

# Coral Matters

THE CORAL REEF RESEARCH HUB MAGAZINE

## HOW THREATENED ARE CORAL REEFS?

Coral Reefs Under Pressure: Beyond the Heat

Also in this issue: Can turbid reefs be a source of resilient corals

Regulars include: Reef roundup, photographer spotlight, stories from the field, coral career column, get the right gear





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# CoRR Hub News

It has been a busy few months at the Coral Reef Research Hub, with new courses being added to our growing educational library and some exciting progress behind the scenes on the CoRR Hub app.

## Three New Courses Released

Over the past few months, we have released three new courses designed to build practical skills for coral reef and marine scientists.

**Introductory GIS** gives an amazing insight into the fundamentals of Geographic Information Systems and their application to marine and coral reef science, providing a starting point for those wanting to develop their spatial data and mapping skills.

**Field Techniques for Coral Reef Scientists** provides a practical introduction to planning and carrying out coral reef research, covering survey design, quadrats, transects, benthic and fish surveys, environmental variables and other field techniques.

**Introduction to R & RStudio for Marine Scientists**, presented by Klaus Stiefel, offers an accessible introduction to using R for marine science, including basic syntax, importing data, plotting and visualisation, working with FishBase data, and using AI to support R coding.

Together, these new courses continue our aim of providing accessible, practical training that helps students and early-career scientists develop the skills they need for research and careers in coral reef science.

## The CoRR Hub App Moves into its Next Stage

There has also been plenty happening behind the scenes with the CoRR Hub app. The first version has now completed its initial round of beta testing with a small group of testers, whose feedback has helped us identify bugs, improvements and areas for further refinement.

In just a matter of days, Version 2 will be ready for testing, and this time we will be opening beta testing to a much larger group. This next stage will allow us to test the app across a broader range of users and devices as we move closer to its full release. The app is an important next step for CoRR Hub, making it easier for members of the global coral reef community to connect, network and access the Hub wherever they are.

With three new courses launched and the app entering its second phase of beta testing, it has certainly been a busy few months at CoRR Hub – and there is plenty more to come.

*The CoRR Hub Team*

# Reef Roundup: Around the World



## Noteworthy coral news from around the world:

1. **Global Story:** *Super El Niño Poses a Growing Threat to Coral Reefs* - A rapidly strengthening super El Niño, combined with record-breaking ocean temperatures, is increasing heat stress on coral reefs worldwide, raising fears of further widespread bleaching. (Nature, 2026)
2. **Great Barrier Reef:** *Signs of Recovery on the Great Barrier Reef* - Coral cover increased slightly in the northern and central Great Barrier Reef after a late monsoon cooled waters and reduced the severity of bleaching in early 2026. (AIMS, 2026)

3. **Florida, USA:** *Major Coral Spawning Effort Produces 1.5 Million Embryos* - Twelve organisations joined forces during Florida's annual coral spawning to produce more than 1.5 million embryos and preserve genetic diversity for future reef restoration. (The Sarasota Record, 2026)
4. **Red Sea:** *Probiotics Help Corals Survive Marine Heatwaves* - Field trials in the Red Sea found that probiotic and postbiotic treatments improved coral health during natural heat stress, opening a potential new avenue for reef restoration. (Kaust, 2026)
- 5.

**5. Micronesia:** *Pacific Nations Strengthen Protection for Climate-Resilient Reefs* - French Polynesia and Tonga joined an international commitment to prioritise protection of coral reefs considered most capable of surviving climate change. (Coral Reef Rescue Initiative, 2026)

**6. Gulf of Mexico:** *Fertiliser Pollution Threatens Previously Resilient Gulf Reefs* - Researchers found that 60–80% of nitrogen reaching corals at the Flower Garden Banks originates from the Mississippi River basin, adding pollution pressure to rising ocean temperatures. (Louisiana Illuminator, 2026)

**7. West Africa:** *'Lost' Coral Community Rediscovered off West Africa* - Scientists reported the rediscovery of living mesophotic coral communities more than 50 metres deep off Benin, an area whose coral habitat had been presumed lost for decades. (Smithsonian Magazine, 2026)

## In more detail: Roundup 6

One of the healthiest coral reef systems in the continental United States may be under increasing pressure from pollution originating hundreds of kilometres away. Researchers studying the Flower Garden Banks in the northern Gulf of Mexico found that, in recent decades, more than 60% – and at times as much as 80% – of the nitrogen reaching these offshore reefs originated from the Mississippi River basin.

By analysing nitrogen isotopes preserved within coral skeletons, scientists reconstructed around 270 years of nutrient inputs to the reef. Human-derived nitrogen began increasing during the nineteenth century and rose particularly sharply after the 1960s, coinciding with the expansion of synthetic fertiliser use. The highest Mississippi-derived nitrogen levels in the entire record occurred in 2016 and 2022–2023 – years that also saw exceptional heat stress, coral bleaching and disease.

The findings are particularly concerning because the Flower Garden Banks have historically been considered remarkably resilient compared with many other reefs in the western Atlantic. The researchers suggest that high nutrient loads and rising ocean temperatures may now be acting together to undermine that resilience, highlighting how reducing land-based pollution could become increasingly important as reefs face intensifying climate stress.



# How Threatened Are Coral Reefs?

## Coral Reefs Under Pressure: Beyond the Heat

A powerful El Niño is developing against a background of exceptionally warm oceans. But heat is only part of the story. From nutrient pollution and disease to overfishing, acidification, sedimentation and physical destruction, coral reefs increasingly face multiple pressures simultaneously. So how threatened are coral reefs today – and what can we actually do about it?

### The next big test

For coral reef scientists, the strengthening 2026 El Niño is difficult to ignore. Strong El Niño events have repeatedly been associated with severe coral bleaching, and this one is developing against an ocean already substantially warmer than it was only a few decades ago.

During prolonged periods of anomalously warm water, corals can lose their symbiotic algae, bleach and eventually die. Importantly, El Niño is now being superimposed upon anthropogenic warming. Research from the Great Barrier Reef indicates that recent ocean temperatures are the highest experienced in at least four centuries (Henley *et al.*, 2024), while analyses of previous ENSO events demonstrate that both acute heat stress and the background thermal environment influence subsequent coral loss (Claar *et al.*, 2018).

But El Niño is about much more than simply “cooking corals”. ENSO reorganises weather and ocean conditions across enormous areas of the planet, changing rainfall, cloud cover, winds, currents and sea level. During the 2015–2016 El Niño, for example, exceptionally low sea levels exposed shallow Indonesian reef flats and caused extensive coral mortality independently of conventional heat-induced bleaching (Ampou *et al.*, 2017).

Tropical cyclone patterns can change too. El Niño typically suppresses Atlantic hurricane activity through increased vertical wind shear, but can increase or redistribute cyclone activity elsewhere, particularly across parts of the Pacific. Research suggests El Niño can supply additional subsurface ocean heat capable of intensifying eastern Pacific tropical cyclones, while future warming could amplify El Niño-associated cyclone risks around some Pacific islands (Jin *et al.*, 2014; Chand *et al.*, 2017).

For reefs in their path, those storms can break branching corals, overturn massive colonies and transform structurally complex habitat into rubble within hours. So the developing super El Niño matters enormously. But it also highlights a problem with the way we sometimes talk about coral reef decline.

### “It's climate change. What can we do?”

Global warming is precisely that: global. A local council, marine park manager or national environment department cannot prevent a marine heatwave from arriving at a particular reef. That fact can easily dominate the conservation narrative. If climate change is the overriding threat, and greenhouse-gas emissions require international action, what can a local reef manager realistically do?

Actually quite a lot.

Climate change may determine the increasingly hostile background conditions reefs face, but coral reefs do not experience temperature in isolation. A reef entering a marine heatwave with clean water, healthy herbivore populations, strong recruitment and relatively little sediment stress is not biologically equivalent to a reef experiencing the same temperature after decades of nutrient enrichment, sewage discharge, overfishing and coastal development. This is where the distinction between global and local threats becomes critical.

Poor water quality is not a universal reef problem in the way rising global temperature is. Remote oceanic reefs may experience extremely low nutrient concentrations and little terrestrial runoff. In some naturally oligotrophic systems, nutrients themselves are not inherently harmful, and recent experimental work from the Maldives has even shown that short-term nutrient enrichment under particular conditions can reduce bleaching severity (Arnull *et al.*, 2026). Nutrient dynamics are complicated.

But where anthropogenic nutrient pollution is a problem, it is often a problem we can actually do something about. That matters.

## Water quality:

### The threat we can manage

Nutrients from fertilisers, sewage and wastewater, together with sediments and other pollutants carried by terrestrial runoff, can profoundly alter coastal reef environments. Excess nutrient availability can stimulate macroalgal growth, alter coral-associated microbial communities and affect coral physiology, reproduction and recruitment. Critically, water quality can also interact with temperature.

Experimental and field research has shown that nutrient imbalance can increase coral susceptibility to bleaching (Wiedenmann *et al.*, 2013), while work on the Great Barrier Reef has demonstrated links between terrestrially derived dissolved inorganic nitrogen and reduced thermal bleaching thresholds (Wooldridge, 2009).

That creates an important management message which can become lost when climate change dominates the conversation.

**“We may not be able to stop the marine heatwave arriving locally, but we can influence the condition of the reef that it arrives at”**

Improving water quality will not make climate change disappear and cannot indefinitely protect corals from extreme warming. But reducing manageable local stressors can improve the chances that corals survive disturbances and that the wider reef ecosystem subsequently recovers. A recent review of tropical reef conservation consequently argues that global climate action and local management should be layered together rather than treated as competing alternatives (Duarte *et al.*, 2025).



Climate change should therefore never become an excuse for inaction on problems that are within local control.

## The uncomfortable agricultural question

This becomes politically and economically difficult when pollution originates on land. Agriculture feeds a human population now numbering billions and provides livelihoods for enormous numbers of people. Fertilisers have played a fundamental role in increasing global food production. Asking farmers to reduce nutrient losses, alter fertiliser application, maintain vegetation buffers or change land-management practices therefore involves real costs, risks and trade-offs. But those trade-offs do not make the pollution disappear.

Agricultural runoff can carry dissolved nitrogen, phosphorus, pesticides and sediments through catchments and ultimately into coastal waters. Globally, agricultural pollution has been estimated to threaten roughly a quarter of coral reef area, although exposure varies enormously among regions (Kroon *et al.*, 2014).

The Great Barrier Reef provides perhaps the best-known example. Sugarcane agriculture is a major source of dissolved inorganic nitrogen entering GBR catchments, while grazing lands contribute large sediment loads. Governments have spent substantial sums attempting to improve agricultural practices and water quality, yet reviews have repeatedly concluded that progress has been insufficient to achieve required targets (Eberhard *et al.*, 2021).

Why isn't the problem simply regulated away?

Because environmental policy does not operate in a vacuum. Farmers must consider profitability, risk, uncertainty and the costs of changing practices. Governments must balance environmental protection against agricultural production, regional employment, food production and political realities. Social norms, trust, regulation and relationships between farmers, government and industry all influence whether better practices are adopted (Coggan *et al.*, 2021; Thapa and Rolfe, 2025).

These are legitimate complexities. But they also demonstrate why water quality can be harder to tackle politically than it appears technically.

It is easier to point towards a global atmospheric problem than to make difficult decisions about what is happening in the catchment immediately upstream.

## The Gulf of Mexico warning

Recent research from the Flower Garden Banks in the northern Gulf of Mexico provides a remarkable demonstration of how far agricultural pollution can travel.

These reefs lie around 160 kilometres offshore and have historically been considered among the healthiest coral reefs in the continental United States. Yet nitrogen isotopes preserved within coral skeletons allowed researchers to reconstruct approximately 270 years of nutrient inputs to the reef.





The results showed a dramatic increase in anthropogenic nitrogen. In recent decades, more than 60% – and at times around 80% – of nitrogen reaching the reefs was estimated to originate from the Mississippi River watershed. Nitrogen loading increased particularly strongly following the twentieth-century expansion of synthetic fertiliser use, while some of the highest values occurred during recent years characterised by extreme heat, bleaching and disease (Jung *et al.*, 2026).

It is difficult to imagine a clearer demonstration that what happens on land does not necessarily stay on land.

### **Florida: Everything eventually meets at the coast**

Florida offers another illustration of this connectivity. Its reef tract exists downstream of a heavily modified landscape encompassing the Everglades, Florida Bay, agricultural areas, major cities, wastewater systems, canals and coastal inlets.

Restoring more natural freshwater flows through the Everglades is essential, but water quantity cannot be considered independently of water quality. Freshwater flows influence salinity and transport nutrients and organic matter, while agricultural runoff, wastewater and urban discharges add further complexity.

The important point is not that Everglades restoration damages coral reefs. It is that connected ecosystems have to be managed as connected ecosystems. Water moved through a watershed eventually carries whatever is in that watershed downstream.....and downstream eventually becomes the coast.

## Are we planting “super corals” into the same old problems?

This question becomes particularly important as coral restoration expands. Increasingly sophisticated programmes are identifying naturally heat-tolerant colonies, selectively propagating particular genotypes, exposing corals to thermal conditioning and exploring assisted evolution. These corals are sometimes popularly described as “super corals”.

There is genuine promise here. Coral colonies and genotypes vary considerably in thermal tolerance, and improving the thermal resilience of restoration stock may become an important part of reef conservation.

But heat tolerance is not the same thing as resilience to everything. A coral selected because it survives unusually high temperatures has not necessarily been selected to tolerate elevated nutrients, sedimentation, low oxygen, pollutants, algal competition or disease. Recent research has even identified genotype-specific trade-offs: an *Acropora cervicornis* genotype that showed strong thermal resistance during the 2023 marine heatwave in Little Cayman also showed greater disease susceptibility (Goodbody-Gringley *et al.*, 2026).

This raises an uncomfortable question about restoration. If we invest enormous resources growing thermally resilient corals and then plant them back into reefs where chronic water-quality problems have never been addressed, what exactly have we solved?

Their additional temperature tolerance may become largely moot if they subsequently succumb to disease, sedimentation, algal competition or another consequence of degraded habitat. Global analyses of restoration increasingly emphasise that restoration cannot simply be scaled up to compensate for continuing degradation and that site conditions and existing stressors must be considered before outplanting (Burdett *et al.*, 2024; Mulà *et al.*, 2025).

Perhaps the first question in restoration should therefore not be “Which coral should we plant?”, it should be “Why did the coral disappear here - and have we fixed that?”

### Disease: part of the same picture

Coral disease adds another layer to the problem. Stony coral tissue loss disease (SCTLD) has devastated reefs across Florida and the Caribbean, while numerous other diseases continue to affect coral populations worldwide.

Temperature can influence coral immunity, pathogen activity and microbial communities, but the relationship is not always simple. Recent experimental work on SCTLD, for example, found lower transmission at 31°C than at 28°C and little effect from experimental ammonium enrichment (Palacio-Castro *et al.*, 2025). We should therefore avoid claiming that warm water or nutrients simply “cause” coral disease.



What is increasingly clear is that coral health depends on interactions between the host, its microbiome, potential pathogens and the surrounding environment (Voolstra *et al.*, 2024). Poor water quality, nutrient imbalance, sediment, pollutants and thermal stress can alter different components of that relationship. Once again, multiple stressors matter.

### **Fishing, sediment, acidification and direct destruction**

Overfishing can fundamentally alter reef function. Removing herbivorous fishes reduces grazing pressure, allowing macroalgae to proliferate, particularly where nutrients are already stimulating algal growth. Algae then compete with corals for space and can inhibit recruitment. Protecting coral without protecting the ecological processes that allow coral to recover is unlikely to succeed.

Sedimentation adds another chronic pressure. Coastal development, deforestation, dredging and agriculture increase the amount of fine material entering reef environments. Sediment reduces light, smothers coral tissue, interferes with feeding and can prevent larvae from successfully settling. A major 2025 review synthesising more than 250 studies concluded that sedimentation affects coral physiology, growth and reproduction, with fine sediments particularly damaging to larvae and recruits (Bhuyan *et al.*, 2025).

Then there is ocean acidification. As the ocean absorbs anthropogenic carbon dioxide, seawater chemistry changes and the availability of carbonate required to construct coral skeletons declines. The result is not necessarily spectacular immediate mortality, but a gradual weakening of the reef's ability to build and maintain its physical structure. Recent observations across natural CO<sub>2</sub> gradients show declining habitat-forming corals and coralline algae and increasing dominance by non-calcifying algae as acidification intensifies (Noonan *et al.*, 2025).

Other threats are far more direct. Anchors and chains crush colonies and scour reef framework. Dredging destroys habitat and increases sediment. Coastal construction removes or modifies reef environments. Poorly managed tourism causes repeated physical damage. These threats may lack the global drama of climate change, but many are also remarkably preventable.

### **And sunscreen?**

Sunscreen deserves mention largely because it receives so much public attention.

Some organic UV filters, including oxybenzone, can affect corals under experimental conditions and have been detected in reef environments. But perspective matters. Reviews have found that concentrations measured on reefs are generally considerably lower than concentrations causing effects in many laboratory experiments, although highly visited and poorly flushed tourist sites can experience elevated exposure (Mitchellmore *et al.*, 2021).



Sunscreen pollution is therefore a legitimate local concern in some places. It is not in the same league as climate change, poor water quality, overfishing, sedimentation or ocean acidification.

Sometimes the threats that are easiest for individuals to act upon receive disproportionate attention, while the difficult systemic problems remain unresolved.

### **So what is the greatest threat?**

If we ask which direct environmental pressure poses the greatest global threat to coral reefs, the answer remains anthropogenic climate change.

Marine heatwaves are becoming more frequent and severe. Ocean acidification is progressing. Tropical cyclone regimes are changing. Without rapid reductions in greenhouse-gas emissions, there is a limit to how much local management can achieve.

### **But perhaps there is a larger answer....**

Look behind virtually every major anthropogenic threat to coral reefs and one factor repeatedly appears: human demand on the planet.

A large and still growing human population requires food, energy, housing, transport and infrastructure. We clear land and intensify agriculture to produce food. We manufacture and apply fertilisers to increase yields. We build cities and resorts along tropical coastlines. We produce sewage and waste. We burn fossil fuels and increase atmospheric CO<sub>2</sub>. We harvest fish. We dredge harbours, move ships, drop anchors and alter watersheds.





Population alone is not a sufficient explanation: consumption patterns, technology, inequality and governance determine environmental impact enormously. One person in a high-consumption economy can exert a vastly different environmental footprint from someone living at subsistence level. But collectively, the scale of human demand is the common pressure sitting behind almost every threat discussed in this article.

Perhaps, then, the greatest threat to coral reefs is not temperature, nutrients, fishing or pollution considered separately. It is the cumulative scale of human pressure and our difficulty in managing it.

The super El Niño confronting reefs now is an immediate and serious threat. We cannot manage it away locally. But that does not absolve governments, industries or reef managers of responsibility for everything that can be managed locally.

We cannot lower the temperature of the Pacific around a reef next summer. We can improve wastewater treatment. We can reduce nutrient and sediment runoff. We can work with agriculture to reduce fertiliser losses without pretending the economic and food-production challenges do not exist. We can protect herbivorous fishes. We can regulate anchoring, dredging and coastal development. We can choose restoration sites intelligently. And we can stop treating coral gardening as a substitute for repairing the habitat into which those corals are planted.

None of those actions removes the need to reduce global greenhouse-gas emissions. They buy reefs something increasingly precious: resilience and time.

Climate change may determine how hard the next blow will be. Local management helps determine the condition of the reef when that blow arrives - and whether anything is left capable of recovering afterwards. Perhaps that is the real answer to the question “How threatened are coral reefs?”

Very.

But not all of those threats are beyond our control.

# Stories From The Field

## What We Owe the Reef: Coral Reef Restoration in Costa Rica

By Sherri Harvey

A coral reef gives more than it appears to.

Look closely and almost every opening holds something alive. Fish disappear between branches of coral. Crabs tuck themselves into crevices. Juveniles find shelter before moving into deeper water. Although coral reefs occupy less than one percent of the ocean floor, roughly a quarter of marine species depend on them for some part of their lives.

Humans depend on them, too. Reefs feed families, support fisheries and tourism, soften waves reaching coastlines, and provide livelihoods. For Pablo Piedra, one of Costa Rica's coral reefs did something more personal.

"The reef gave me everything. It gave me a life."

Piedra spent sixteen years underwater as a divemaster on Costa Rica's southern Pacific coast. Over time, he watched familiar reefs change. Coral formations bleached, broke apart, or disappeared. Algae spread across places once crowded with living coral. Visitors could still descend into blue water and see beauty. Piedra could see what was missing.

"If you're taking something, it's your responsibility to maintain it," he told me when we met in Uvita through S.A.F.E. Worldwide, a wildlife and habitat conservation organization that supports projects all over the world.

Eventually, making a living from the ocean while watching it deteriorate no longer made sense. Piedra and others began building a small laboratory where vulnerable coral could be kept alive, grown, studied, and eventually returned to the sea.

That effort became Costa Rica Coral Restoration (CRCR), based at Marino Ballena National Park, where Piedra is co-founder and project leader.

The reef had sustained him for years. Now he wanted to give something back.

Photo credit: Sherri Harvey



## Growing Coral for a Changing Ocean

Laboratory Director James Jacob came to coral differently. Before it became his profession, it was his hobby.

Jacob kept coral in home aquariums, where enthusiasts routinely shared fragments. A friend might break off a small piece of coral, and Jacob would take it home and grow it. The same act that fascinated him then—creating conditions in which a fragment could survive—is now central to his work.

Only the stakes have changed.

Jacob monitors temperature and water quality, measures fragments, watches for disease and bleaching, and tracks which corals grow fastest and tolerate stress.

The team is also attempting something more difficult: sexual reproduction. By mimicking temperature, light, seasonal, and lunar cues that trigger spawning in the wild, researchers hope to produce genetically distinct offspring rather than clones of existing colonies. Genetic diversity matters when the goal isn't simply growing more coral, but creating reefs capable of adapting to an increasingly unpredictable ocean.

The question becomes larger than restoration: Which corals can survive the ocean that is coming? Under ordinary circumstances, restoration follows a progression:

**Reef → fragment → laboratory → growth → acclimation → reef.**

But that assumes the coral has somewhere safe to return.

## When the Reef Turns White

Increasing ocean temperatures and repeated marine heat stress complicate that return. During the severe 2015–2016 El Niño, researchers documented major declines in live coral cover along Costa Rica's Pacific coast, including Marino Ballena.

And bleaching is only part of the problem.

Reefs face warming seas, ocean acidification, overfishing, coastal construction, agricultural runoff, sewage, chemicals, and other pollutants. Stress accumulates.

Bleaching itself can look deceptively beautiful. Under heat stress, coral expels the microscopic algae that provide much of its energy and color. The coral turns brilliantly white as its skeleton becomes visible through translucent tissue. If conditions improve, it may recover. If they don't, it can starve and die.

A reef doesn't have to disappear in one catastrophic event. It can lose a little, then a little more, until there isn't enough left to recover.

That makes the CRCR laboratory both hopeful and unsettling. Humans are removing coral from the environment where it evolved because, for the moment, a tank can sometimes be safer than the ocean.

Current conditions have forced the team to suspend outplanting laboratory-grown coral. Instead, they are keeping fragments alive and preserving the genetic diversity of the local reef.

The cycle has changed:

**Reef → laboratory → growth → waiting.**

Still, the coral grows.

## Mimicking the Moon

Keeping coral alive is only the beginning. CRCR is also producing knowledge: which individuals survive, reproduce, grow quickly, or tolerate heat—and under what conditions.

That knowledge matters beyond Costa Rica. Restoration projects around the world face similar problems with limited time and money. Sharing discoveries about spawning, genetics, disease, and heat tolerance can prevent another laboratory from repeating years of trial and error.

Perhaps that is another form of reciprocity. A coral fragment is shared and grows into something more. Knowledge can do the same.

But science has limits.

A laboratory can control water chemistry. It cannot control everything entering the sea. Restoration teams can propagate coral but cannot stop pollution, regulate every coastal development, or solve climate change. Restoring reefs therefore requires working with something considerably more difficult to control than coral. People.

## Growing the Next Generation

For co-founder Laura Ruiz Madrigal, education is part of the answer.

Costa Rica is celebrated for its biodiversity, but that reputation doesn't make its reefs invulnerable. Loving a place doesn't mean pretending it is protected. It means accepting responsibility for what happens to it.

CRCR's education center brings an ecosystem normally visible mainly to divers into view for schoolchildren, families, tourists, and local residents, including children from underserved communities who may grow up beside the Pacific without ever seeing what lies beneath it.

Sometimes the lesson begins with a fish they already know.

Nemo.

Where does Nemo live? What is coral? Why do fish need reefs? What happens when coral dies?

A cartoon fish becomes an entry point into marine biology—and agency.

Climate change can feel impossibly large, particularly to a child. CRCR brings the conversation down to everyday choices: plastic, chemicals entering waterways, consumption, waste, and conservation.

One plastic bottle won't destroy a reef, just as one changed habit won't save it. That isn't the point. Environmental responsibility begins with understanding that ordinary choices have consequences and those choices accumulate.

Photo credit: Sherri Harvey

Young people can also influence adults. They can ask questions, change family habits, participate in conservation, and speak up at school and in their communities.

Piedra and Ruiz Madrigal put it more simply:

### **Be loud.**

In the laboratory, Jacob and his team are asking how to grow coral capable of surviving the future. The education program raises a parallel question:

Can we grow the people who will care for those reefs, too?

One generation is trying to repair what has already been damaged.

The next is learning how to damage less.

That, too, is reciprocity.

### **Hope Isn't Required**

Near the end of our conversation, I asked Piedra about hope.

"I have zero hope," he said.

Then he kept talking.

The contradiction was more interesting than optimism. Piedra has watched money and power overwhelm environmental intentions. He doesn't necessarily believe people will change quickly enough simply because they understand the problem.

But hope isn't why he does this.

He does it because he believes in the cause and in some of the people he reaches. Because the work makes him happy. Because after everything the reef gave him, doing nothing would mean walking away from a relationship that shaped his life.

Perhaps conservation doesn't require believing everything will turn out well. Perhaps it requires deciding what is worth doing even when there is no guarantee.

Photo credit: Sherri Harvey



## What We Give Back

I arrived at Costa Rica Coral Restoration carrying one question:

What does it take to return life to a damaged reef?

I thought the answer would lie mostly in the science: fragmentation, cultivation, monitoring, reproduction, acclimation, outplanting.

Those things matter. But the coral can be grown. The water still has to receive it.

That may be the uncomfortable boundary of restoration science. Humans can fragment coral, grow it, study it, and coax it toward reproduction. But returning coral to the ocean without addressing what is happening to the ocean means returning it to many of the forces that damaged it in the first place.

Piedra spent years receiving something from the reef - a livelihood, beauty, experience, belonging - before deciding the relationship demanded something in return.

Perhaps that is the larger story.

A reef itself is built on relationships: coral and algae, fish and habitat, sunlight and water, growth and decay. Our relationship with it is another one.

We take food and livelihoods from reefs. We swim above them and dive beneath them. We ask them to support fisheries, tourism, and coastal communities while absorbing the consequences of a world changing above them.

The reef keeps giving.

Reciprocity asks us to consider the other half of that relationship:

**After everything reefs give us, what are we willing to give back?**

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Sherri Harvey is a conservation storyteller and educator, weaving science, stories, and images to inspire curiosity, deepen our connection to the natural world, and encourage its protection.

*An expanded version of this article can be found on our website here.*

Photo credit: Sherri Harvey



# Turbid Reefs as a Source of Resilient Coral

By Sophie Coxon

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Sophie is a recent graduate with an MSc in Marine Systems & Policies, having gained a distinction at the University of Edinburgh. She is a PADI Advanced Scuba Diver, qualified Scientific Diver, and enjoys freelance writing on the side!

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Coral reefs are known for the vivid and diverse kingdoms of colour and biodiversity they harbour, often associated with crystal clear, oligotrophic waters of low nutrient content and extremely high water clarity. Whilst this is true of many tropical reefs, a broad spectrum of reef types exists across the global oceans, occupying a variety of habitat types from turbid lagoons to muddy estuaries, cold water complexes and even the brackish rivermouth of the Amazon (de Mahiques *et al.*, 2019). As the current seascape faces intense and rapid change, researchers are increasingly looking at coral reefs adapted to more extreme and adverse conditions as a source of resilient genes for potential restoration initiatives. The classic textbook coral reefs found clustering in clear water atolls and around islands of sparkling water clarity are facing perhaps the most significant challenge as the oceanic environment becomes increasingly hot, acidic, polluted and disturbed (Sully & van Woesik, 2020).

Corals are being exposed to rapidly intensifying pressures on top of ocean warming - such as nutrient pollution, sedimentation, and worsening storm damage - causing stress, bleaching, disease and death of entire reef areas. Despite being the most well-known and widely appreciated, corals in oligotrophic waters - those which are most visited by divers and holidaymakers - are possibly faring the worst in the unpredictable new conditions climate change is causing, especially in areas which have experienced multiple periods of abnormally raised temperatures (Sully, 2020).

Originally assumed a threat to coral health, high turbidity may now become an ecological advantage under climate change, depending on its origin. Often located in nearshore environments such as rivermouths, sloping shorelines or adjacent to mangrove habitats, turbid water environments are characterised by low visibility, high concentrations of nutrient and particulate matter, slow or minimal water circulation and generally occupy a significantly shallower depth range than clear-water reefs (Zweifler *et al.*, 2021).



This combination makes for a distinctly extreme environment, where organisms must withstand vast temperature variations, constant smothering by sediment, potential exposure to the air in low-tide events, and inconsistent levels of solar radiation, as well as severe wave energy during coastal storms. Consequently, the biota which thrives in turbid environments is sleekly adapted to the tough conditions, and has evolved to harness certain elements to various advantages. A shallow turbid zone does not fit the standard habitat requirements for oligotrophic reefs - but an entire suite of turbid reef corals inhabit these areas, and are beginning to be recognised for their potentially superior abilities to survive future climate change pressures (Dee & Zweifler, 2026).

To withstand such harsh conditions, turbid-adapted corals exhibit a range of effective survival tactics. Whilst many of the genera and species which are found in oligotrophic zones also inhabit turbid reefs, their specific morphotypes, composition, and algal symbionts are fundamentally different, making turbid reefs ecologically separate and unique from other reef types (Zweifler *et al.*, 2021).

The presence of suspended sediment in the water column has been found to paradoxically benefit turbid zone corals, acting as a UV sunscreen which reflects a large percentage of the solar radiation which may otherwise damage delicate coral and microalgal cells. At a finer scale, the corals themselves have a variety of mechanisms for coping under high sediment loads; when turbidity is so high that photosynthesis becomes insufficient to meet the coral organism's energy requirement, many turbid reef corals can quickly switch to nematocyte-based predation, known as heterotrophic plasticity (Luo *et al.*, 2024).

This provides a buffer of energy to allow conditions to settle and photosynthesis levels to ramp up again, avoiding starvation. *Platygyra* and *Acropora* coral types are especially heterotrophically adaptable, able to rapidly switch feeding methods when water turbidity spikes. Boulderling coral types, such as *Porites*, are known for being abrasion-resilient due to their compact shape, though this makes them acutely susceptible to smothering under layers of sediment. To combat this, *Porites* acclimated to turbid reefs will release films of mucus, once every 30 days (tracking the lunar cycle), which acts as an effective cleaning mechanism, similar to shedding a skin and preventing buildup of sand and debris. *Pavona* corals instead rely on their lettuce leaf-like or upright growth forms to prevent sedimentation, growing in thin vertical planes (Jones *et al.*, 2019).



It has also been found that corals within turbid reef environments are genetically predisposed to better survive higher temperatures, having undergone a long process of natural selection in these dramatic turbid zones, and, importantly, have coevolved over long ecological timescales with their *Symbiodinium* microalgal counterparts, under these challenging circumstances. The symbionts that turbid reef corals harbour tend to be from a distinct genus, recognised for high heat and stress tolerance. A further layer of resilience is granted by the ability of many turbid reef corals to switch out their algal symbiont for more favourable, hardy species when conditions begin to heat up. Species of the *Durudinium* microalgae genus offer a particular advantage under stress, able to withstand temperatures 1-2 degrees celsius above most other genera, and are highly efficient in variable light conditions; photosynthesis is effective in low light conditions, and when turbidity reduces, excess light availability is regulated using cellular mechanisms to prevent the production of reactive oxygen species, which are the main trigger for bleaching (Hussain *et al.*, 2025).

Scientists are now taking turbid reefs into the lab, to test whether assisted breeding or genetic modification of resilient corals might help produce resilient super-corals, and if these advantageous traits can be transferred to oligotrophic corals to enhance resilience. Because turbid and oligotrophic reefs are completely different and distinct ecosystems, hardy corals from a turbid reef cannot simply be fragmented and transplanted to a clear-water zone and expected to grow. However, the biological mechanisms which enable turbid-adapted coral morphotypes to withstand the extreme conditions seen in high-turbidity regions - which oligotrophic reefs are edging closer to - may provide a bank of genetic resources that can be used in crossbreeding initiatives to create hardier oligotrophic coral types which are better able to survive future reef conditions.

Despite their tried-and-tested ecological resilience, turbid coral reefs are not immune to the pressures currently facing marine ecosystems, and to assume that the answer to future reef recovery lies within these muddy, murky waters would be short sighted. Fringing shorelines across the tropics, turbid reef zones are often the first marine habitat to absorb undiluted runoff, such as agricultural effluent, sewage and industrial wastewaters, and are experiencing rapid declines due to coastal development, overfishing and pollution. Focusing on the genetic and morphological details of various surviving corals is no doubt an important endeavour, but attention must not be diverted from the most pressing of climate issues that affects every habitat on Earth: global warming. Perhaps turbid reef corals are equipped with a better-adapted toolkit for surviving future climate scenarios, however they alone do not solve the ecological collapse predicted for many tropical, oligotrophic reef systems; recovery is a multifaceted challenge that must be tackled proportionately across each facet and sector, beginning at the root cause.



# Photographer Spotlight

Florent Charpin

Florent Charpin is a recreational scuba diver, underwater photographer and creator of [Florent's Guide to the Tropical Reefs](#) (an amazing free resource that Florent has put countless hours into!). Based in New York City, Florent has been diving since 2002 and has explored tropical reefs across the Caribbean, Pacific, Hawaii, French Polynesia and beyond. Combining his passion for underwater photography with an interest in marine species identification, he created Reef Guide as a personal project to document and share the extraordinary diversity of tropical reef life. The site has since grown into an extensive photographic identification resource, featuring more than 2,200 species and 9,000 images of reef fishes, corals, invertebrates and other marine life from around the world.



Snow-Goddess Nudibranch (*Ardeadoris poliahu*)  
Photographed in Hawai'i



Blackcap Basslet (*Gramma melacara*)  
Photographed in the Caribbean

A number of Florent's pictures also feature in the book 'An Underwater Guide to Anguilla, British West Indies' ([Available here](#)).

Stalked Sea Squirt (*Nephtheis fascicularis*)  
Photographed in Indonesia



# Get the Right Gear

## GoPros – The little camera every coral field researcher should carry

You might not be conducting photoquadrats or video transects, but a small action camera is still one of the most useful pieces of kit you can take into the field. Whether it is a GoPro or one of the many cheaper alternatives now available, having a compact underwater camera with you means you can create a visual record of almost every dive.

Modern action cameras pack an impressive amount into a remarkably small package. They can capture high-resolution photographs and video, offer wide-angle views ideal for underwater environments, and many have excellent image stabilisation. Add a suitable underwater housing and they can accompany you on virtually any reef survey without the bulk, expense or complexity of a conventional underwater camera system.

For researchers, that makes them useful far beyond dedicated photographic surveys. Clip one to your equipment, keep it in a BCD pocket or carry it on a small handle and you can quickly document survey sites, habitat condition, unusual coral colonies, equipment setups or anything else that might be useful when you are back on land. Photographs and video can provide valuable context that written field notes simply cannot.

And then there are the encounters you weren't expecting.

Anyone who spends enough time underwater knows that reefs have a habit of producing surprises. A sea turtle might cruise past your transect, a manta may appear out of the blue, or you might suddenly find yourself looking at a whale shark. More importantly from a scientific perspective, you may encounter an unusual behaviour, an unfamiliar species, a rare colour morph, bleaching, disease or something you have simply never seen before.

Without a camera, you are relying on your memory. With one, you have a permanent record that can be examined later, shared with colleagues and potentially used to help identify exactly what you saw.

Their greatest advantage is therefore perhaps their convenience. A sophisticated camera system may produce better images, but it is another substantial piece of equipment to prepare, carry and manage underwater. An action camera is small enough that there is very little reason not to have one with you.

You certainly don't need the latest or most expensive model. Older GoPros and lower-cost action cameras can be perfectly adequate for creating a field record. A secure attachment, reliable housing and sufficient battery and memory may ultimately matter more than having every new feature.

So even if photography isn't part of your survey methodology, consider adding a small action camera to your standard field kit. Because the one dive when you decide to leave it behind will inevitably be the dive when the whale shark turns up!

# Stories from the Field

## The Best Orgy of My Life!

*One magical night witnessing mass coral spawning in Punta Allen, Mexico*

## Waiting for the Reef to Snow

By Franz Behrmann

### One night monitoring the spawning of critically endangered elkhorn corals in Punta Allen, Mexico

According to the navigation system, we had about 30 minutes left. Two and a half hours later, I was beginning to understand why Punta Allen is considered remote. The road south had gradually deteriorated into an obstacle course of potholes and uneven ground. Our car was not exactly built for it. At some point, the small pendant hanging from the rear-view mirror began swinging so violently that I took it down before it could become a projectile. Progress became painfully slow as we tried to find a route that would not leave the underside of the car somewhere on the road behind us. When we finally arrived, I climbed out and announced how exhausting the journey had been. Raúl laughed. “Exhausting for you? You slept half the way.”

He had a point.



Photo credit: Franz Behrmann

Finally, we had reached Punta Allen, a small fishing village at the end of a narrow peninsula on Mexico's Caribbean coast. With fewer than 500 inhabitants and the nearest city hours away, life here moves at a different pace. The sea is never far away, and fishing remains deeply woven into the community. But Punta Allen's fishers are not simply extracting from the waters around them. The community has a history of managing its marine resources, particularly its valuable lobster fishery, and local fishers participate in monitoring the ecosystems on which their livelihoods depend. That collaboration was why we were here. We had come to monitor the spawning of *Acropora palmata* – the elkhorn coral – together with members of the local community. Unfortunately, the corals had little interest in how tired we were.



Photo credit: Franz Behrmann

## Waiting for darkness

There was barely time to recover from the drive before we had to prepare the equipment and head to the harbour. Punta Allen's most enthusiastic residents were already waiting for us. Mosquitoes. Surrounded by mangroves and tropical vegetation, the village offers them ideal conditions, and as we loaded the boat they descended on us with considerably more enthusiasm than I would have preferred. Soon, however, we left them behind. The last sunlight of the day stretched across the shallow turquoise lagoon as our small boat headed away from the village. Gradually, the colours disappeared. We continued into the darkness until our torches finally picked out the reef below. The boat slowed, we dropped anchor and switched off the engine. And then we waited.

Suddenly Lucy shouted. "Look at that!" A patch of water beside the boat was glowing. Bioluminescence. We leaned over the side. Another flash appeared, then another. For several minutes, monitoring coral spawning was temporarily forgotten as everyone stared into the black water. "There! There's more!" Each disturbance seemed capable of producing another burst of light. Lucy looked out across the lagoon. "Forget about all the money in the world," she said. "This is what really matters." For a moment, nobody seemed particularly inclined to disagree. And the corals had not even started yet.

## The signal

After roughly an hour, it was time. We pulled on our gear and slipped over the side into water close to 30°C. The deepest part of the site was barely four metres below us. There was no dramatic wall or endless blue beneath our fins – just a shallow Caribbean reef illuminated by the narrow beams of our torches.

We began checking the *Acropora palmata* colonies. Elkhorn coral was once one of the defining species of shallow Caribbean reefs. Its large, branching colonies create complex habitat and help dissipate wave energy before it reaches the coastline. Today, after dramatic declines throughout its range, the species is Critically Endangered. With fewer colonies left on many reefs, every spawning event represents a precious opportunity for sexual reproduction. I was inspecting another colony when a torch began waving wildly through the darkness. Raúl.

He was signalling for me to come over. As I approached, he pointed towards the surface of the colony. It was set. Looking closely at the polyps, I could see small bundles beginning to protrude from some of them. The colony was preparing to spawn. Many reef-building corals are hermaphroditic broadcast spawners. Rather than mating directly, they package eggs and sperm together into bundles and release them into the water column. When multiple colonies spawn synchronously, the bundles rise towards the surface, break apart and allow eggs from one colony to encounter sperm from another. Timing is everything. And we were about to see it happen.

We placed funnel-shaped collection nets over selected colonies, with a small collection tube at the top. When the corals spawned, the buoyant egg-sperm bundles would rise into the nets and accumulate in the tubes instead of drifting away into the water column. In other words, we had fitted the corals with condoms. And then we were waiting again.

I wandered across the shallow reef, following an octopus for a while. Large polychaete worms appeared in the water column, twisting through the beams of our torches, while all manner of tiny creepy-crawlies seemed to materialize wherever the light fell. The reef at night was anything but asleep. It simply belonged to a different cast of characters. Every few minutes I returned to the corals. Still waiting. And then one polyp released its bundle.

## When the reef began to snow

At first, there were only a few. Small bundles lifted away from the colony and drifted upwards. Then another polyp released. And another. Within minutes, the reef changed completely. Hundreds of tiny bundles were rising through the beams of our torches. More colonies joined in, and suddenly the water around us was filled with them. It looked as though it were snowing underwater. I had known what we had come to see. I understood the biology. I had been waiting for exactly this moment. But none of that prepared me for how it actually felt to be surrounded by it. The rest of the reef noticed too. Fish appeared and began picking off bundles as they drifted upwards. Crustaceans joined the feast. Animals that had been almost invisible minutes earlier seemed to materialise from the darkness. The sudden abundance of activity attracted larger visitors as well, and sharks began moving through the edge of our torchlight.

For the corals, this was reproduction. For much of the reef, it was dinner. And for us, it was time to work. The collection nets filled as the positively buoyant bundles accumulated in the tubes above the colonies. We moved between them, checking the spawn and collecting enough material for our work while the reef continued releasing millions of potential beginnings into the water around us. Eventually, we had what we needed. I surfaced, climbed back onto the boat and let out a shout. I couldn't help it. It was one of the most extraordinary night dives I had ever experienced.

Photo credit: Franz Behrmann



## A new generation

On board, we carefully mixed the spawn collected from different colonies. In the wild, eggs and sperm have to find each other in a vast and constantly moving water column. Mass spawning helps tip the odds in their favour, but as coral populations decline and colonies become more isolated, successful encounters can become less likely. By bringing the gametes together ourselves, we could improve those odds. Later, releasing the developing offspring back onto the reef felt strangely personal. After spending the night waiting for their parents to spawn, collecting their bundles and helping them find one another, I couldn't help feeling a little like a proud coral mother. Drunk on pride, it was time to head home.

## Exactly where I wanted to be

The boat started moving towards the lagoon. This time, the darkness that had surrounded us all evening put on one final show. Every splash against the hull produced tiny flashes of bioluminescence. The wake briefly shimmered behind us before disappearing back into black water. Then I looked up. Far from the lights of Cancún and the Riviera Maya, the sky above Punta Allen was crowded with stars. The Milky Way stretched overhead clearly enough to see its pale band crossing the darkness. Below us, the sea was glowing. Above us, so was the sky.

A few hours earlier I had been complaining about the exhausting journey to get here – apparently forgetting that I had slept through a considerable part of it. Now I was soaked, tired and knew that another long day of fieldwork would eventually follow. But sitting in that little boat, with bioluminescence flashing in the spray and the Milky Way overhead, I had one of those rare moments when everything felt exactly right. **I was exactly where I wanted to be.** By the time we were sitting together later that night, I could barely keep my eyes open. When I finally reached my bed, I was completely exhausted. And completely happy.

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Franz Behrmann is a marine biologist specialising in coral ecology, whose background in scientific diving has inspired a growing interest in underwater photography and ocean storytelling.

Photo credit: Franz Behrmann



# Coral Career Column

## Choosing the Right Career Path

There is no single qualification that makes you a coral reef scientist. Most careers begin with a degree in marine biology, marine science, ecology, zoology or a related subject, but what comes next depends on where you want to go. A Master's can help you specialise and develop research skills, while a PhD is usually necessary if you want to pursue an academic research career. For many professional roles, however, practical experience and technical skills can be just as important as additional degrees.

The key is to think about what kind of work you actually want to do. Coral reef science includes field ecology, restoration, conservation management, fisheries, genetics, GIS, environmental consultancy, policy and many other areas. Academic careers tend to focus more heavily on research, publishing and teaching, while NGOs, government agencies, consultancies and restoration organisations often offer more applied roles.

Once you have a direction, look at real job advertisements. What do employers repeatedly ask for? R? GIS? Scientific diving? Coral identification? Statistics? Field survey experience? Project management? This quickly shows you which skills and experience you need to develop next.

Internships, research projects, field courses and volunteering can help you gain that experience, but choose them carefully. Look for opportunities that teach real, transferable skills rather than simply adding another line to your CV.

Finally, don't worry if your direction changes. Very few careers follow a perfectly straight path. Explore the opportunities available, find the jobs that make you think "I would love to do that", look at what those people did to get there – and start building your own route towards it.

Learning to dive is essential for many coral career paths



# CAN YOU TEST A CLAIM?

## Invitation for feedback on the ReefHealer project (Alarivean)

### About Alarivean

Alarivean is an aquatic prosperity company providing water-treatment and aquatic ecosystem remediation services. It develops technologies intended to address environmental stresses affecting marine and freshwater systems, including hypoxia and dead zones, harmful algal blooms, nutrient loading, contamination and thermal stress. It uses mobile treatment systems designed to operate directly within affected water bodies.

Central to its approach are its SeaBreather and ReefHealer vessel-based systems. These draw water through an onboard treatment process and return it to the surrounding environment. The technology incorporates oxygenation, real-time water-quality monitoring and operational controls. Controlled oxidation processes are used only in a separate harmful-algal-bloom and water-treatment mode, run clear of live coral.

Alarivean is developing this approach for applications ranging from coastal ecosystem remediation and harmful algal bloom mitigation to improving water quality around vulnerable marine habitats. The company also emphasises independent monitoring and regulatory oversight as part of its proposed treatment programmes.

### **Critical reviewers are wanted for a proposed coral heat-stress intervention**

The Coral Reef Research Hub is in conversation with Alarivean about how its water-remediation processes might support coral restoration efforts around the world. Alarivean has asked us to invite qualified persons to review this proposed work and give feedback on it. You can find full details below on how to access the full invitation.

**[VIEW INVITATION](#)** (CoRR Hub Members)

**[VIEW INVITATION](#)** (Non-Members)

Note: These pages will only remain active until the end of 2026



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## COMING SOON: CoRR Hub Mobile App



Our Mobile App has completed its initial round of beta-testing and is almost ready for the second round! These are exciting times, and we hope that when the app is released it is a real game-changer for coral reef scientists around the world.



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