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HOW TO REGROW CORALS ALONG THE RIVIERA MAYA – INSIGHTS FROM PROJECT MEXICO

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A unique project has its headquarters in Puerto Morelos: scientists, aquarists, local stakeholders and authorities work together to restore Mexico's dwindling coral reefs. Main focus is to develop, test and apply new techniques and methods for larger-scale restoration. First successes are promising—still there is a lot to do!

Coral reefs once flourished along the Riviera Maya. They are highly diverse and productive ecosystems, also essential for coastal protection, providing economic goods and attracting tourists. During the last decades, a series of hurricanes, diseases and bleaching events have taken their toll among reefs throughout the Caribbean. Today, many of those reefs have changed from being once dominated by stony corals—the builders of the reef itself—to places where coral cover is low and macro algae, sponges and soft coral sprout. This process is called 'phase shift'. Further stressed by overfishing, pollution and rising seawater temperature, some corals do not produce offspring anymore. Without corals, reefs and their inhabitants will disappear within a few decades.

At the Unidad Academica de Sistemas Arrecifales ('the Reef Systems Academic Unit", UASA), a satellite campus of UNAM (the Universidad Nacional Autonoma de Mexico) in Puerto Morelos, the headquarters of a unique project is located. Partners from several institutions, organizations and authorities, national and international ones, work together to give coral reefs a future: Project Mexico. This pilot project aims at studying how to implement larger scale restoration by taking advantage of corals' sexual propagation.

How it all began

Since 2007, Dr. Anastazia 'Ania' Banaszak—a research professor at UNAM—and her team have been conducting research on coral reproduction and restoration at the UASA, whereas on Curaçao, SECORE and partners have been working on Project Curaçao to study coral restoration using sexual reproduction. Then, at the International Coral Reef Conference in Cairns 2012, Ania and Dirk—Dr. Dirk Petersen, founder and executive director of SECORE—came together to discuss the possibilities to join forces. They agreed that the focus of a future collaboration should be based on the need to develop and apply methods for larger-scale restoration. The idea for Project Mexico was born.

First task of the new collaboration was a joint coral restoration workshop hosted at Puerto Morelos in 2013—the initial one, as workshops have continued to happen every year since. Two years later, after funding was granted, 'Project Mexico' was officially launched with Ania as the lead on-site. "The success of our project is based on the fact that we have many key collaborations", says Ania. "Apart from SECORE, we work with aquarium professionals from Xcaret Eco Park, and also with several aquariums in the USA. A close collaborative partner is the National Authority for Natural Protected Areas (CONANP) dealing closely with the various directors of the nearby National Parks that have coral reefs such as the Parque Nacional Arrecifes de Puerto Morelos (PNAPM). Scientists from national and international universities conduct research and collaborate within the framework of this project."

Photos: 'the Reef Systems Academic Unit', UASA, at Puerto Morelos **left)** Dr. Anastazia 'Ania' Banaszak, ©Sina Löschke; **mid)** UASA Jetty, ©Reef Patrol; **right)** UASA campus, **below)** endangered elkhorn coral, both ©Paul Selvaggio.



Growing coral recruits

Sexual coral restoration has a great potential for scaling-up coral restoration. During spawning events one may be able obtain huge numbers of coral recruits—literally millions if handled accordingly—that are all genetically unique.

It all starts with the magic nights of coral spawning: “We have worked with a number of species, but our main focus is on one, extremely important species in shallow water, **Acropora palmata**, the elkhorn coral, which is listed as a critically endangered species today (IUCN, Red List of Threatened Species)”, explains Ania. “This species still spawns well, but natural recruitment is low to non-existent. So, we collect eggs and sperm on the reef during spawning nights and fertilize them **in vitro** on the research vessel (when sperm meets egg). After several washing steps in the laboratory we culture the embryos and resulting larvae until they settle on specially conditioned coral substrates and form baby corals”.

Easier said than done because Caribbean Acropora are quite delicate to handle—but year-long experience makes for success. Still, unforeseen adversities may happen any time: “Last year, we had an unusual outbreak of ciliates that feasted on the recently settled recruits. Otherwise we would have produced a lot more coral recruits. Luckily, we caught the outbreak in time and saved at least half of the recruits. It taught us to be more vigilant”, says Ania.

Working with sexual coral reproduction one may produce millions of coral larvae that could be raised into genetically diverse corals; genetic diversity is maintained 'on the side' and natural selection could play its role according to prevailing conditions. Nevertheless, new cost-effective techniques to culture such huge amounts of larvae are needed. Together with Mark Schick (Shedd Aquarium) and other partners, the so-called 'pools' were developed.

The pools are a follow-up idea, first implemented by Makoto Omori und Kenji Iwao, Akajima Marine Science Laboratory. The idea is to culture coral embryos in big floating devices and provide them with settlement substrates once the larvae are ready. In the future, such pools could be moored at a sheltered jetty or bay and coral recruits may be directly transferred to the outplanting site without the need for a land-based lab or nursery.

The first prototype was tested in 2015 in Mexico and the results were promising. A revised version was used in 2016's spawning work at Mexico, as well as on Curacao. “In 2017, we will work with a further refined version of 'pools' using several replicates”, says Ania. “In the future, these devices could provide a relatively easy way to handle huge amounts of fertilized eggs and sexual recruits without ever touching them, which supersedes a lot of handling time. We need to develop technically simple methods that can be applied at our various operating sites.”

Photos: top row, working with corals' sexual reproduction **left)** collecting elkhorn coral spawn, ©Paul Selvaggio; **mid)** a lot of fertilized coral eggs, **right)** checking settlement of coral larvae under fluorescence light, both ©Reef Patrol; row below, testing large-scale techniques **left)** coral substrates in bins with settling larvae, ©Reef Patrol; **mid)** 2015's pool version, ©Paul Selvaggio; **right)** 2016's pool version, under construction by Aaron Jeskie, ©Reef Patrol






Planting corals on larger scales

To date, individually attaching coral fragments or settlement substrates containing sexual recruits takes a major portion of time and money invested into coral restoration efforts. Together with the general handling time and a lot of cleaning done during nursery periods, this limits the numbers of corals that could be used in current restoration efforts. So how to outplant more coral with less effort?

“The settlement substrates we use were recently developed by SECORE and have a tetrapod form, to facilitate anchoring to the reef without the need to use a glue or any type of cement”, explains Sergio Guendulain, who works with Ania as a technician in Project Mexico. “Furthermore, to make the substrates attractive to the larvae, we condition the tiles in the ocean. This process takes approximately two months and allows for the growth of biofilm and coralline algae that induce the larvae to settle.”

“We transport the substrates to the outplant sites in Puerto Morelos, Sian Kaan and Xcalak and place the substrates into the natural nooks and crevices in the reef”, says Ania. “However, it is actually more complicated. In 2015, the bulk of the substrates were stacked in crates in the pools at Xcarets facilities. So we had to get a truck to Xcaret to load up the substrates in water filled containers to make the 250 kilometer journey south to the outplant site. All transportation was done at night to reduce temperature effects on the corals, because all of this work is done in the summer. As soon as we arrived at the beach closest to the outplant site, the containers were loaded onto a boat to do the seeding before the sun was high and the temperature was too hot.” Seeding corals is no work for late risers!

In 2016, the outplanting process was similar, but the coral recruits were seeded only on the reef site within the Puerto Morelos Reef National Park; it is a degraded site that still has a few colonies of **Acropora palmata**. “Weather was a definite challenge this year”, says Ania, “lots of rough weather and rain really restricted us and affected the recruits. Planned monitoring dives often needed to be re-scheduled several times. Logistics are sometimes a

challenge too, for instance to move the really heavy crates with the substrates and the water when they start their journey to the reef. But luckily my dream team is a fantastic and very experienced group; together we rise to all challenges."

"This year, I would like to try putting the coral settlement substrates in nurseries for a little while until the recruits get established and then transfer them to the reef rather than seeding them directly at a very young age", explains Ania. "This is because we see a lot of macroalgal overgrowth and evidence of predation. Maybe if they are a little older when we ouplant them onto the reef, we will have higher survival rates. We will also try seeding them within different levels of reef degradation to see how it affects the survival of the corals."

Photos: top row, settlement substrates **left)** Dr. Dirk Petersen, executive director and founder of SECORE with coral settlement substrate, **mid)** bringing crates with pre-conditioned substrates to the UASA lab, **right)** delicate primary polyps of elkhorn corals under fluorescence light on tetrapod, all ©Reef Patrol; row below, out to the reef **left)** crates with settlement substrates containing coral recruits, **mid)** seeding corals along the line, **right)** outplanted substrates with recruits of 2016's cohort, all ©Sandra Mendoza Quiroz.






Monitoring coral restoration success

To evaluate whether the applied methods are functioning, each coral substrate and each coral recruit on it needs to be tracked down and monitored; every change and loss documented. And monitoring the survival of outplanted corals bears another challenge: the substrates are literally so difficult to see that it is tricky to find them. After a while, the substrates incorporate into the reef structure and become invisible to the naked eye while the corals overgrow the substrates and attach themselves to the reef. "We use band transects and we know how many substrates we sowed per square meter", says Sergio. "So when we do the monitoring we make sure to do it in exactly the same place and basically we search for each substrate. If you do not and only swim around it is very difficult to find them again." Therefore, each site was georeferenced before transferring the new corals to the reef and survey lines were put out to map each tile and to be able to conduct surveys over time. Generally, four to five tiles are outplanted per m².

In 2015, 500 coral settlement substrates were outplanted and monitored regularly. "After two months, we found 73% of the tiles and after eight months we found 27% of the tiles; or approximately one tile per m², which is what we would aim for in restoration efforts", says Ania. "At this point it is harder to monitor as the tiles are fully incorporated into the surrounding substrate and many could not be rediscovered. After one year, only nine of the retrieved substrates had recruits on them. Our last survey was in the second week of December and all nine are healthy and growing. During October and November some were a little pale due to a mass bleaching event in Puerto Morelos' reef, but they all survived and are looking healthy again. The probable cause of why so few recruits survived is the huge Sargassum bloom that we had in the area, which affected water quality for over a year. Close to the shore the water was getting anoxic, which of course is likely to affect post-settlement survival of the young corals."

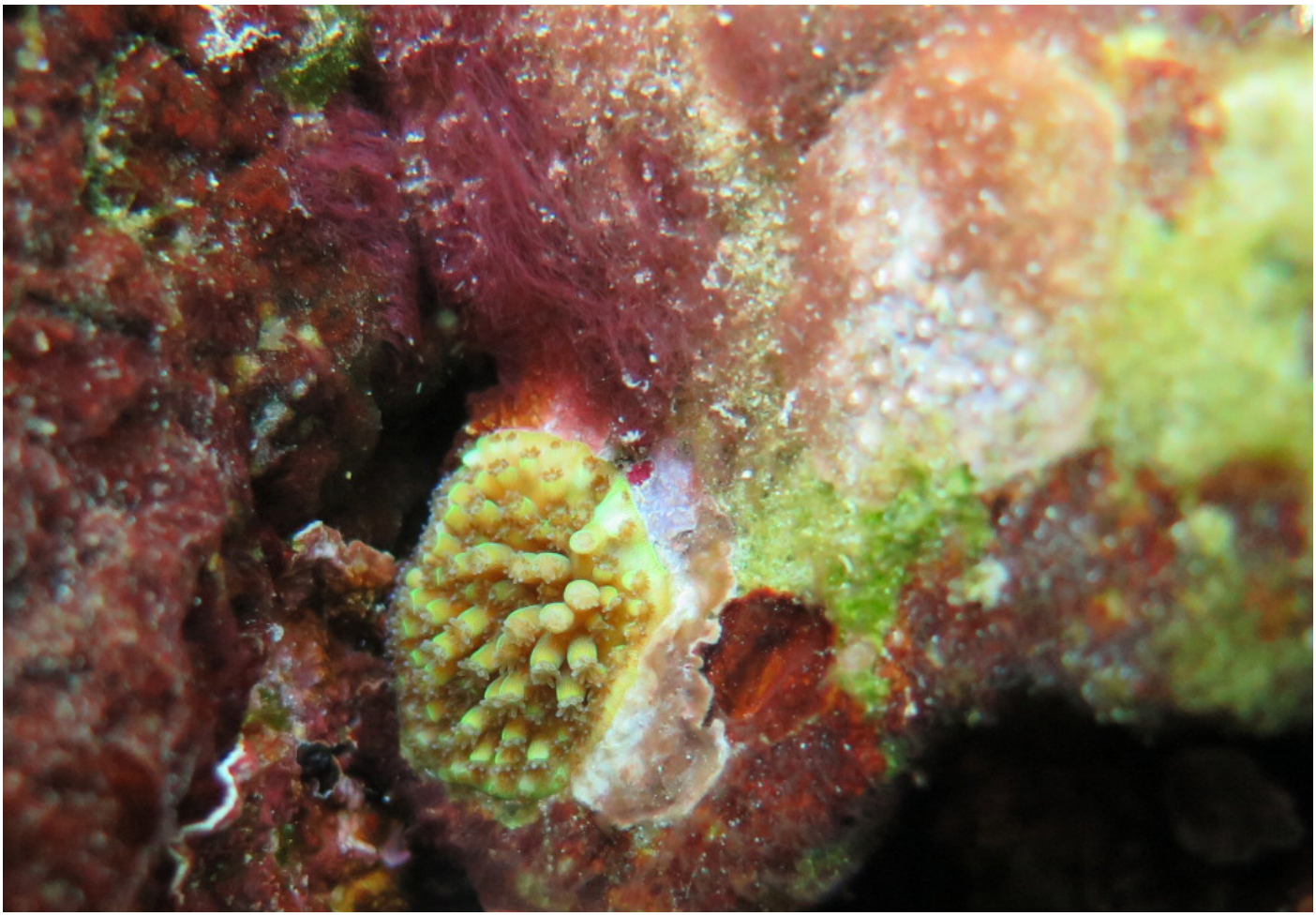
The 2015 Sargassum bloom may look like a kind of random, catastrophic event; catastrophic it was, but it was also in all probability man-made and its bloom spread widely in the Caribbean. A 'Sargassum bloom series' started

already in 2011, with its last and biggest bloom event in 2015—so far. The reasons for this bloom series are complicated, but a most likely scenario may be a combination of factors: “It is believed that the recent influxes are related to massive sargassum blooms occurring in particular areas of the Atlantic, not directly associated with the Sargasso Sea, where nutrients are available and temperatures are high. The sargassum consolidates into large mats and windrows and is transported by ocean currents towards and throughout the Caribbean. Some scientists associate the cause of sargassum with higher than normal temperatures and low winds, both of which influence ocean currents, and they draw links to global climate change.“ (Source: Doyle, E. and J. Franks, 2015, Sargassum Fact Sheet)

The coral cohort from 2016's spawning season seems to be coping better. A similar number of substrates was outplanted and, after four months, at least half of the tiles still had at least one coral recruit. This is quite good, keeping in mind that post-settlement mortality is a tight bottleneck for growing corals and part of the natural selection for the prevailing conditions. “That is why our strategy is to outplant so many in the hope that some will make it”, explains Ania. “Of course we are also working on trying to dramatically improve the post-settlement survival.”

Photos: time series of growing corals within the reef **left)** 3rd September 2015, the day the recruits were seeded, each white point in a sexual recruit of an elkhorn coral, ©Sandra Mendoza Quiroz; **mid)** October 2015, fewer recruits and they are now pigmented, as they have taken up their symbiontic algae, crucial for their survival, ©Sergio Guendulain; **right)** January 2016, bigger and fewer recruits that look healthy, ©Sandra Mendoza Quiroz; **below)** August 2016, the substrate is hardly visible, it has been cemented into the natural substrate by red calcareous algae, but one can still see the grooves just below the coral recruit that shows there is a settlement substrate below it, ©Ángela Alegría





Education and outreach

Since 2013, Ania and her team together with SECORE and international aquarium professionals have conducted workshops for local stakeholders, reef managers and authorities on coral reproduction and restoration. Currently, the lead aquarium partners are the California Academy of Sciences and the Columbus Zoo and Aquarium (CZA). For instance, senior aquarist Aaron Jeskie (CZA)—together with other aquarium professionals—attended the 2016 workshop as an organizer and shared his knowledge in coral husbandry and technical know-how. He was also the one responsible to install the pools' test set-up.

During the workshops, spawning work is accomplished in teams in the laboratories at UASA and Xcaret, and knowledge and hands-on practices are shared. Every hand is needed during the long night shifts of spawning work.

Student courses on coral reproduction and related themes accompany the annual spawning workshops. In 2015, there was an especially comprehensive course 'From Coral Reproduction to Reef Restoration' and due to popular demand it was repeated in 2016. During the courses each year, the students learn the theory and get the chance to take part in making spawning nets and hands-on experience with the practical side of spawning work at UASA. The benefit is mutual: “Coral restoration cannot be done by a small group of environmentalists. We need a lot of people who know how to do the techniques and help us“, explains Ania.

Last spawning season, the film team from Reef Patrol joined the workshop. Together we are producing a documentary to spread the word about the joint work in Mexico—coming soon! You can get a first glimpse by watching the trailer 'Saving the Mexican Acropora palmata'.

There are other initiatives like Mares Mexicanos that raise awareness about coral reefs and their alarming status. They, for instance, compiled a nice and informative movie, featuring some of UASA's scientists—including Ania—as well as parts of the work done for Project Mexico: Puerto Morelos Arrecifes del Caribe.

Photos: **left)** spawning work in the UASA's laboratory with students and workshop participants, ©Paul Selvaggio; **mid)** night dive and boat team at Xcaret, **right)** Reef Patrol at work during spawning night, both ©Reef Patrol



First successes—but the work has just begun

Corals face the over-arching threat of raising seawater temperature and ocean acidification caused by human's emission of greenhouse gases, as well as local stressors such as pollution—e.g. by feeding raw sewage into our oceans, which degrades water quality considerably.

“The main problem for reefs are basically human behaviors”, says María del Carmen García Rivas, director of the Puerto Morelos Reef National Park (CONANP). “We have very little wastewater management and, in addition, our legal framework is not very strict and so, the reefs are being filled with organic material and algae cover increases. On the other hand, we have overfishing and the consumption of fishery resources during the closed season. We apply the law and basically what we want is that the corals are healthy and this we aim at achieving with environmental education, with courses, with measurements. We work very closely with academic institutions, especially with the National Autonomous University of Mexico and their Project Mexico at the UASA, which we have here close by. They, together with other institutions, have researched this reef for more than 30 years, so we are very close monitoring the state of health of the reef. We consult with them and try to apply findings to our management.”

“My future vision of this project is that we become a research and training center for the whole Caribbean and Latin America”, says Ania. “We need many people working to restore coral reefs and using sexual coral restoration to maintain a high genetic diversity of corals and help them to survive all the climate change condition they will be receiving within the next coming decades. If we really want to give coral reefs a future we all need to work together and from many different sides. There is the saying that to raise a child, it takes a village. My belief is that to restore reefs it will take many villages.”

You can meet Ania in this short video clip, the first of our portrait series by Reef Patrol introducing SECORE's experts—please enjoy!

Photos: **top)** representative of Mexican authorities with Ania at UASA, **below)** just after sunset: getting ready for spawning dive, both ©Reef Patrol

Title photo: elkhorn coral, ©Paul Selvaggio

by Carin Jantzen

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