

"…these hardy reefs have survived and even flourished in recent years"

Although the reefs dominated by massive coral species survived the recent bleaching event much better than those dominated by branching species there are some signs that the juvenile branching corals are coming back; they are starting to appear both on these reefs and on sub-tidal reefs which were similarly affected. Recovery will probably take at least 5 years or longer, and will of course depend on any re-occurrence of depressed sea levels and the intensity and frequency of future temperature-induced bleaching events. The most recent reef surveys of 2012 show that recovery is well under way on reefs dominated by massive species with very limited recovery on those dominated by branching species. However, the balance of species has changed on the massive dominated reefs. *Porites* always dominated, but now it has increased its dominance at the expense of other massive species which were harder hit by the bleaching and are taking longer to recover - but recovering they are.

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I think our study has shown us many things - not only the value of long-term monitoring in following communities and even individual coral colonies over time but also the benefits that can be gained from studying corals in extreme environments and their ability to adjust and survive under stressful conditions. Having seen these reefs actually thrive and prosper during the last decade at a time when many reefs elsewhere in the world were in decline highlights the tenacity of corals at this particular site in Phuket.

1

Coral Reef Magic in Tuléar

Michel Pichon

"...more than a hundred coral species begging for names and I was unable to identify more than two dozen or so"

It was August 1961, in Tuléar, Madagascar, when Jean Marie Pérès, our enthusiastic Institute Director, leased a piece of land by the seashore. Here, on top of a sand dune, the Tuléar Marine Station was born and a group of young and energetic PhD students from the Marine Station and Oceanographic Centre in Marseille, France, spent the next 8 months of their lives.

At that time, Tuléar was simply the perfect place to study coral reefs. Although just below the Tropic of Capricorn, marine life boasted the typical "tropical high diversity". Our first exploration had us sporting a "Calypsophot" (the first underwater camera and the ancestor of the "Nikonos") that Jacques-Yves Cousteau himself had brought to the lab shortly before our departure. We crossed a narrow beach and encountered our first mangrove forest. Not the large estuarine type, but a curtain of trees that gave us our first taste of mangrove mud and biting mosquitoes. When we reached the reef flat, it was completely exposed as it was nearing low tide. As we moved towards the reef front, the text books began unfolding in front of our widening eyes ... patches of *Lyngbya* and *Vaucheria* on the highest parts of the mud flat, rapidly replaced by seagrass beds. Not the meagre *Zostera* type we were used to along our northern European shores, but a dense, lush, dark green meadow, almost totally covering the substratum. Trying to remain hidden, but still highly conspicuous with their vivid colours and unusual shapes, were bright starfish *Protoreaster* and a number of echinoids and gastropods. Also, *Harpa*, *Lambis*, *Cassis*, and many more, all so bountiful it was like standing in front of a Museum display. Then, all of a sudden, there they were, my first corals, stretching more than 400 m towards the sea. The rolling stones, the coralith forms like *Siderastrea savignyana* and *Goniopora stokesi*, *Pavona varians* and a few others, at times in such abundance they even outcompeted the seagrasses. There was also of course *Cycloseris cyclolites*, with sometimes more than one hundred individuals per square metre! But for me, the best was yet to come. Although I had carefully flipped through the pages of the few taxonomic publications I had in hand, there were more than a hundred coral species begging for names and I was unable to identify more than two dozen or so. For the others … forget about the genera, let alone the species … but one has to start somewhere!

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"...as we moved towards the reef front, the text books began unfolding in front of our widening eyes"

While moving carefully along the reef flat and looking down at the kaleidoscope of colors and shapes in front of us, the coral communities began changing. All of a sudden, raising our eyes to see how far we were from the breaker zone, there it was, a sight I will never forget. An immense virtually monospecific field of tall branching *Acropora*, nearly half a metre high, extending almost to the reef edge, and as far as one could see left and right! This was the most impressive, bewildering vista I have ever encountered on a reef flat, and to this day I still vividly remember the deep impression it left on me by it sheer size, lushness, and intrinsic beauty. It covered hectares and hectares, and was impossible to cross. In order to reach the reef front we were forced to take long detours to reach a couloir of sand and rubble deposits that conveniently interrupted the *Acropora* zone. This safe passage was quickly dubbed "*the National 7 expressway*" after the famous freeway running down the Rhone Valley in France. That day we were lucky the sea was calm; usually, even in the total absence of wind, heavy swells originating in the southern ocean would crash on the reef front with huge breakers sweeping across nearly the entire reef flat and making it almost impossible to reach the edge.

But when one could get there, it was pure magic. Through crystal clear waters and against a pink background of a solid coralline algal pavement we saw a multitude of brightly coloured and often fluorescent faviids as well as a bewildering diversity of *Acropora* species covering the top and sides of reef spurs which plunged deep along the fore reef slope. Confused and perplexed by all these forms, alike yet subtly different, I decided then and there that I should not venture too far into the minefield of *Acropora* identification. Luckily, Carden Wallace came to the rescue fifteen years later, so thank you Carden! I could not escape noticing some other spectacular members of reef front communities, such as the pencil sea urchins, *Heterocentrotus mamillatus*, several large glossy green species of *Turbo*, and the bright yellow fire coral *Millepora platyphylla*. A first intimate encounter is well remembered.

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During subsequent days, low tide was spent exploring the reef flats, often 1-1.5 km wide, frantically scribbling on our writing slates and filling our buckets with specimens. Fascinated and mesmerized by the richness and novelty of our discoveries, we often forgot the time until the rising tide reminded us that the reef show was over and *terra firma* was far away. Fortunately, we had hired two knowledgeable native Vezo fishermen (a semi-nomadic coastal ethnic group living in SW Madagascar) whose keen eyesight could easily see that these two tiny black dots on the horizon were our fellow students Fred and Jack hurrying back. And just when the water had reached chest level and we were each trying to figure out what the next move should be…abandon buckets, writing slate and the rest and start swimming to shore… we would be hauled out of the water by two powerful Vezo arms and unceremoniously flipped into the canoe for a timely rescue. If these guides could track us anywhere on the reef flat, they found it more challenging following our surface bubbles when we dove on the outer slope. This was a whole new game for them as diving was for us, at a time when there was no backpack or BC, no pressure gauge and state of the art was the twin hose single stage Mistral regulator.

"…a time when there was no backpack or BC, no pressure gauge and state of the art was the twin hose single stage Mistral regulator"

The heavy swells and treacherous breakers forced us to begin each dive well away from the surf zone but even then, once closer in we found ourselves forced to perform an incessant underwater ballet. Perhaps because of the strong surge and backwash currents another cause for amazement awaited us below … lots of corals, lots and lots, except in deeper parts where all life had been scoured away. Most corals here were very sturdy...they had to be in order to survive...but there was also an abundance of large cup shape colonies, often several metres across. We would often encounter large Triton shells, a collector's temptation, and the fatty pink *Choriaster granulatus*, quickly dubbed "*soft toy starfish*", a real favourite for photographers. The fish life was just as amazing, and beside the innumerable brightly coloured butterfly, angel, and parrot fish, roamed the true reef masters…enormous groupers, large and imposing enough that they thankfully kept hungry sharks at bay. I also clearly remember the maori wrasses, one so huge that while swimming indolently near the surface and seen from below, it was sometimes mistaken by the divers as our waiting rubber dinghy.

"…the receding tide exposed a reef flat that appeared almost as white as snow"

The arrival of December brought dark black clouds heavy with rain, and the quickly swollen rivers burst banks and sand dunes before flowing into the sea. A few days later to our surprise, the receding tide exposed a reef flat that appeared almost as white as snow. Yes, it had 'bleached'. Even though this word was not yet part of the vocabulary, we made the connection between freshwater ingress and loss of colour. I remember writing in my field book: "*Looks like the zooxanthellae have gone. Perhaps a cleansing and regeneration mechanism triggered by a spike of low salinity. Could be seasonal?*"

This wonderful dream that was Tuléar lasted eight months, but it passed by in a flash, and when we arrived back home we were left pondering whether or not it had happened at all.

TULÉAR TODAY: My last trip to the reefs of Tuléar was in October 2009. Gone are the vast expanses of branching *Acropora* on the reef flat, gone is the pink pavement of the algal ridge, gone are the forests of branching staghorns on the lagoonal slopes, gone are the large and less large fish, gone are the Turbo and triton shells, and even the seagrass beds are moribund. It seems that everywhere I looked I could only see dense fleshy algae and large deposits of sand and rubble. But surprisingly, even though the coral cover has vanished and collapsed to less than 5%, there has been little loss in coral species diversity. To me, this is a small ray of hope, and I will cling to it. I cannot accept that the reefs of Tuléar of yesteryear are a paradise lost forever…

1

60 Years Ago on East Africa's Coral Reefs

Frank Talbot

"The rich and varied coral beds were like luscious planted gardens"

In 1954 my wife Suzette and I, both fledgling biologists in our twenties and just married, went to live on the East African island of Zanzibar. As a young fisheries scientist at the East African Marine Fisheries Research Organisation (EAMFRO), I dove on coral reefs around Zanzibar and beautiful places along the coasts of Kenya and Tanganyika (as it was called then). I bought myself a second hand Cousteau/Gagnan scuba valve designed just a few years earlier and somehow taught myself to how dive (not wise - I had a few close calls - which you can ask me about later).

"I remember believing the tales of Zanzibar children being taken by these giants"

The coral seascapes in the crystal clear waters of Zanzibar were simply superb in their overall beauty of form, movement and colour…it was like diving in an underwater paradise. The rich and varied coral beds were like luscious planted gardens. Some of our first dives were scary when "gangs" of intimidating predatory carangids and schools of barracudas swam up close to look at us. We had never seen anything like this in temperate waters, and I initially thought there was some chance that these predators would come after us like a pack of hungry dogs. The reefs were covered in clouds of damselfish, butterfly fish, wrasse, and angelfish moving in and through the coral, while schools of cardinalfish rested in dark caves. Impressive multispecies schools of surgeonfish, rabbit fish and parrotfish attacked the algal surfaces on corals. A grouper (*Plectropomus*) would sometimes drift quietly close to these unsuspecting feeders, like an overseeing "uncle", but ready to gulp in an instant if one came too close. Huge schools of snappers, emperors, and sweetlips were also abundant … and in those spearfishing days some would often be taken home to eat after an exciting weekend of exploring.

In the reef channels it was common to see the largest of all groupers (*Epinephalus lanceolatus*), which can grow up to 225 kg, majestically patrolling and accompanied by a few dozen smaller fish acting like a guard of honor. I remember believing the tales of Zanzibar children being taken by these giants. On one memorable occasion, a guest that was swimming with us was intrigued by a huge grouper that steadily approached her until she was looking straight into its great open yellow mouth. She hit the surface screaming, until another swimmer came to her rescue, and the creature sank back down into the depths. Other large species were also common, like the strikingly marked potato cod, which John Morgan named *Epinephelus tukula* after its local Seychelles name. These are still fairly common on the Great Barrier Reef and because they are large, beautiful and extremely tame in protected areas, are sought after by sports divers for viewing and photography. Small reef sharks were common, and sometimes when I laid fixed nets at night on Tutia Reef in an attempt to determine the total complement of species, many sharks would become entangled. One early morning an angry shark freed itself and bit me on the right side of my chest, luckily missing any major blood vessels but removing some superficial muscle. Tiger sharks up to some 1360 kg were occasionally taken by fishermen and proudly exhibited in the Zanzibar fish market. In one unforgettable dive, John Morgans and I were chased by one, but after John bravely dove directly at it, it swam below and away from us, perhaps deciding we were not worth eating.

2

In spite of their richness, one could not say these East African reefs were pristine. For probably over 2,000 years artisanal fishermen in local ngalauas (outrigger dug out canoes), and mashuas (planked open lateen rigged sailing boats ~9 m long, would fish by handline along the reefs and channels, setting big net traps for migrating kingfish or kanadi (*Scomberomorus plurilineatus*) and place small baited basket traps on seagrass beds or coral reefs. Somalis, sailing down the coast in small dhows carrying cattle for sale, sometimes used more destructive fishing techniques. I would come across groups of a dozen or more of these visitors, who would chase fish across a reef by swimming in a line, each holding a stone on the end of a rope, repeatedly lifting and smashing down on the coral, herding the fish towards a net held by other divers

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which stretched from the surface to the coral bed. In spite of this, by the number of fish I saw underwater I could only assume that fishing had little impact. At that time there were few subsistence fishermen, and the fish market had only recently acquired a refrigerated room, so each fisherman usually fished just a few days a week, taking fish for food or bartering and selling in local markets.

I remember that when underwater the living coral cover deceptively appeared to be close to 100%, but when measured vertically was usually only 30-40%. Whereas in the lagoons and more sheltered waters we would find fast growing Acroporas (e.g., *A. hyacinthus* and staghorn *Acropora*) often forming 100% cover. My overall impression of a typical reef in Zanzibar, and those I worked on in Tanzania, was that they were extremely rich in genera and number of individuals, with big roaming schools of fish (particularly predators). It is a shame that not having the accessible and fancy technology of today, that this image is now difficult to prove.

I have attempted to compare fish taken in 1955 in East Africa (on Tutia Reef, Tanzanyika, as it was then called) using very small explosive charges that killed fish in a circle of about a 9 m radius with samples taken using the same technique in 1970 from One Tree Island reef on Australia's Great Barrier Reef by myself and colleagues (by Queensland permit in those days…now no longer permitted!). The results, for 11 samples in each case, are interesting. The average number of species per sample was not that different; 32 for Tutia and 37 for One Tree, but the cumulative number of species was 154 for Tutia and 225 for One Tree. A stark difference could be seen with the number of individuals per unit area; averaging 119 for Tutia, with a total of 1,310 for all samples; and with an average of 342 for One Tree with a total of 3,764. But I must admit that these data cannot be trusted. First, the sample size on very varied reef surfaces was small, and second, the small explosives may have missed all major highly clumped schooling fish. Nevertheless, it suggests that smaller fishes feeding in daylight on and about the coral reef surface were more numerous and also richer in species on One Tree. The latter is not surprising as the total species numbers taken on the two small reefs by all methods were 500 for Tutia and an amazing 860 for One Tree.

WERE THE REEFS I SAW 60 YEARS AGO RICHER IN SPECIES AND NUMBERS THAN TODAY?

My first answer is that my data are poor and comparisons are difficult. The Zanzibar reefs I saw 60 years ago were in the Western Indian Ocean; an area much lower in species richness than those I dove on some 30 years later on the Great Barrier Reef. My second answer is that the number of medium sized schooling predatory fishes did seem greater … with more and larger schools in Zanzibar waters. While this may be merely subjective, it is perhaps reasonable to believe that the sizes of these predatory fish have declined as fishing pressures have grown. One clear case of overfishing we were responsible for was on Tutia Reef which had schools of red snapper (*Lutjanus bohar*). In trying to study their reproductive biology I tried to catch a sample of 50 every second month. With six crew handlining from the research vessel, it was easy to catch 50 the first month, but each time it became more difficult until we could only catch 10 or less and I finally gave up. My assumption was that I was fishing one or two schools (perhaps a few 100 fish) and I was in fact fishing them out in that particular area. I never saw any local fishermen on that reef, so could only imagine that the reduction was due to our fishing alone.

"…an absolute plethora of life, and a reef experience reminding me again of those long ago days in East Africa"

As Clive Wikinson's annual assessments have shown [Status of the Coral Reefs of the World; Australian Institute of Marine Science] there is no doubt that in many areas of the Indian and Pacific Oceans the coral reefs are now depauperate, with lower numbers of larger species, and many with significant damage. But in some areas of the Great Barrier Reef, and on many isolated reefs, one can still find high coral cover and fish populations rich in species and numbers. Visiting Scott Reef in 1979, my faith in the resilience of isolated coral reefs was restored. In spite of light fishing by occasional Indonesian fishing boats, the marine life was staggering… medium sized predatory fish that attacked our dinghy's propeller blades, there were huge masses of lagoonal corals, multitudes of sea snakes and ravenous cruising tuna in the ten mile lagoon… an absolute plethora of life, and a reef experience reminding me again of those long ago days in East Africa.

My thanks are due to Dr. Hugh Sweatman for providing comments on this manuscript.

Jamaican Reefs Remembered

Judith Lang

"…very soon these gorgeously beautiful ecosystems would begin falling apart"

I was barely sixteen in late 1958 when someone loaned me a face-mask for a few minutes and I became completely transfixed by what I saw underwater. Soon after, I bought some basic snorkeling gear and went swimming whenever possible on reefs fringing the cays a few km offshore of Port Royal. My companions were recreational spearfishers whose small boats were powered by 10-hp Seagull outboard motors. One knew of some "secret" outcrops that attracted lobsters and every few months when my parents were throwing a party, we'd snare a bucketful for Mum.

Parts of Port Royal had disappeared into the harbor during a 1692 earthquake. My initial uncertified diving occurred above a section of the sunken town that had been excavated during a National Geographic-Smithsonian-Link Expedition in 1959. Later that year I joined the Jamaican branch of the British Sub-Aqua Club and learned to scuba. I didn't dive with them very much because the club only had about half as many 40 cu ft tanks as divers. Lacking underwater pressure gauges, the first group would submerge for a pre-agreed upon depth and time while those of us in the second group would snorkel above, hoping to have some air left in whatever tank we each received when it was our turn to dive.

In my youth I was blissfully ignorant of historical overfishing and oblivious to the absence of big fishes. Instead, I was entranced by the colorful kaleidoscope of small reef fishes like slippery dick, rock beauty and sergeant major. I saw much, but lacked a vocabulary with which to name or describe the creatures growing on the substratum. During this time I wrote a poem and it still exists today because, unbeknownst to me, it was published in an anthology of contemporary Jamaican writing. I may have known little about biology, but it captures the beauty and wonder I felt as the following excerpt illustrates:

> *"In the water I am accepted, suspended, carried along or free to wander at will; to move among the brittle, beautiful corals, watching the play of fish fulfills me as nothing I have ever known on earth."*

I was the first to notice what I later learned was a tiny orange cup coral (*Tubastraea coccinea*) growing on a reef off Port Royal… decades before it was understood to be an invasive and actively spreading in the Caribbean. Because of this find, during the following two summers (1960, 1961) I had the amazing privilege of working with renowned reef scientist, Dr. Thomas Goreau, Sr. His lab, which was considered remarkable for being air-conditioned, was on the University College of the West Indies campus (now the University of the West Indies). I remember turning the handle of a hand-cranked mechanical calculator to number-crunch data resulting from innovative radioisotope uptake experiments he conducted with his wife, Nora Goreau.

On many weekend day trips, Goreau trailered a small locally constructed wooden boat, engine and gear across the mountains to explore the shallow (<20 m) fore reefs rimming Jamaica's north coast. My most vivid memories are of majestic buttresses rising at least 4-6 m above meandering, sand-filled channels that were sometimes roofed over to form intricate tunnels lined with colorful encrusting animals and crustose coralline algae. The buttress reefs were constructed primarily of the massive star coral (*Montastraea annularis*, now recognized as a three species complex), crowned with elkhorn (*Acropora palmata*) or fire (*Millepora complanata*) corals, and fronted to seaward by tangled fields of staghorn coral (*A. cervicornis*). I learned to identify corals underwater while helping to map their depth and habitat distributions. There was no thought of quantifying live coral cover because it probably exceeded 60% on many reefs, and fleshy macroalgae were remarkable only in their scarcity.

When I rejoined Goreau's group as a graduate student in 1966, his research interests had shifted to the fore-reef escarpments and slopes near a temporary lab facility in Discovery Bay. Corals, calcareous algae and sponges, some new to science and many previously unseen in their native habitats, were being found during short excursions on air to depths of about 25-60 m. Most exciting were the coralline sponges (then called sclerosponges), which inhabit deep cryptic spaces. I missed the discovery of the first specimen when an informal poll of its likely identity produced one vote each for Cnidaria, Porifera and Foraminifera! Also memorable were the evenings that Goreau was in Discovery Bay and everyone assembled by the tanks of running seawater to gaze in amazement at the fluorescent colors revealed by certain marine organisms when illuminated by a UV light he had purchased.

Non-diving scientists were already visiting the Discovery Bay Marine Laboratory (DBML) to get collections of organisms. As other students and scientists who could scuba arrived, the searches broadened to include octocorals, crinoids, boring and epibenthic sponges, etc. Physiological, biochemical and geological investigations were initiated, along with the first efforts at ecological quantification. In the meantime, Goreau's energies increasingly were focused on creating a new laboratory that would have superb diving and wet lab facilities, as well as a dormitory and apartments. Built on the western side of Discovery Bay, with funds from Britain, the U.S.A. and the University of the West Indies, it was officially opened in the spring of 1970. Having ushered in a new beginning for marine science in Jamaica, a few weeks later Goreau, only 45, tragically died of complications arising from cancer.

At this time, we were aware that artisanal catches were much lower in the fish pots (Antillean "Z" traps) along northern fringing reefs than in similar traps set along the south coast. Also, the nearshore fish fauna was depauperate everywhere compared to less densely populated or more affluent areas of the Caribbean. I "famously" told a pair of ichthyology grad students attending DBML's first ever reef ecology class in 1970 something like, "*we know, but the lack of fishes doesn't seem to matter to the sessile reef benthos*." Thinking that fish scarcity couldn't affect corals was a temporary illusion; very soon these gorgeously beautiful ecosystems would begin falling apart. After Hurricane Allen smashed the north coast in 1980, a rarity of large predators allowed surviving corallivores to consume the broken fragments of the formerly dominant elkhorn and staghorn corals. (Meanwhile, acroporids elsewhere in the Caribbean were dying from disease.) Furthermore, the ubiquitous black sea urchin (*Diadema antillarum*) was an underappreciated key herbivore on reefs that lacked large-sized parrotfishes. After *Diadema* was nearly extirpated region-wide by a water-borne disease in 1983, macroalgae would settle much faster than any stony coral or crustose coralline alga could recruit or grow.

"Today, I am ever so grateful to have experienced the Jamaican reefs before most baselines had collapsed"

Along with overfishing and, in places, destructive fishing, coastal waters near centers of human population worldwide have been inundated with innumerable land-based sources of pollution, affecting even remote areas via atmospheric deposition. Most significantly, the carbon dioxide and other greenhouse gases that have been warming the globe are causing mass-bleaching mortality events and subsequent outbreaks of disease, thereby decimating many tropical reefs. Today, I am ever so grateful to have experienced the Jamaican reefs before most baselines had collapsed. Like many others, I feel such sadness that so many of nature's gifts have been squandered, on land as well as underwater. To younger generations: sincerest apologies for the excesses of your elders. I remain convinced that we humans can still choose to control the triple threats of overpopulation, overdevelopment and overconsumption. Even though fishing pressures have greatly escalated since my youth and could only be reversed with great difficulty, the recently created Jamaican fishery reserves and coral nurseries are reasons for new hope. Encouragingly, corals and crustose coralline algae are still recruiting in pockets of naturally replenished *Diadema!* The glass is always half full, and we all share responsibility for what happens next.

1

Deep or Shallow, Depending on the Winds

Rolf P.M. Bak

"Wave action decided for me what I would do during my daily dives"

Driving to the lab in the morning always was a good thing in the early seventies. The last part of the road run along the coast and I could see the living tips of the *Acropora palmata* branches sticking out of the water with each passing wave. Wave action decided for me what I would do during my daily dives. High waves meant I would have to work deep, at least at depths seaward of the *Acropora* zone. When the winds were not that powerful and wave action not that strong I would be able to work with *Acropora* colonies at depths from 1- to 2 m. Our boat would get us to our study site Buoy One, just seaward of the belt of *Acropora palmata* that fringed the shore along most of the coast in Curaçao. Colonies of *Acropora* built a dense forest in the shallows and on those quiet days I could continue my growth and lesion regeneration observations. I am not a fishperson but even I could not help noticing the abundance of fish such as squirrelfish, glassy sweepers, cardinal fish and soapfish, all hiding among the *Acropora* branches. The

"...abundance of fish such as squirrelfish, glassy sweepers, cardinal fish and soapfish, all hiding among the Acropora branches"

seaward edge of the *Acropora* zone was a good place to start the day if you could avoid the numerous urchins, *Diadema*, present in high densities on the reef bottom. There were more *Diadema* than there was shelter under coral ledges, in crevices and holes, and those that could not find shelter clustered on the bottom, forming dense prickly forests. These spiky patches in their turn giving shelter to the flat bodies of crabs (*Percnon*), which hid under the urchin tests. I wonder what happened to these crabs after the great *Diadema* die-off in 1983.

On windy days we were forced to move into deeper waters, crossing a broad sandy belt with gorgonians, mostly *Pseudopterogorgia*, many of these with populations of the snail *Cyphoma*, and a mixed community of dispersed corals such as *Siderastrea, Montastraea, Meandrina, Diploria*. *Acropora cervicornis* was not common at Buoy One but it was widespread in dense forests at this depth in other areas along the coast. At one of my favourite sites,

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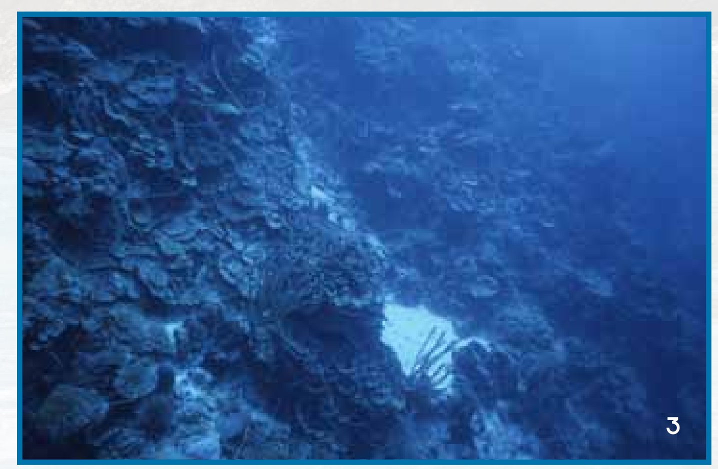
towards the eastern tip of the island, there was a contest going on between *A. cervicornis* and *Montastraea annularis*. The two species together covered the reef bottom totally with *cervicornis* clearly growing faster, the mass of its branches overwhelming the slower-growing *M. annularis*. However, *annularis* is more aggressive and it killed *A. cervicornis* off through mesenterial aggression wherever the overgrowing species came within reach. It looked to me at the time that *cervicornis* was going to be the clear winner in the end, but then, in 1983, white-band disease interfered and nearly all *cervicornis* died off. *M. annularis* is still common at that site.

Back to our Buoy One dive, crossing from the *palmata* belt to deeper water we cannot help but see lots of fish. Spotted and Yellow Goatfish ploughed though the sandy bottom. Lizard fish shot off when approached too closely. At intervals large schools of Doctorfish would pass, nearly always accompanied by Trumpetfish, more rarely Cornetfish. Wrasses such as Blueheads and Yellowheads were everywhere. At depths greater than 6m we approached the seaward steep seaward facing reef slope and coral cover increased significantly. Here we found the highest diversity of scleractinian corals. Many coral colony surfaces hosted neongobies and the worm *Spirobranchus*. It was a mixed community of the common Caribbean reef corals. Locally the community could be characterized by a profusion of *Dendrogyra cylindrus* or dominated by extensive beds of *Madracis mirabilis.* This was also the zone where the brilliant red *Mussa angulosa* occurred though not as commonly as the other phaceloid branched coral, *Eusmilia fastigiata*. Between the corals we saw many other benthic organisms including sponges such as *Callyospongia plicifera, C. vaginalis, Niphatus erecta, Neofibularia nolitangere* and anemones, particularly *Condylactis gigantea, Bartholomea annulata* and the painfully stinging *L. danae*.

"Damselfish were so numerous that it was impossible to lie still on the reef bottom doing counts or observations"

Many of these anemones were hosting guests such as crabs and shrimp. Closer to the edge and on the seaward slope agariciids were the dominant corals. Most was *Agaricia agaricites* but *Helioseris* was not rare at all. Damselfish were so numerous that it was impossible to lie still on the reef bottom doing counts or observations because of the continuous attacks and bites of the damsels in one's legs or arms. On the seaward steeper part of the reef, fish such as Royal Grammas and Fairy Basslets were numerous and the white antennae of *Stenopus* shrimps would stick out from under many coral colonies. So did the arms of the three crinoid species (*Nemaster*) that were fairly common. This was also the depth where there was a fair chance to find either of the Mycetophyllias, *aliciae* or *ferox*. *Scolymia's* occured on the slope with *S. lacera* generally found somewhat shallower than *cubensis*. *Madracis* species were common and deepwater *Agaricias* such as *lamarcki* and *grahamae* showed high cover at the deep reef, extending to 50, 60m and beyond. In the drop off area Blue and Brown Chromis were abundant in the water column.



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Between the corals hid the common small groupers, Coney and Graysby. Rock Hinds occurred here but larger groupers were not regularly seen at Buoy One. The more exposed, less dived south-east coast of Curaçao had larger groupers such as Nassau and Marbled grouper. The south-east coast was also a good place to admire the fluorescing colours of Black Durgeons, swimming in the current over the edge of the reef drop off. This was also the place to see Nurse Sharks. At our regular dive site we found them always in the same two, three large sandy depressions in the thick coral cover. Other species of sharks were rarely seen. In fact the only place I saw those, including an exciting meeting with a weird hammerhead shark, was on the very rough exposed north-east side of the island where hardly any divers were ever seen. There is no doubt that Buoy One represented the general distribution of organisms over the reefs in Curaçao, but there was significant variation depending on exposure to wind and waves. An example of that variation along the coast was the distribution and density of sea fans, *Gorgonia*, which was strongly depending on wave force. Sea fans were absent at Buoy One only becoming very dense towards the eastern, trade wind exposed, tip of the island.

Thinking back to what the reef looked like in the seventies there is one overwhelmingly clear difference with the way it looks today. In the seventies the whole reef, all surfaces, all dead coral, was clean, all substratum showing the sharp outlines of clean rocky structure. Except for crustose corallines there were no algae in sight apart from for the turfs in the territories of the damselfish. Macroalgae such as *Halimeda* or *Lobophora* were completely absent from the reef at the time. The big change in reef substratum in Curaçao, from clear outlines to fuzziness, occurred in 1983-1984 and coincided with the large scale demise of the urchin *Diadema antillarum*. This changed the reef from a bottom where conspicuous algae were totally absent to a bottom where algal turfs cover all dead surfaces and where macro-algae such as *Halimeda* are common at intermediate depths and Lobophora covers a significant part of the seaward reef slope. I remember reading literature in the seventies, by respected authors such as Ginsburg and Milliman, pointing out the importance of algae such as *Halimeda* in reef sediment production, thinking such statements were bizarre. At the time there was no single *Halimeda* in sight on the Curaçao south coast reefs. I did not see one Halimeda, despite spending thousands of hours diving those reefs.

"...the change in algae (now more), fish (now less), corals (now less) and all other interesting beautiful animals (now less)"

In conclusion: yes the change in algae (now more), fish (now less), corals (now less) and all other interesting beautiful animals (now less) makes diving, as an aesthetic experience, for me much less interesting. Fortunately we can easily go deep over the reef slope in Curaçao and though the deep *Agaricia's* such as *grahamae, aliciae* and *undata* have suffered through coral diseases and deep bleaching it still feels good, between corals, far from the madding crowd.

1

Early Coral Reef Scapes: from the Caribbean to the Eastern Pacific

Peter W. Glynn

"...what impression did this first coral reef experience make on me? It was exhilarating, awesome, and magical"

Below I offer some vignettes of my first impressions of coral reefs, beginning in the late 1950s. My journey began in the Caribbean (Belize, Puerto Rico) and moved to the tropical eastern Pacific (Panamá, Galápagos Islands), where I discovered true coral reefs in a region long believed to be lacking these dynamic ecosystems.

CARIBBEAN - BELIZE

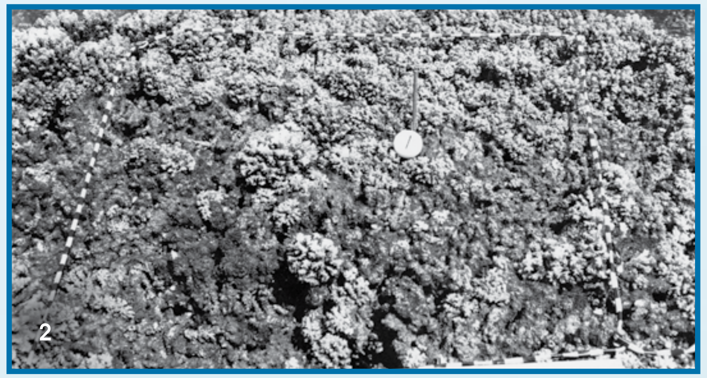
Inspired by F. G. Walton Smith's book, *Atlantic Reef Corals* (1948), I ventured to Belize (formerly the British Honduras) in 1959 to observe firsthand what was touted as the great barrier reef of the Caribbean. Thanks to a Mexican fishing ketch hiring divers, I was able to sail and surface dive along the barrier reef for two weeks. At one remote site, I was astonished to observe fields upon fields of vibrant, golden-brown Elkhorn (*Acropora palmata*) and Staghorn (*Acropora cervicornis*) corals, the former present on exposed reef fronts and the latter in more protected leeward habitats. Massive and mounding corals, many several meters high, were also abundant, providing shelter for large schools of groupers, snappers and other fishes. The fish biomass taking shelter in the cavities and caverns under these mammoth corals was extraordinary. Spiny lobsters were everywhere and could often be seen crawling over seagrass patches, even during daylight hours. So what impression did this first coral reef experience make on me? It was exhilarating, awesome, and magical. It gave me an incessant visceral urge to learn more about how this magnificent ecosystem came into being and how the interplay of various ecological processes structured its formation. These are the fundamental questions that have driven my research agenda over the past 52 years.

CARIBBEAN - PUERTO RICO

By design, my first faculty position in the early 60s was at the University of Puerto Rico in Mayagüez. The university's marine field station was on Magueyes Island near the fishing village of La Parguera. This Island is surrounded by mangroves and numerous inner-shelf patch and linear reefs. Here was an opportunity to study reefs with the support of a nearby lab, and to share the excitement of coral research with colleagues and students. A series of nearby mid-shelf reefs - Media Luna, Enrique, Turrumote, Corral and Laurel - were actively accreting formations as was evident from the high cover of branching and massive coral species, all seemingly reaching towards the sea surface. Adding to the vibrant golden-brown, gray, green and pink coral colors was a kaleidoscopic array of other colors and patterns displayed by reef-associated flora, invertebrates and fishes. Near the insular shelf edge one could observe deeper drowned reefs, relicts of a lower sea-level stand. These formations were especially fascinating because many of the same morphological features present on shallow reefs, fore- and back-reef zones, spurs and grooves, and cavities of varying size could be seen on these deep reefs that began growing about 10,000 years ago and then gave up about 4,000 years later during sea level rise. I shared my initial impressions with David R. Stoddart and Thomas F. Goreau, two Caribbean researchers whose work had motivated my own.

"These are the fundamental questions that have driven my research agenda over the past 52 years"

A reef zone that fascinated me early on was the shallow reef flat of the mid-shelf reefs. This zone was dominated by branching finger coral (*Porites furcata*), forming continuous fields of green/brown-colored branches. Why this fascination? In large part because of the overwhelming biodiversity supported by these corals. It was in Puerto Rico, although I can't remember the exact circumstances, where I began to discover and appreciate the multitude of species that live cryptically in and among the spaces and cavities of corals. This is a truly fascinating hidden community of organisms that finds the necessary resources to support its often enormous biomass and much of what makes up the reef's epifauna. Indeed, Robert Ginsburg has ventured that the biomass of this out-of-sight community often exceeds that of visible coral structures in which shelter is found. A green brachyuran crab (*Mithrax sculptus*) associated with *Porites* has a net beneficial effect on its host, and a polychaetous worm corallivore (*Hermodice carunculata*) a negative effect by consuming its tissues. So, not only did a beautiful and diverse coral formation enthrall, but an invisible subsurface cryptic community with diverse ecological functions has added to the intrigue of the coral reef ecosystem.



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PANAMA AND EASTERN PACIFIC

Reef research in the 60s and earlier was not always convenient, especially in the remote eastern Pacific where laboratories, and scuba and ship support were often marginal or unavailable. Also, this was a period of total freedom in the sense that all diving behavior was up to the researchers' discretion, and activities such as experimental manipulations, collecting, and drilling, were uncontrolled. Obviously this could have good and bad consequences. Today many aspects of reef science have benefitted from technological advances, such as the evolution of diving gear, U/W photography, videography, GPS, and waterproof data recorders.

A totally different kind of coral reef, but no less beautiful and captivating, was encountered by my colleagues and myself on the Pacific side of the Panamanian Isthmus in the late 60s. These reefs were located mostly on offshore islands, e.g., the Pearl Islands, Coiba Island, and other islands in the Gulf of Chiriquí. This was an exciting time because we were finding reefs where none were supposed to exist. I was encouraged by J. Wyatt Durham with these discoveries because he predicted in several early publications that true (actively building) coral reefs would be found in the eastern tropical Pacific. Eastern Pacific coral reefs are typically paucispecific, built by a few coral species with the branching coral genus *Pocillopora* figuring prominently. Similar reef types were discovered and characterized in the Galápagos Islands in

3

1975 by Gerard M. Wellington, Charles Birkeland, John W. Wells and myself. Like the *Porites* reef flats in the Caribbean, *Pocillopora* colonies with their intermeshing frameworks harbor an enormous trove of species. Exposing the multitude of cryptic metazoans, both surface-dwelling sessile and vagile species as well as endolithic taxa, was like opening Pandora's Box. This presented another level of fascination - trying to unravel the biological and ecological roles of this panoply of animals. Unlike Pandora's Box, much of the cryptic fauna is not malevolent, and not all cryptic species exhibit overwhelming negative effects on corals. Several crustacean species affect their coral hosts positively. For example, obligate xanthid crab (*Trapezia* spp.) and alpheid shrimp (*Alpheus lottini*) symbionts of *Pocillopora* keep their host's tissues free of debris and settling organisms, promote interbranch circulation, and also fend off corallivores such as the Crown-of-Thorns sea star *Acanthaster planci*. The exquisitely colored Harlequin shrimp (*Hymenocera picta*) also shelters in *Pocillopora* frameworks and preys on *Acanthaster*. The polychaete worm *Pherecardia striata* is another cryptic species that indirectly benefits corals by preying on *Acanthaster*. Cryptic species with negative effects on corals are the gastropod corallivore *Jenneria pustulata* and several endolithic sponge and bivalve bioeroders.

"This disturbance event was actually a harbinger of global warming"

4

DISTURBANCE, DEGRADATION AND RECOVERY

Back in Puerto Rico a reconnaissance of the Laurel study reef in the early 70s revealed a complete absence of the *Porites* biotope, ostensibly destroyed by storm-generated waves. In a 2008 review of the Biology and Ecology of Puerto Rican Reefs by David Ballantine and colleagues, this biotope was not mentioned; it is possible that it has not recovered over the past 40 years.

The 1982-1983 El Niño event had unexpected and startling effects on corals throughout the equatorial eastern Pacific, causing widespread coral bleaching and mortality of numerous reef-associated species. Coral reefs in Panamá and the Galápagos Islands suffered high coral mortality with subsequent severe bioerosion and eventual collapse and loss in many areas. This disturbance event was actually a harbinger of global warming, an anthropogenically driven change that has taken a large toll on coral reefs in all tropical regions. Happily, significant recovery of coral cover and resumption of framework growth have been documented recently in some eastern Pacific areas – Panamá and the central and northern Galápagos Islands. This offers a ray of hope, at least in the short term.

1

The Reefs and People of the Comarca Kuna Yala

John Ogden

"If you told me in 1970 that the luxuriant coral reefs of the Kuna Yala would look the way they do today, I would have said you were crazy"

In 1968, I finished my PhD at Stanford University and with a bit of luck I landed a post-doc fellowship at the Smithsonian Tropical Research Institute (STRI) in Panama. Faced with the prospect of two lonely years, I overcame my reluctance to commit and married Nancy Buckman in 1969. Shortly thereafter, we headed for Panama, never imagining that almost 20 years would pass before we would return to the U.S. mainland.

"...we gathered a mountain of gear, a small boat and motor,...and sailed...to the Kuna Yala"

We rented an apartment in a crowded, noisy part of teeming Panama City and soon realized that living in the city greatly reduced our field time in the water. On a visit to the picturesque Comarca Kuna Yala (San Blas Islands) we saw the potential of living next to our fields sites. We were also curious to find out more about the Kuna people, who fiercely maintained their traditional culture and governed the Comarca largely independently of Panama. They lived on a few densely populated small islands, grew coconuts on many uninhabited islands, farmed plots on the mainland, fished, sailed and paddled traditional cayucos, exported spiny lobster and entertained occasional tourists. Decision made, we gathered a mountain of gear, a small boat and motor, loaded them onto a small wooden cargo boat and sailed down the Atlantic coast to the Kuna Yala. A large, ramshackle overseer's house on Isla Pico Feo, a former copra factory, became our new home.

2

FOUR DECADES OF CHANGE (1971-PRESENT)

If you told me in 1970 that the luxuriant coral reefs of the Kuna Yala would look the way they do today, I would have said you were crazy. Our return visits in 1991 and again in 2010 gave us snapshots that made the changes seem sudden and alarming. On each visit we examined our old field sites, took notes and photographs and spoke with our aging Kuna friends about their reefs.

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The impact of increasing human population: Since 1970, the Kuna population has grown by at least 50% and the mining of coral rock for island-building has increased. While this was traditionally done by hand, in 2010 we noted that heavy, powered equipment has recently been used. Drinking water, still carried by boat from shallow wells on the mainland or collected in cisterns, is an increasing problem during dry periods. Continued use of traditional over-water outhouses and growing numbers of flush toilets directly deposit raw sewage near the beach. The rising use of plastic and ineffective management of solid waste has choked some of the islands with trash and disposal only appears to be effective where a single hotel owner has control of an island. On the mainland, expanded lowland farming and industrial logging at higher elevations cause so much sediment run-off during the May to November rainy season that coastal waters can become completely opaque.

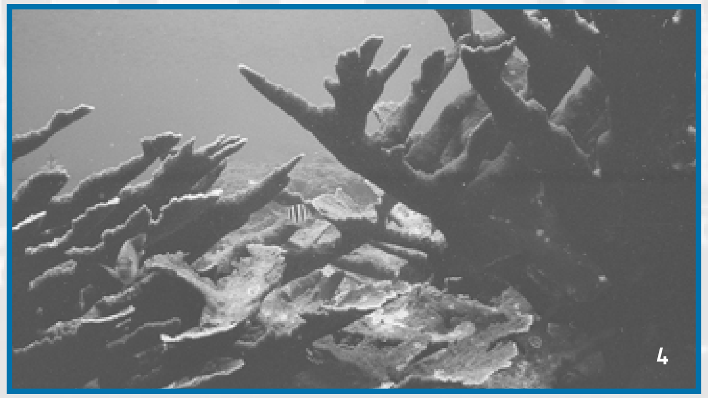
"...large fishes are now rare, catches have declined severely"

In 1971, large predatory fishes including groupers, snappers and sharks and herbivorous parrotfishes were not abundant, but could still be seen and fished at most reef sites. Large fishes are now rare, catches have declined severely, and the Kuna rely more on canned fish. Similarly the export fisheries for lobster and queen conch have also declined.

Change in coral reefs: In 1971, the reefs of the Kuna Yala were luxuriant with four prominent reef-building coral species (*Acropora palmata*, *A. cervicornis*, *Montastrea annularis*, and *Porites porites*), over 60 species altogether, and were among the most diverse sites in the Caribbean. The sheltered waters of the Gulf of San Blas fostered huge banks of *A. cervicornis*, extending from just below the surface to over 10 m in depth. In other areas, *Agaricia agaricites* formed extensive carpets over the seafloor and *Porites* formed rounded, rolling banks as large as tennis courts. To the east, outside the Gulf, where the long fetch of the Caribbean Sea brought great waves from the north, a booming surf crashed on solid algal ridges and corals were small and encrusting. But behind the ridges were found huge colonies of *Montastrea*. To this day, these remote islands and reefs are among the most beautiful seascapes I have ever seen.

"...behind these ridges we found some of the largest colonies of Montastrea"

In 1991, revisiting our field sites, we observed a decline in *Acropora* corals consistent with what had been documented all over the Caribbean. Warmer temperatures leading to bleaching, and various coral diseases had done great damage. The mass mortality of the herbivorous sea urchin *Diadema antillarum* in 1983-84 had upset the balance between corals and benthic algae. The large mounding *Montastrea* had large blotchy dead patches and once large banks of *A. cervicornis*, *Agaricia* and *Porites* were taken over by the brown algae, *Lobophora* and *Dictyota*.



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When we again returned in 2010, we were surprised and encouraged to see that the dramatic decline we observed between 1971 and 1991 had slowed. Even reefs close to heavily populated islands appeared healthier (except those where coral mining has occurred). We were encouraged by the recent recruitment of small acroporid colonies in some locations. As the reefs with the highest coral cover tended to be found near channels to the open sea, it is likely that water circulation is important to moderate seasonal high temperatures as well as keeping them free of sediment. While we recorded evidence of coral mining and intensive fishing pressure on the reefs near populated islands, more remote reefs further east with open exposure to the sea appeared in good health.

5

THE FUTURE OF CORAL REEFS IN THE COMARCA KUNA YALA

Based on our long-term observations, I have made three recommendations to the Kuna Congreso. First, stop coral mining, particularly the destruction of patch and barrier reefs near populated islands. These reefs provide a free and natural buffer against rising sea levels and storm surges, and are the economic future of the region through tourism. Second, implement a system of marine protected areas (MPAs) that encompasses a minimum 20% of the coral reef area of the Comarca. Third, draw on Kuna history to educate the youth and build an understanding of the unique relationship of the people with the sea and coral reefs. Such knowledge will help efforts to bring fishing, waste disposal and use of other ecosystem services into balance with the ability of the environment to provide them.

These were the first coral reefs we had ever seen, and like most people during a first intimate encounter, we were captivated by their beauty and diversity. We spent an idyllic year and a half of our youth exploring them and living among a people who depended upon them. We were saddened to see their condition in 1991, but by then we had observed similar disturbing declines in our new home in St. Croix, US Virgin Is. In 2010, as our baselines of comparison had shifted to a new reality, we looked for and were encouraged by signs of recovery. Of course, these qualitative observations require a healthy skepticism but we think they demonstrate the potential resilience of the ecosystem, combining people and coral reefs, in resisting and recovering from environmental change.

I would like to thank our friends and colleagues at the Smithsonian Tropical Research Institute, our old friends among the Kuna, and my wife and partner, Nancy Ogden.


1

Coral Reefs at La Parguera Puerto Rico...1970 Until Now

Alina M. Szmant

"...the shallow fore reef terrace was covered as far as one could see with A. cervicornis thickets"

In the summer of 1964, as an 18 year-old freshman at the University of Puerto Rico, I took my first marine ecology course with Peter Glynn and Jack Randall in La Parguera. I was so taken by the richness and colorfulness of the corals and fishes that I changed my major from chemistry to marine biology. I have vivid memories from that time but really had only a limited understanding of what I was seeing. Over the next five years as an undergraduate, a graduate student at Scripps, and a summer in Hawaii with Len Muscatine and Howard Lenhoff, I learned much of what was then known about corals and coral reefs. When I returned to UPR Mayaguez and to La Parguera in 1970, I set out to reconnoiter the extensive and varied coral reefs of the area. I visited many of the larger reefs, diving into the deeper fore reef zone and swimming up the depth profiles until I floundered in the reef crest zone. I made crude drawings of coral distribution and now wish that underwater photography was as easy then as it is now. As I look back through my limited slides taken with my Nikonos II, I regret that I can't find photographs that adequately illustrate what I clearly remember.

"...I regret that I can't find photographs that adequately illustrate what I clearly remember"

Probably the most spectacular and distinct reef at that time was Margarita Reef (2-3 km long - the most extensive bank reef on the SW Puerto Rico shelf). The fore reef only descended about 10 m but was formed almost entirely of live *Acropora palmata* spur and groove, as far as one could swim. The beautiful, healthy, majestic and classically shaped colonies were all oriented in growth position, with branches pointed into the swell. Seaward of the *A. palmata* colonies, the shallow fore reef terrace was covered as far as one could see with *A. cervicornis* thickets. Margarita Reef is the only place I've seen such extensive living *A. palmata*, but today, only a few scattered, small patches of living coral remain. Most of the colonies have extensive dead patches colonized by damselfishes, or are infested by corallivorous snails. I witnessed an impressive *A. palmata* and *A. cervicornis* recruitment event in the early 90s, but when I looked for it again a decade later, it had vanished.

The second most impressive coral reef formation was Turrumote reef, typical of larger bank reefs offshore of La Parguera, with a fore reef descending 20 m before leveling off at the insular shelf. The west end of this reef was made up of enormous colonies of *Montastraea faveolata*, many over 3 m in height and diameter, that cascaded down the fore reef slope for 3 to 15 m. Large fishes, green moray eels, nurse sharks and lobsters were common in the skirts of these gigantic colonies. In 1982, this reef was still intact and the colonies appeared healthy. As bleaching episodes began to affect La Parguera in 1987, year by year partial mortality and disease killed many of these corals. Today perhaps only 30% remain, a remarkable few in relatively good shape considering that surrounding corals may be all dead. In 2005, severe bleaching occurred, and the remaining corals lost more live tissue, didn't spawn or spawned very little for three years in a row. Eggs from 2008 spawn yielded sickly larvae that would not settle. But by 2009, most of the survivors regained their dark color and spawned profusely and we were able to raise healthy larvae. I hope this means that the few survivors are more tolerant of elevated temperatures, and that their offspring may help with recolonization.


2

The third reef site that I recall with awe (and of which I do have some photos) is the offshore shelf edge reef that is still known locally as "The Buoy" in honor of a large concrete block deployed back in 1969 by physical oceanographer Graham Giese. This site is 6-7 km offshore in deeper water and was chosen because it could be relocated by triangulating 3 line ups of a coastal hill, the mangrove clump on Turrumote islet, and the air conditioner that was on the top of a large condominium on Playa Santa. This was long before GPS, and the small wooden research boats we used had no electronic devices (the 25-40 hp motors even had manual pull starters). The Buoy was easy to find because visibility usually exceeded 30 m. It was our favorite dive site, not just for work but also to immerse ourselves in the beauty of it all. The shelf edge was characterized by a well-developed drowned spur and groove system that started about 15 m deep and continued down the insular shelf beyond 40 m, where it turned into a talus slope. The spurs were covered by >80% living coral, mostly small and medium sized *Montastraea, Siderastrea, Diploria, Colpohyllia* and other common genera, and large patches of *A. cervicornis* thickets. The grooves were narrowed from in-growth from the sides of the spurs by platy *M. franksi* and agaricid corals. The grooves were full of large schools of 60+ cm snappers, 1-2 m long barracudas that hovered within the water column, and giant green morays that inhabited overhangs and ledges common along the slope. These offshore deep reefs maintained their high live coral cover for a couple of decades after all the fishes were fished out, and the inshore reefs had started to decline. However, major coral loss began with the 1998 bleaching event and especially following the 2005 bleaching event. During the fall of 2005, torrential rains caused an extensive turbid and thick freshwater lens that extended across the entire width of the shelf along the SW coast of Puerto Rico, and lasted for several weeks. The combined stress (temperature, salinity, turbidity) led to major bleaching, disease and mortality, documented by Ernesto Weil, on the UPR faculty since 1996. Just before this happened, in the summer of 2005, we recorded the highest experimental settlement rate of M. faveolata larvae on substrates conditioned at this site compared to ones conditioned on inshore reefs. Alas, all of the spat died during that warming … it pains me the most to think about what has happened to these coral communities.

"Large fishes, green moray eels, nurse sharks and lobsters were common"


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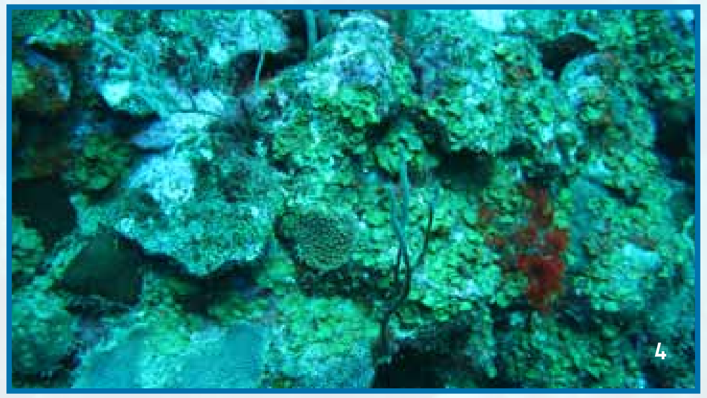
Over the past three decades, I've explored coral reefs in Florida, the Bahamas, Mexico, Belize, and Roatan, and more recently in the Netherland Antilles. Until Curaçao, I had not come across any coral communities that compared to my memories of La Parguera in the 70s and early 80s. The fringing reefs along the north coast of Roatan must have been much like the Puerto Rican bank and shelf edge reefs I remember, with well-developed spur and groove and huge *Montastraea* heads. But by 2000, the coral had been decimated by the 1998 Caribbean bleaching. Glovers Reef had amazing cascades of large *Montastraea* heads in 1987, but when I visited the Belize Barrier reef in 2003, they were mostly dead. The remote Bahamas reefs I visited (Joulters, Andros Barrier Reef) changed dramatically from 1987 to 1991, with major outbreaks of black band disease. Most recently, I worked on Curaçao and in 2007 I visited a west-end reef known as Watamula that has an extensive development of *M. faveolata* and *M. annularis* colonies. I nick-named this reef "*Montastraea* Heaven", and showed photos of this amazing place to a number of management types in the hopes that something would be done to protect it. Unfortunately, warm water induced bleaching hit the area in 2010, and as of June 2012, at least half of the coral has died. *Montastraea* spawn from this site likely reached reef areas west of Curaçao, and as such would have been a critical source of larvae. A nearby reef known as Mushroom Forest has a topography similar to Watamula but most of the large *Montastraea* colonies were already dead when I first visited in 2007, so maybe it was inevitable that Watamula's corals were not meant to have a long life in this world. There is an extensive patch of *A. cervicornis* on Roatan's southern shelf, known as Smith Bank, near a new cruise ship channel, and again I have not heard of any efforts to protect this unique and important area. I find it very frustrating that when such hot spots of remaining coral are found, there is no mechanism in place to protect them. They are our only hope for future coral reefs that have any semblance to the reefs I knew four decades ago.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"...when such hot spots of remaining coral are found, there is no mechanism in place to protect them"

Episodic Recruitment

Charles Birkeland

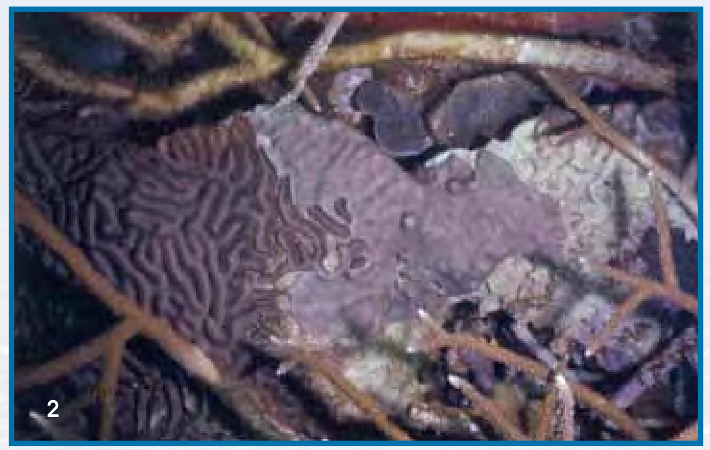
"... these outbreaks of coral predators did not support my initial expectation of coral reefs as stable, steady-state systems"

In 1970, I left the cold dark waters of Puget Sound for a post-doc in the warm clear waters of Panama's coral reefs. I'd been indoctrinated with the stability-time paradigm, expecting a predictable system in which each species on coral reefs could be counted on to be in its allocated niche as determined by competition for space. I expected that recruitment past the "wall of mouths" and into the stable system tightly controlled by competition for space would consist of a few lucky individuals scattered about. Back in 1955, in their classic study of the Enewetak reef, Eugene P. and Howard T. Odum concluded that "...the reef seems unchanged year after year…", "…With such long periods of time, adjustments in organismal components have produced a biota with a successful competitive adjustment…", and "It is concluded that the reef community is, under present ocean levels, a true ecological climax or open steady-state system". We should therefore strive to determine "How are steady state equilibria such as the reef ecosystem self-adjusted?" In 1973, Robert Endean based deductions on "… the generally accepted view that coral reefs are very stable biotic associations…"

But the reefs I saw in 1970 had my anticipated clear zonation patterns substantially confused by large monospecific patches of scleractinians, didemnid tunicates, and gorgonaceans in the Caribbean and these plus large patches of corallimorpharians and sponges in the Pacific. The stability-time hypothesis seemed problematic.

"The stability-time hypothesis seemed problematic"

The coral reef in front of the Smithsonian Tropical Research Institute's Galeta Lab on Panama's Caribbean coast was dominated in 1970 by the tunicate *Trididemnum solidum*. This large population stayed for at least a couple of years. *Trididemnum* readily overgrew colonies of most of the scleractinian species, expanding in one direction and sometimes receding on other colony borders, opening bare spots that allowed for recruitment of corals or other invertebrates or algae. Rolf Bak and his colleagues later found a 900% increase between 1978 and 1993 of *T. solidum* ("all hard



reef substrata were overgrown…as a virtually uninterrupted population along the coast") along 84 km of fringing reef at Curaçao. In Palau in 1981, I saw that thick rubbery *Lissoclinum patella* were overgrowing corals over large areas and the abundant smaller *Lissoclinum voeltzkowi* were weighing *Enhalus* seagrass blades down onto the sand. In American Samoa, in August 2007, *Diplosoma similis* carpeted the forereef slope and reef flat around the bases of corals in Fagatele Bay and at Onesosopo, and extensive patches of this species were also reported 214 miles north on Swain's Reef. Many of these large-scale "outbreaks" of photosynthetic ascidians occurred distant from human disturbance.

In the early 70s, at many sites, there was a dramatic increase in abundance of the "coral-eating sponge" *Terpios hoshinota*. It was widespread in Guam, and along the southeast shore covered most of one section of reef terrace nearly a kilometer in length. It was common throughout Micronesia (Palau, Yap, Chuuk (then Truk), Saipan, Rota, Aguijan, Pagan), and also at Cebu Island, Philippines and Taiwan (Dick Randall, *pers. comm.*), at Okinawa (Masashi Yamaguchi, *pers. comm.*) and in the Indian Ocean (Hansa Chansang, *pers. comm.*). Thomas Le Berre has said that *Terpios* seems to do best where corals are doing well or recovering, yet when outbreaks of *Terpios* have occurred more recently, observers tend to blame them on human activities. In the past they were mostly found distant from concentrations of human.

In the Indo-West Pacific, the extensive areas of reef carpeted by ascidians, sponges with photosymbiotic symbionts, corallimorpharians, octocorals or coral species (especially acroporids) appear to result from massive recruitment events. They typically persist for several years. They have frequently been considered to be "phase shifts", but they most often occur in clear and apparently unpolluted waters far from concentrations of humans and where the reef community appeared to be in good condition.

Echinoderms have been considered "the boom-bust phylum". *Acanthaster planci* had abrupt recruitment events over extensive areas in the late 60s. The 1969 outbreak in the Carolines occurred on 19 high islands spread across 3000 km and there were other outbreaks of tens of thousands to millions on other years in the Samoa Islands, Cook Islands, the Marianas, Hawaii, the GBR, and the Ryukyus. Of course, these outbreaks of coral predators did not support my initial expectation of coral reefs as stable, steady-state systems.

"...thousands of carcasses would drift up on beaches in windrows"

There were also massive recruitment events of fishes. The Hawaiian filefish *Pervagor spilosoma* rarely recruited in abundance, but 1944, 1975, and 1982-1987 were years of mass recruitment in which it was probably the most abundant fish in the Hawaiian Archipelago and thousands of carcasses would drift up on beaches in windrows. During 1982-1987, the recruitment was heavy throughout the 2500 km of the Hawaii Archipelago from the big island to Midway. In 2003, surveyed reefs had an average of 1000 *Priacanthus meeki* per 100 m of reef perimeter where *P. meeki* was not usually observed. Likewise, in 1988-1989, 50-90 *Zanclus cornutus* were found per 100 m along those same reef perimeters.

In the mid-70s, Peter Sale proposed the Lottery Hypothesis for reef fish which recognized that although competition for space certainly exists, the pattern of relative abundance of species is largely affected by the local history of successful recruitment. This certainly applies to colonial reef invertebrates. Although they can be observed frequently competing for space, the very first thing I noticed upon arriving in the tropics after graduate school was those large patches of single species colonial reef invertebrates displaying a complex history of previous disturbance, recruitment, and recovery. Rather than the stable system promulgated by the ecology texts of the 60s, the reef community was a mosaic of patches in various stages of recovery from various disturbances.

Over the years, our interpretations of patterns observed on coral reefs has gone in different directions for resources we extract vis-á-vis from the nonextracted benthos. We older scientists are intensely aware of the present scarcity of sharks and large fishes as compared to four decades ago. More recent generations of fishers and observers see the impressive diversity and numerical abundance of smaller reef fishes and view this as normal. This "shifting baseline" buffers the blame for human activities that reduce standing stocks of sharks and large reef fishes. In contrast, recent generations of scientists are alerted to large recruitments of benthic invertebrates, but are quick to interpret them as signs of deterioration of the normal functioning of the coral reef system brought about by human activities. The "shifting baseline" mollifies our concern for overharvesting reef resources, but we may be too quick to make issue over an extraordinary recruitment of benthic invertebrates.

My greatest regret is that I did not take time to document things the way they were in the 70s because I assumed they would return. When I first dove behind the University of Guam Marine Lab in the mid-70s, there was a large school of bumphead parrotfish *Bolbometopon muricatum* always around. They were fished out by the late 70s and I never saw another *B. muricatum* anywhere on Guam during the next 20 years. I learned too late that I should never assume what I see today will be there for study tomorrow.

Charlie Veron's Maps

Charlie Veron

"I believe that many corals are now regionally extinct or nearly so"

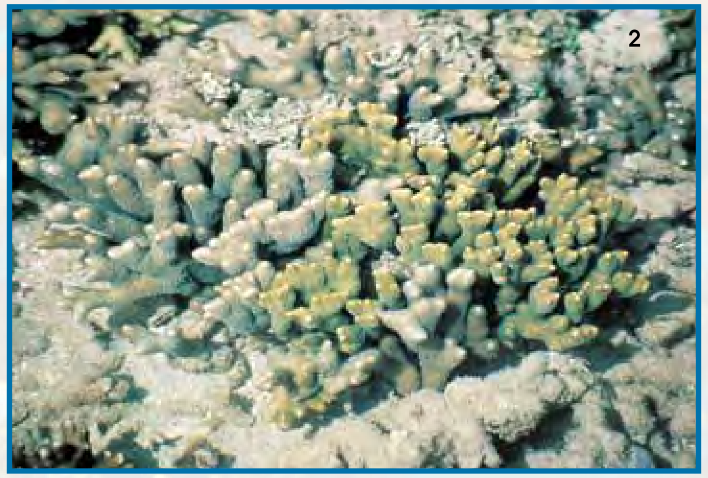
In the summer of 1975 I made my pilgrim voyage from Australia to America to study coral specimens in various museums and universities. I also wanted to meet the famous John Wells, a sort-of-mentor in coral taxonomy, with whom I had been corresponding with for several years. John was a Professor of Geology at Cornell University, although by this time he was semi-retired. Apart from his work on taxonomy, he had long been considered the world's custodian of coral distribution data, records he kept on a large sheet of graph paper pinned to a board on his study wall.

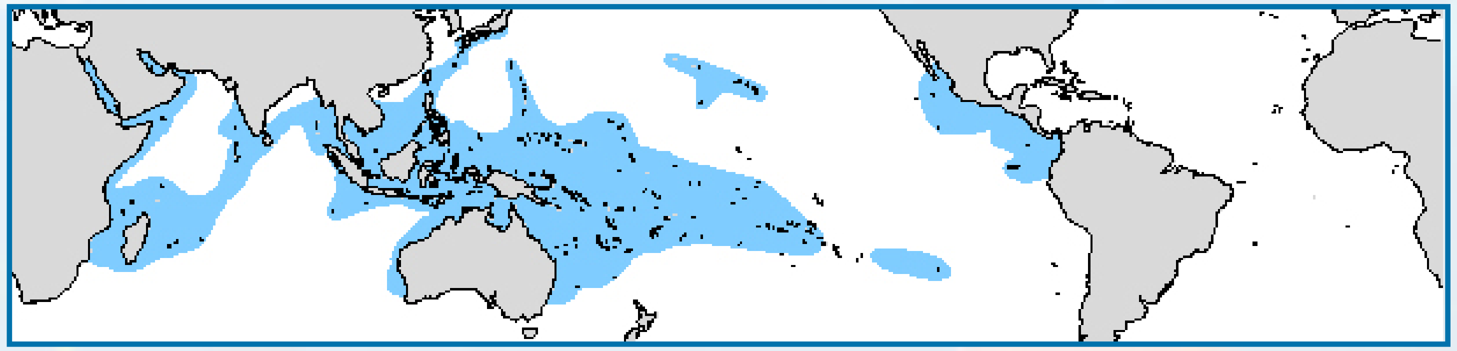
Coral genera were neatly listed down the left side (in order of most to least widespread) and places – mostly countries – headed the other columns (in order of most to least diverse). The whole thing was covered with crosses in pencil indicating "present" and there were hundreds of changes and question marks. Of course, any modification in the order of rows or columns created quite a mess, so there were many patches stuck on with tape, some ageing and peeling away. I spent an hour or so adding new crosses here and there and also a few more question marks, all of which we discussed animatedly. John explained that over the years he had redrawn the whole thing several times, but a new edition was now called for as this one was clearly falling apart. New edition needed or not, I was a little taken aback once our discussion ended and John ceremoniously took the sheet off his wall, rolled it up, handed it to me and said "*Your job now*". I must admit I wasn't too happy about this, so I kept it tucked away in a corner of my study back in Townsville. Temporarily forgotten, a couple of years passed when fate intervened: a magical machine which called itself an "*Apple Computer*" came onto the market. Having transferred John's masterpiece into this new device, I could now easily make any changes I wanted! We sure have come a long way since those days and I'm happy to say I still record coral distributions at the species level, which is why I am telling you this story.

A few years ago I was collecting coral on the Great Barrier Reef to compare the taxonomy of about 100 species via systematic studies of their DNA. After three weeks of detailed collecting I found myself still short of a branching *Montipora*. This was strange – I remember these corals being everywhere – in fact weren't branching *Montipora* often the dominant species of shallow inshore coral communities? Eventually I found what I was looking for in Geoffrey Bay, Magnetic Island, near Townsville, the place where Ben Stobart had studied two morphs (or species?) in 1992. However, I could only find one and the other was apparently missing altogether. This was something to worry about. Certainly I could tick branching *Montipora* off my "still wanted" list, but I still had to find *any* colony of the four other species, all of which used to be fairly common in the 70s and 80s.

"This was strange – I remember these corals being everywhere"

We all know about mass bleaching and we also have a good idea about coral susceptibility and what conditions cause it to occur. Usually, mass bleaching records reside in estimates of percentage death, but what about species details? Where can one find out about the fate of branching *Montipora* on the Great Barrier Reef, or the Ryukyu Islands, or anywhere else? When a species is actually killed off at a mass bleaching site there is simply no record of it. This is not very informative. As far as I am concerned, this is where a lot of questions – and alarm – reside, and it is not just with branching *Montipora*. *Pocillopora damicornis* for example is, or was, the most studied coral in the world. For good reason; it is common throughout the Indo-west Pacific, or was. When I worked





Map of the distribution of Pocillopora damicornis *in my book Corals of the World. The blue patches come from hundreds of records. The current equivalent is much more detailed, with dates on records.*

in the Ryukyu Islands in the 1980s, it was everywhere, frequently forming large monospecific stands. Try finding it now: they are still there, but nowhere is this species common and it never forms big stands anymore. In essence, these corals have been wiped out by mass bleaching and are becoming regionally extinct.

Actually, I believe that many corals are now regionally extinct or nearly so. What about the iconic *Acropora palmata* in the Caribbean? Or the tiny *Leptoseris papyracea* in the Galapagos? The same story? I'll admit that it is impossible to say definitively that any coral is extinct, even regionally, however, I can say that species that were once common are no longer so. I have tens of thousands of abundance records of coral species. Some are measurements from transects; some are visual estimates; and others are photographic records. All made at different times, in different places, forming a jig-saw pattern where some of the puzzle pieces now appear to be going missing.

My maps are going out of date, and losing accuracy. Certainly I am still adding records, but I don't delete any except for taxonomic reasons. The reality is that all records should now have a date with them. Perhaps these maps will one day be published electronically for everybody to play with, but they will no longer be statements of where a particular species is, but rather where it once was. I wonder what an accurate map of *Pocillopora damicornis* will look like 50 years from now, or even 20?

"The future for corals is not something to be predicted by computer models; it is plainly obvious for all to see"

Since my book, *A Reef in Time: the Great Barrier Reef from Beginning to End*, was published, my colleagues sometimes refer to it as a "particularly bleak" view of the future, or words to that effect. It is indeed bleak, mostly doom and gloom, but that is not my point of view nor anybody else's. It is simply reality. Corals are the most vulnerable of all marine creatures to temperature increases stemming from greenhouse gas warming, the core driver of climate change. The damage that has happened to coral reefs in only a few decades is clearly visible. Most reefs of coastal Asia, for example, are almost unrecognisable compared to my memories of when I first worked on them. This is not only due to mass bleaching, but much of it is. It is pure folly to imagine that what has happened to date won't continue into the future, and do so at an accelerating rate. Because of ocean lag time, corals are currently being killed off by carbon dioxide levels of the 1990s. The future for corals is not something to be predicted by computer models; it is plainly obvious for all to see. World, wake-up: it is actually, really, happening.

It never even crossed my mind, when talking to John Wells all those years ago, that a record in a table or a dot on a map needed a date to go with it. Yet students today think this obvious; they are already attuned to a different world. By the time these students are my age – a mere instant in the history of any coral species though that may be – most of what I once saw, and thought to be "normal", will be subjects of wonder to only be seen in photos or on video.

Authors

Alina Szmant

Alina's research includes her pioneering work on the reproduction and physiological ecology of Caribbean corals, and the role of nutrients in coral reef ecology, working mostly in Puerto Rico and the Florida Keys. She was a member of the all- female Tektite II aquanaut team in 1970, a founding member of ISRS, former Biological Editor for Coral Reefs and served on the Water Quality Technical Advisory Committee of the FKNMS.

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Barbara's research focuses on ecophysiology of Indo-Pacific corals, particularly on their responses to light and temperature and their scope for acclimatisation. She has worked on reefs in Thailand, Indonesia and the Maldives. She co-founded the ISRS and was both Secretary and Vice-President of the Society. She has also served as the Environmental Editor and and Editor in Chief of the journal Corals Reefs.

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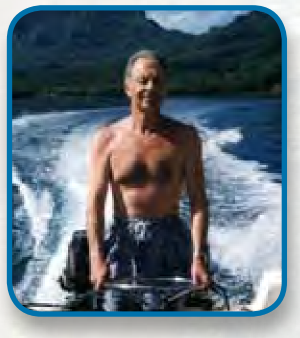

Bernard Salvat

Bernard's first research, which began in the 60s, was on New Caledonian coral reef ecology. He chose the French Polynesia and Moorea to implement a Research Center which became CRIOBE. Most of his publications relate to atolls and resource management and conservation involvement in the early 70s with the IUCN and UNESCO MAB program. He organized the 5th ICRS in 1985 in Tahiti and Chaired the International Society for Reef Studies. He contributed to the Global Coral Reef Monitoring Network by launching the Polynesian Mana node in the Central and East Pacific.

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Chuck's interests include natural history traits that determine ecosystem-level effects of certain species and how rates of nutrient input can determine differences in community structure. He has worked mostly in Micronesia and American Samoa and was an aquanaut on Tektite II in 1970 and Hydrolab in 1978. He was a founding member and third president of ISRS. He served as general editor of Micronesica for 8 years and as a contributing editor for MEPS for 30 years.

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Charlie, former Chief Scientist at the Australian Institute of Marine Science (AIMS), is now an AIMS Associate. He is the author of the three volume Corals of the World, and author of 100 scientific articles, including 14 books and monographs. He has been the recipient of the Darwin Medal, the Silver Jubilee Pin of the Australian Marine Sciences Association, the Australasian Science Prize, the Whitley Medal and has received special mention in the Eureka Awards. Charlie discovered and described 20% of all coral species in the world.

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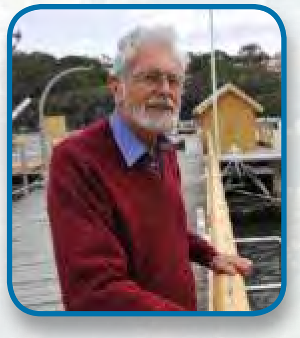

Frank Talbot

Frank is responsible for establishing the One Tree Island research station and later the Lizard Island Research Station. He served as the Director of the Australian Museum, the California Academy of Sciences, and (Smithsonian) National Museum of Natural History. In 1967, Frank attended the 1st International Coral Reef Symposium at Mandapam Camp, India. He was recently appointed a Member (AM) of the Order of Australia.

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Jack currently holds the position of Senior Ichthyologist Emeritus at the Bishop Museum in Honolulu and is Editor for the Indo-Pacific Fishes. He is a former member of the Graduate Faculty in Zoology, University of Hawai'i, former Director at the Institute of Marine Biology, University of Puerto Rico and of the Oceanic Institute, Hawai'i. He has 848 publications in marine biology, including 14 regional guide books on fishes. Jack is responsible for describing 795 valid species of marine fishes.

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John built and directed the West Indies Laboratory of Fairleigh Dickinson University, St. Croix, and the NOAA saturation diving facility Hydrolab. In 1988 he became the Director of the Florida Institute of Oceanography and built the Keys Marine Laboratory. He is now working to establish a research network of Caribbean marine laboratories to provide scientific input to new policy initiatives in regional ocean governance. He is the former President of the International Society for Reef Studies and a Fellow of the AAAS.

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Judith Lang

Judy described the 1st mechanism by which different corals compete directly. Breathing air at one atmosphere during submersible explorations that began in 1972 "cured" her cohort of diving deep with scuba. Retired from the University of Texas, she provides training materials and surveys for the AGRRA (Atlantic and Gulf Rapid Reef Assessment) project and travels *Our Reefs: Caribbean Connections*, an educational outreach reef conservation exhibit.

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Michel Pichon

Michel has studied corals and coral reefs over the last 50 years. He conducted research in the Red Sea, the Indian and Pacific Oceans and his interests include coral taxonomy, community structure and zonation, organic and inorganic carbon metabolism He has been based for >22 years in Australia, first at James Cook U., then as Deputy Director, Australian Institute of Marine Science. He has published more than 100 scientific papers, co-authored four books on the reef corals of Australia's GBR and two on the corals of the Mascarene Islands and South Yemen (Gulf of Aden).

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Peter Sale

Educated at U. Toronto and U. Hawaii, Peter's professional career in Australia (U. Sydney 68-87), USA (U. New Hampshire 88-93) and Canada (U. Windsor 94-06) spanned the emergence of coral reef ecology as hypothesis-testing, experimental science. He challenged entrenched ideas about ecology and pioneered the study of recruitment of reef organisms. A past President of both the Australian Coral Reef Society, and the International Society for Reef Studies, he now leads projects applying science to coastal marine management in tropical regions worldwide.

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Peter W. Glynn

Peter's coral reef research began in Puerto Rico in the early 1960s and has continued in the tropical eastern Pacific, from the late 1960s to the present. Species' interactions affecting coral community structure have been an active area of his research. His research has also centered on the disturbance ecology of eastern Pacific reefs, especially in relation to El Niño sea warming events, coral bleaching/mortality and community recovery. A long-time member of the International Society for Reef Studies, he was awarded the Charles Darwin Medal in 1992 in recognition of his work.

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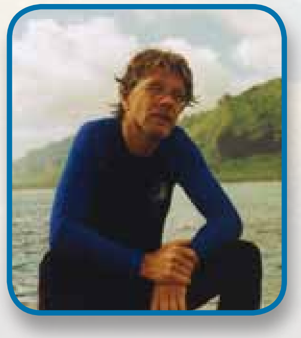

Rolf P.M. Bak

Rolf began his career as leader of the Coral Reef Project at the Carmabi research station in Curaçao NA in the 1970s. He later became a research scientist at NIOZ and the University of Amsterdam. His broad approach to coral reef ecology includes microbial studies and temporal change on reefs. In addition to the Caribbean, he has worked in Indonesia, French Polynesia, Maldives, and Antarctica. At present he is focussed on his long term reef monitoring program (begun early 70s) in Curaçao and Bonaire. He is Editor in Chief of the journal Coral Reefs.

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Photo Credits

Alina M. Szmant
1. Alina, Scripps, 1970 (Scripps Institution of Oceanography Archives)
2. The Buoy, 1973 (A. Szmant)
3. The Buoy, 2008 (A. Szmant)
4. The Buoy, 2008 (A. Szmant)
5. Background: The Buoy spur and groove, 2008 (A. Szmant)

Authors page: Alina, Curaçao, 2005 (Charles Mazel)

Barbara Brown
1. Barbara, finishing reef survey during the wet SW monsoon, 1979 (Matthew Holley)
2. Intertidal reef flats dominated by poritids, faviids and the agariciid, *Coeloseris mayeri*, S.E. Phuket, Thailand, 1991 (B. Brown)
3. Gleaning for molluscs and octopus on intertidal reef flats, Phuket, Thailand, 1980s (B. Brown)
4. Luxuriant intertidal reef , early coral bleaching event, S.E. Phuket, Thailand, May 2010 (Niphon Phongsuwan)
5. Background: Coral reef, MPA at Simillian Islands, Thailand, 2006 (Konstantin Tkachenko, Marine Photobank)

Bernard Salvat
1. Bernard, 1991
2. The coral reef ecosystem (800 m large) was pristine, Moorea, Radiale de Tiahura, 1971 (B. Salvat)
3. Bernard Salvat and Jeana Marc Zanini on the barrier reef, Moorea, Radiale de Tiahura, 1998 (Christophe Le Petit)
4. The site today with dredged channels and tourism complex, Moorea, Tiahura site, 2000 (B. Salvat)
5. Background: Bernard on the outer slope, 15 m, Moorea, Radiale de Tiahura, 1998 (Christophe Le Petit)

Charles Birkeland
1. Charles, May 1970 (Brian Gregory)
2. Trididemnum solidum overgrowing a Caribbean coral, Glover's Reef, Belize, November 1971 (C. Birkeland)
3. Outbreak of *Acropora hyacinthus*, Fagatele Bay, Tutuila, American Samoa, August 2007 (C. Birkeland)
4. Rather than the stable system promulgated by the ecology texts of the 60s, the reef community was a mosaic of patches in various stages of recovery from various disturbances, Ucubsui Reef, San Blas Islands, Panama, 1973 (C. Birkeland)
5. Background: San Blas, Panama, 2005 (Wolcott Henry, Marine Photobank)

Charlie Veron
1. Charlie on Hinchinbrook trip, first time to GBR, 1964
2. The two forms of branching *Montipora*, Geoffrey Bay, Magnetic Island where Ben Stobart conducted his study in 1992 (B. Stobart)
3. A community of five species of branching *Montipora* at the Ryukyu Islands, Japan, 1984 (C. Veron)
4. Background: Coral reef, Indonesia, 2010 (A. Dansie)

Authors page: Charlie at Kimbe Bay, Papua New Guinea, 2009 (Louise Goggin)

Frank Talbot
1. Giant grouper (Mepps, Dreamstime.com)
2. Dhows at sunset, Stone Town, Zanzibar, 2007 (Melanie King)
3. Background: Fishermen in Zanzibar, 2010 (Dester, Dreamstime.com)

John E. Randall
1. Jack with model of White Shark, age 67 (Australian Museum)
2. Outer edge of reef flat, lee side of Onotoa Atoll, Tungaru Islands (J.E. Randall)
3. Buck Island, St. Croix, U.S. Virgin Islands (Sandy Hills-Starr)
4. Diversity of coral, Palau (Patrick L. Colin)
5. Mechechar, Palau (Patrick L. Colin)
6. Background: Hanauma Bay (F. Schneidewind)

Authors page: Jack, age 80 (Bishop Museum)

John Ogden
1. John, St. Croix, 1979 (J. Ogden)
2. Our home, Isla Pico Feo, 1970-71 (J. Ogden)
3. Coral rock mining (Arcadio Castillo)
4. Elkhorn coral (*Acropora palmata*), Aguadargana, 1970 (J. Ogden)
5. Finger coral overgrown by algae, Isla Pico Feo, 1991 (J. Ogden)
6. Background: Wichubhuala at sundown, 2010 (J. Ogden)

Judith Lang
1. Judy, early 1960s (unknown)
2. Judy diving on the fore reef slope, Discovery Bay, Jamaica, mid-to-late 1960s (Eileen Graham)
3. Judy diving above a tangle of *Acropora cervicornis*, ~20 m on the fore-reef escarpment, Discovery Bay, Jamaica, 1973 (Phillip Dustan)
4. Discovery Bay Marine Laboratory, Jamaica, 2012 (J. Lang)
5. Background: Discovery Bay scene in Jamaica, 2012 (J. Lang)

Authors page: Judy, 2011 (Liz Smith, Khaled bin Sultan Living Oceans Foundation)

Michel Pichon
1. Michel, 1965 (R. Derijard)
2. Part of the immense field of branching *Acropora* at low tide. Ifaty reef flat, 1961 (M. Pichon)
3. Michel and two marine station staff on their way to the barrier reef , Tulear, 1965 (R. Derijard)
4. Background: Madagascar coast, 2009 (Pierre-yves Babelon Dreamstime.com)

Peter F. Sale
1. Peter, One Tree Island, 1975 (P.F. Sale)
2. Censusing fish, southern GBR, Australia, ca 1985 (P.F. Sale)
3. Boat arriving on One Tree Island, Australia, late 70s (P.F. Sale)
4. Aerial view of One Tree Island, Australia, 1975 (One Tree Island Research Station)
5. Background: Aerial view, GBR (Great Barrier Reef Marine Park Authority)

Authors page: Peter, Heron Island, 2008 (A.J. Hooten)

Peter W. Glynn
1. Peter, Baja California, 1951 (John Elwell)
2. A m^2 sampling plot on the Saboga Island tidally exposed reef flat showing an abundance of pocilloporid corals, Pearl Islands, Gulf of Panamá, January 1974 (P.W. Glynn)
3. Uva Island forereef dominated by *Pocillopora* spp. before the 1982-83 El Niño bleaching/mortality event, Gulf of Chiriquí, Panamá, September 1975, 2-3 m depth (P.W. Glynn)
4. Peter measuring corals on the Darwin Island coral reef, Galapagos Islands, June 2012 (J.S. Feingold)
5. Background: Aerial view of Belize Cayes, 2009 (Hanneke Van Lavieren)

Rolf P.M. Bak
1. Rolf, 1973 (Carmabi)
2. Seaward slope 40 m, Buoy One, Curaçao, 1978 (Rolf P.M. Bak)
3. Seaward slope 40 m, Buoy Two, Curaçao, 1978 (Rolf P.M. Bak)
4. Background: Curacao, 2010 (Kjersti Joergensen, Dreamstime.com)

Authors page: Rolf, 2004 (Erik Meesters)

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1. Judy diving, ~12 m, on the fore-reef terrace, Discovery Bay, Jamaica, 1973 (Phillip Dustan)
2. Barbara Brown (left) and Betsy Gladfelter, 5th International Coral Reef Symposium, Tahiti, 1985 (J. Ogden)
3. Pachyseris, deep outer slope, Tiahura Sector, Moorea, French Polynesia, 1985 (Claude Rives)
4. Background: Coral reef, Meso America (Bob Steneck)

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2. Jack with model of White Shark, age 67 (Australian Museum)
3. Judy diving at 35 m along the fore-reef slope, Discovery Bay, Jamaica, 1972 (Phillip Dustan)

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1. Intertidal reef flats dominated by poritids, faviids and the agariciid, *Coeloseris mayeri*, S.E. Phuket, Thailand, 1991 (B. Brown)
2. Kimbe Bay, Papua New Guinea, 2009 (Louise Goggin)
3. Hanauma Bay (F. Schneidewind)
4. The two forms of branching *Montipora*, Geoffrey Bay, Magnetic Island where Ben Stobart conducted his study in 1992 (B. Stobart)
5. David Stodardt (L) and Bernard Salvat (R), Berkely, San Francisco, International Society for Reef Studies Meeting, 1991 (B. Salvat)
6. The site today with dredged channels and tourism complex, Moorea, Tiahura site, 2000 (B. Salvat)

Faculty and students participating in the Experimental Coelenterate Biology graduate training course taught on Coconut Island, Hawaii Institute of Marine Biology, University of Hawaii, summer of 1970 (University of Hawaii archives).

Front row (L to R): Stephen D. Young, John Rees, and Howard M. Lenhoff
Middle row (L to R): L.H. DiSalvo, Alina M. Szmant, K. June Lindstedt, Clayton B. Cook, and Leonard Muscatine
Back row(s) (L to R): Eric Eisenstadt, John M. Gosline, Conrad Clausen, Rosevelt L. Pardy, Dennis A. Powers, Gordon R. Murdock, unknown, Lary V. Davis, and Richard N. Mariscal
Missing: Amada Reimer and Vicki Buchsbaum Pearse

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