REEF ENCOUNTER

The news magazine of the International Coral Reef Society

ICRS
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Reef Encounter is the Magazine Style Newsletter of the International Coral Reef Society. It was first published in 1983. Following a short break in production it was re-launched in electronic (pdf) form. Contributions are welcome, especially from members.

INTERNATIONAL CORAL REEF SOCIETY

The International Coral Reef Society was founded (as the International Society for Reef Studies) in 1980, at a meeting in Cambridge, UK. Its mission is to promote the acquisition and dissemination of scientific knowledge to secure coral reefs for future generations.

CORAL REEFS - THE JOURNAL

The International Coral Reef Society also publishes through Springer its premier scientific journal entitled "*CORAL REEFS*". The Journal publishes high quality scientific papers concerning the broad range of fields relevant to both modern and ancient reefs. For further details, including the list of editors see here.

ABOUT THE COVER | *Catalaphyllia jardeni*, from the Great Barrier Reef. Photograph: Ed Lovell. From the revised Corals of the World website. (see page 24).

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PRESIDENT'S MESSAGE

Christian R Voolstra, ICRS President

Coral reefs continue to stand at the forefront of the global climate crisis. Over the past few years, recurrent marine heatwaves and mass bleaching events have underscored the accelerating pace of change across tropical oceans. These developments remind us that coral reefs are not only among the most biodiverse ecosystems on the planet, but also among the most climate-sensitive. For the International Coral Reef Society (ICRS), this reality reinforces the importance of a strong, connected, and globally inclusive scientific community.

ICRS exists to advance coral reef science and to ensure that knowledge informs effective conservation and management. At a time when reefs face unprecedented pressures, our collective role as scientists, practitioners, and educators has never been more important. Robust evidence, transparent communication, and international collaboration remain essential if we are to understand the trajectory of reef ecosystems and identify viable pathways forward.

Over the past year, the Society has continued to strengthen its efforts to support the next generation of coral reef scientists and to broaden participation from regions where reefs are most abundant - but research resources often very limited. Through expanded travel support, student awards, and targeted initiatives for early-career researchers, ICRS seeks to reduce barriers to participation in the global reef science community, particularly in regions where many of the most pressing research and conservation challenges coincide with uneven access to training, infrastructure, and funding. These efforts culminated in the largest outlay of awards in the Society's history, totaling nearly $250,000, made possible through generous contributions from members and philanthropic partners.

A central focus for the coming period is the **16th International Coral Reef Symposium (ICRS 2026)** to take place in Auckland, New Zealand, this coming July. The Symposium represents the largest global gathering of coral reef scientists and practitioners, and preparations are well underway with an outstanding local organizing committee. Beyond being a venue to present new science, the Symposium provides an opportunity to strengthen collaborations, develop new ideas, and engage with policymakers and stakeholders concerned with the future of coral reefs. Importantly, we are working to ensure broad international participation so that the meeting reflects the full diversity of the global reef community.

At the same time, the Society continues to support initiatives that enhance openness and coordination in coral reef research. Increasingly, progress in our field depends on shared data resources, standardized methodologies, and collaborative networks that span disciplines and geographic regions. Strengthening these foundations will help ensure that coral reef science remains both rigorous and actionable.

Despite the scale of the challenges facing reefs, the coral reef community has repeatedly demonstrated its ability to innovate, collaborate, and respond. The dedication of ICRS members - from students and early-career researchers to senior scientists and practitioners - remains one of the Society's greatest strengths.

I encourage all members to remain and become actively engaged with the Society, to participate in upcoming initiatives and meetings, and to continue fostering the collaborative spirit that defines the coral reef research community.

Sincerely,
Christian R. Voolstra, *President, International Coral Reef Society*

EDITORIAL

Rupert Ormond, Editor, Reef Encounter

Welcome to another packed edition of Reef Encounter. For North American readers, please note our name is and always has been "Reef Encounter" – in the singular. While the plural may seem to make more obvious sense, the origin of the name (as described in detail in a past issue) lies in the British love of puns[1]. At the time of the very first issue there was a charming romantic film, hugely popular in UK cinemas, called "Brief Encounter". It dramatized the unrequited love between two commuters who met briefly at a railway station. So Reef Encounter was a play on the name of the film. This tradition has continued as the newsletter has further expanded, with the names of an increasing number of sections introducing further puns linked to the "Reef" prefix – hence Reef Edge, "Reeflections", and "Reefactions".

Frustratingly, we have only been able to get this issue out several months after originally intended. In December, while playing the part of the father-narrator in a musical production of "The Night Before Christmas"[2] at our Scottish Island carol concert, I picked up the latest Covid virus, which left me knocked out for many weeks. Undoubtedly the fact that I am approaching my 80th birthday did not help, so I have reached the conclusion that, after 12 years in the role, the time has come for me to step down from the position of editor-in-chief of the Society's news magazine.

Thankfully, Deborah Gochfeld, of the University of Mississippi, has accepted to take on the chief editor's duties. I have agreed to serve as deputy editor for a year or two to "inshore" a smooth transition. In turn Caroline Rogers, who has been a faithful deputy editor, also for 12 years, has opted to give up this role, while remaining for a while on the editorial panel. I cannot express my immense gratitude to Caroline for her work in support of my efforts. Without her deep common sense and refined proof-reading skills Reef Encounter would over recent years have been a much less professional production - though we still sometimes debate such questions as the use of a comma after the word "and", where British and North American usages tend to differ[3].

With such questions in mind, it is worth remarking that Deborah will be the first non-British chief editor of Reef Encounter, of whom there have until now been five or six, including still active members Sue Wells and Brian Rosen, since the Society was founded in Cambridge (England) in 1980. I trust Deb will come to uphold the punning tradition. Since its earliest editions Reef Encounter has also frequently included relevant cartoons and suitable anecdotes, a tradition that could perhaps be encouraged in these grim times.

It has been a privilege to serve as chief editor of Reef Encounter. It has justified my correspondence with old friends and helped me make more new ones of all ages – many of whom I have yet to meet. It has been a voluntary (unpaid) task which I have been glad to undertake for one embarrassing reason. I was one of the handful of people at the Cambridge meeting which came up with the idea of the Society. But, feeling under the usual pressures of younger scientists to establish a career, I did relatively little at that time to help get the ball rolling. The heavy lifting was done by our first President David Stoddart, by Barbara Brown, then at Cambridge but later at Newcastle, and by Peter Spencer Davies, whose lecturing on coral reefs at Glasgow University I eventually took over. I can only hope that, after 8 years as Corresponding Secretary and 12 years at the helm of Reef Encounter, I have now made up for earlier omissions! I look forward to meeting many of those with whom I have corresponded over the years at ICRS16 in Auckland.

Rupert Ormond

[1] A pun is a form of wordplay that exploits multiple meanings of a term or similar-sounding words for humorous effect.
[2] A popular Christmas poem, by the American writer Clement Clarke Moore, properly titled "A Visit from St. Nicholas".
[3] A case in point – the example here is sometimes known as an "Oxford" comma, that conforms to neither standard UK or US usage, but which I believe makes the sentence easier to understand – "shorely" the point of grammar!

ICRS Honors and Awards 2025

ICRS Officers and Council announced, in June 2025, the following recipients of ICRS Honors and Awards for 2025:

Eminence in Research Award: Sean Connolly, Smithsonian Tropical Research Institute, Panama

Mid-Career Award: Raquel Peixoto, King Abdullah University of Science & Technology, Saudi-Arabia

Early Career Award: Daniel Wangpraseurt, Scripps Institution of Oceanography, USA

Coral Reef Conservation Award: Alma Paola Rodríguez-Troncoso, Universidad de Guadalajara, Mexico

World Reef Award: Ewout Knoester, Reefolution, Kenya

Science Communication Fellowship: Igor Pessoa, King Abdullah University of Science & Technology, Saudi Arabia

Ruth Gates Fellowships: Maya Powell, University of North Carolina Chapel Hill, USA, and **Alexandra Pineda Muñoz**, National University of Colombia - Caribbean Campus, Colombia

The following members have been elected to **ICRS Fellow's** status:

Ilsa Kuffner, United States Geological Survey, USA

Jacqueline Padilla-Gamino, University of Washington, USA

Alastair Harborne, Florida International University, USA

The following have been awarded **Graduate Research Fellowships**:

Eleanor Casement, Leibniz Centre for Tropical Marine Research, Germany

Mu-Han Chen, Boston University, USA

Ninon Martinez, Boston University, USA

Marcelina Martynek, University of Pennsylvania, USA

J. David Muñoz-Maravilla, University of Puerto Rico, Puerto Rico

Manuja Promodya Hendawitharana, Gent University, Belgium

The following nominees have been awarded the **John Ogden President's Award** to enable them to attend the International Coral Reef Symposium in New Zealand in July 2026:

Daud Bin Awang, Department of Fisheries, Malaysia

José de Jesús Adolfo Tortolero-Langarica, Tecnológico Nacional de México and Universidad Nacional Autónoma de México, México

ICRS Honors and Awards 2026

ICRS Officers and Council have announced the following recipients of ICRS Honors and Awards for 2026:

Eminence in Research Award: Kimberly Ritchie, University of South Carolina, USA

Mid-Career Award: Hollie Putnam, University of Rhode Island, USA

Early Career Award: Thomas M. DeCarlo, King Abdullah University of Science & Technology, Saudi Arabia

Coral Reef Conservation Award: Lisa Carne, Fragments of Hope, Belize

Ranjeet Bhagooli, University of Mauritius, Mauritius

World Reef Award: Ahmed Sh Ibrahim Sh Aba, Marine Research and Coastal Development Center, Somalia

Science Communication Fellowship: Julia Koorn, Wageningen University & Research, Netherlands

Ruth Gates Fellowships: Abigail Turnlund, University of Oldenburg, Germany

Bailey Wallace, University of Miami, USA

The following members have been elected to **ICRS Fellow's** status:

C. Mark Eakin, Corals & Climate, USA

Kimberly Ritchie, University of Rhode Island, USA

Verena Schoepf, University of Amsterdam, Netherlands

The following have been awarded **Graduate Research Fellowships**:

Kurt Bryant Bacharo, Philippines

Genevieve Dallmeyer-Drennen, USA

Genevieve Hennessy, Australia

Juan Pablo Lozano-Peña, Colombia

Mikaela Salvador, USA

Sophie Wong, USA

The Society's Darwin Medal

We are pleased to announce that Professor Ove Hoegh-Guldberg, Emeritus Professor at the University of Queensland, has been unanimously selected as the 2026 Darwin Medallist.

The Darwin Medal[1] is the Society's premier honor, awarded once every 4 years to one eminent late-career Society member who is recognized worldwide for major scientific contributions throughout their career. The list of past honorees can be found on the Society website at https://coralreefs.org/awards-honors-fellowships/darwin-medal/. We received an exceptionally large number of nominations this year, and the committee was impressed by the quality and impact of many highly deserving candidates.

The following excerpts from Ove's nomination captures the importance of his work for coral reefs and society at large: Professor Ove Hoegh-Guldberg has made foundational, field-defining contributions to coral reef science, climate change biology, and the global understanding of the future of coral reef ecosystems. His research has reshaped the trajectory of coral reef biology, informed international climate policy, catalyzed major global initiatives, and established the empirical and conceptual frameworks upon which much of modern coral reef climate research rests. His scientific record, global leadership, community service, and contributions to public understanding constitute an unparalleled body of work that fully aligns with the purpose and legacy of the ICRS Darwin Medal.

Throughout his career, Ove has demonstrated scientific courage by articulating the risks that ocean warming posed to coral reefs—long before the broader community was prepared to accept these conclusions. His early projections in the 1990s and 2000s—that mass bleaching would intensify and that coral-dominated reef ecosystems could collapse within decades without rapid emissions reductions—were met with strong scepticism, and he was widely labelled a "doom-and-gloom" scientist for presenting evidence that challenged prevailing assumptions.

Despite this criticism, he remained steadfast in his commitment to rigorous analysis and clear communication of emerging risks. Increasingly frequent and severe global bleaching events and sustained reef decline have since validated these early warnings, underscoring both the accuracy of his science and the prescience of his leadership. Ove's willingness to confront uncomfortable truths, grounded in empirical evidence, has been instrumental in shifting scientific, public, and policy discourse toward recognizing the existential threat that climate change poses to coral reefs.

Prof. Hoegh-Guldberg will be presented with his medal and deliver the plenary Darwin Lecture at the 16th International Coral Reef Symposium, 19–24th July 2026 in Auckland, Aotearoa New Zealand. Please join us in congratulating him on his achievements.

Professor Christian R. Voolstra, ICRS President
Dr. Verena Schoepf, ICRS Honors and Awards Committee Chair

[1] Named (of course) for Charles Darwin, who not only published a seminal work on coral reefs, but spent time studying at Cambridge (UK) where the Society was founded.

Meet the team

Behind ICRS Social Media

You may have noticed some recent changes across ICRS social media channels. The Society has brought together a new team to lead its social media and broader communications efforts, strengthening how we connect with our global community.

At a time when social media plays a central role in how we share information and engage with one another, a strong online presence is essential for any organisation. Through an open and competitive selection process, ICRS selected two outstanding students to support and enhance the Society's communications. We are fortunate to have them on board as we continue to grow and refine ICRS's digital presence. Here we ask each of them about their interests in science communication.

Crystle Wee. 2nd Year PhD Student at James Cook University, Townsville, Australia.

Area of expertise: Coral restoration, coral seeding

Crystle Wee

What inspired you to apply for this role with ICRS?
Science trained me to think logically and systematically, but at heart, I have always been a creative person. Through social media, photography, and art, I've found that storytelling can move people in ways that data alone cannot. When I saw this role, I recognised it as a natural place to channel that instinct toward something that deeply matters to me - the conservation of coral reefs and the livelihoods of people who depend on them.

What sustains my motivation are the many researchers I've had the privilege of learning from. Their curiosity and solution-oriented thinking remind me that being hopeful is not naive. Through collaboration, creativity and a lot of rigorous work, we can turn the tide against coral reef degradation. However, much of this good work needs amplification. We may be the last generation with a real window to prevent the functional collapse of coral reef ecosystems. That urgency makes strong science communication not just valuable, but essential.

ICRS sits at the heart of the global reef science community. For me, this role is an opportunity to create a platform to connect coral practitioners and researchers worldwide. I hope to create scientific content that is not just accurate but easily understood beyond the echo chamber of marine science. I hope to build relationships with more members of the coral reef community, whether they are scientists, conservationists, policymakers, filmmakers, traditional owners, students, divers, fishermen, or enthusiasts. That combination of purpose, people, and reach is exactly what drew me to apply.

Why do you think social media is important for a scientific society like ICRS?
I first began to use Instagram to share pictures of marine life I took while diving in the murky waters of my home, Singapore. To my surprise, many of my friends and family had no idea that one of the busiest shipping channels in the world could be located right next to coral reefs. If it weren't for social media, these conversations and awareness of such conservation would not have been raised.

Conferences like ICRS provide a vital global platform for coral researchers and marine scientists to exchange ideas. However, a common limitation is that these discussions can remain within academic echo chambers. Many scientific publications are also restricted by paywalls or written in language that is inaccessible to broader audiences. I feel that social media offers a powerful way to bridge this gap. It enables the dissemination of scientific knowledge to a global audience, including those who may not have access to conferences or direct engagement with experts. Importantly, it also reaches younger audiences, increasing awareness of educational pathways, scholarships, and opportunities within marine science. In an increasingly digital world, reliable scientific information must be communicated in ways that are both accessible and engaging. Through effective management of ICRS social media channels, we can expand the reach of coral reef science, supporting not only the current research community but also inspiring and informing the next generation of scientists.

What message would you like to share with the ICRS community?
More than ever before, the world has become increasingly fragmented by politics and ideologies. The ocean does not recognise political boundaries, and coral reefs face similar challenges worldwide. Every individual contribution to the ICRS community is important, and we need a united front to conserve coral reefs. By drawing the best minds together, we can understand the stories and states of reefs at local levels and then bring this knowledge to a global platform. We are already acting locally - it's time to stitch these narratives together for global solutions and bring "all hands on deck" for the continuity of coral reefs.

Luiza Campos

What inspired you to apply for this role with ICRS?
Since I began my research journey, I have immersed myself in the study of coral reefs, driven by my deep admiration for these vital ecosystems and the awareness of the significant threats they face, which could potentially render them almost nonexistent by the end of the century. Over time, I came to see science communication as a central part of addressing these challenges, as effectively responding to the threats facing coral reefs depends not only on research, but also on how this knowledge is shared and understood beyond academia. Although I did not grow up in a coastal city, I lived relatively close to the ocean, yet I had never learned about coral reefs or their importance until I was around 14 years old. This lack of awareness was not only personal, but also reflected in the people around me, many of whom had little to no contact with this topic.

Luiza Campos. Undergraduate student in Biological Sciences at University of São Paulo, Brazil

Area of expertise: Coral bleaching and Symbiodiniaceae.

When I entered university and began working in coral reef research, I became very aware of the contrast between the urgency of topics discussed in academia, such as coral bleaching, and the limited public awareness of these issues. Through my involvement in outreach projects, I saw firsthand how significant this gap can be. These experiences led me to engage more deeply with science communication, not only as a way to share knowledge, but also to create dialogue and learn from different audiences. Applying for this role at the International Coral Reef Society felt like an opportunity to contribute to bridging this gap on a larger scale, making coral reef science more accessible while fostering engagement between the scientific community and the broader public.

Why do you think social media is important for a scientific society like ICRS?
Social media plays a key role for a scientific society like the International Coral Reef Society because it allows knowledge to move beyond traditional academic spaces and reach diverse audiences simultaneously. While in-person interactions, such as conferences and outreach events, remain essential, they are often limited by geographic, financial, and institutional barriers. In this context, social media becomes a powerful tool to broaden participation, bringing into the conversation people from different regions, socioeconomic backgrounds, and lived experiences, including groups that are often underrepresented in environmental and climate discussions.

At the same time, this expanded reach also comes with challenges, as misinformation about science and climate issues spreads easily online. This makes the presence of scientific societies like ICRS on social media even more important, as they can provide reliable, accessible, and evidence-based information to wider audiences. Beyond dissemination, it also creates opportunities for dialogue. Platforms can foster discussions, exchange of ideas, and connections between researchers, students, and the wider public from around the world when used thoughtfully. This plurality of platforms and audiences makes social media not just a communication tool, but a space for engagement, collaboration, and more inclusive scientific conversations.

What message would you like to share with the ICRS community?
We truly appreciate the engagement and contributions of the ICRS community across different spaces, including social media. These interactions are essential for building a more connected and active scientific community, and we are always open to suggestions, feedback, and new ideas. It is important to continue strengthening a science that is collaborative, inclusive, and plural, one that values diverse perspectives and experiences from different regions of the world. Much like coral reefs themselves, which are shaped by their diversity and complex interactions, our scientific community also benefits from a wide range of voices, backgrounds, and ways of thinking. Expanding whose voices are heard in coral reef science is essential, especially considering that many communities most affected by environmental and climate challenges are often underrepresented in global discussions.

Finally, I would like to highlight that science is not built in isolation. As researchers and members of this community, we also share a responsibility to communicate our work beyond academia, making knowledge more accessible and relevant to society. Strengthening these connections between science and society is essential for building a more informed, engaged, and inclusive global community.

Please contact the communications team with any content you would like to share by emailing us at icrs.comms@gmail.com

Luiza Campos, Crystle Wee, Mark Eakin and Mariana Rocha de Souza

International Coral Reef Symposium

19-24 July 2026 • Auckland New Zealand

Working together to ensure a future for coral reefs

Registration is open!

Register now and join us at the 16th International Coral Reef Symposium (ICRS) in Auckland.

Hosted in New Zealand for the first time, ICRS 2026 holds special significance. New Zealand, with its strong cultural ties to the Pacific and its commitment to sustainable development, offers a unique setting to address the challenges facing coral reefs.

Against the backdrop of Oceania's stunning coral reefs, this symposium will foster discussions on innovative solutions with worldwide relevance. As we come together in Auckland, let us build upon the successes of past symposia and forge new pathways toward a sustainable future for coral reefs. Together, we can ensure that these irreplaceable ecosystems continue to thrive for generations to come.

Register today and save!

Don't miss out - special EARLY BIRD rates are only available until Sunday 24 May 2026.

Visit the website for pre & post Symposium tour options

www.icrs2026.nz

Meet our Keynote Speakers

Dr Greg Asner
ASU Center for Global Discovery and Conservation Science, Hawaii

Dr Tamatoa Bambridge
CRIOBE, French Polynesia

Prof Julia Baum
University of Victoria, Canada

Prof Christina Hicks
University of Lancaster, UK

Dr Dan Hikuroa
University of Auckland, New Zealand

Prof Paul Kench
National University of Singapore

Prof Cynthia Riginos
Australian Institute of Marine Science/University of Queensland, Australia

Prof David Suggett
King Abdullah University of Science & Technology, Saudi Arabia

Prof Virginia Weis
Oregon State University, USA

International Coral Reef Symposium

Working together to ensure a future for coral reefs

www.icrs2026.nz

Sessions and themes

1. **Traditional Knowledge and management**
2. **Historical perspectives on coral ecosystems**
3. **Cell and molecular biology of reef organisms**
   - Sub theme: Holobiont Responses
   - Sub theme: Omics and Molecular Foundations
   - Sub theme: Symbiosis and Microbial Ecology
4. **Coral reef ecology and connectivity**
   - Sub theme: Deep Reefs
   - Sub theme: Distributions
   - Sub theme: Diversity
   - Sub theme: Ecology and Evolution
   - Sub theme: Functional Ecology
   - Sub theme: Regional reefs and corals
5. **Coral reef monitoring and assessment at scale**
   - Sub theme: Climate Impacts
   - Sub theme: Ecosystem Change
   - Sub theme: Function and Recovery
   - Sub theme: Monitoring Innovation
   - Sub theme: Pollution
6. **Modelling the trajectories of future reefs**
7. **Socio-ecological feedbacks: reef value, use, and stewardship**
8. **Innovations in reef conservation and intervention**
   - Sub theme: Art
   - Sub theme: Biotechnology
   - Sub theme: Programs
   - Sub theme: Systems
   - Sub theme: Technology

www.icrs2026.nz

International Coral Reef Symposium

Working together to ensure a future for coral reefs

the return of:

Reef Futures

Riviera Maya, Mexico

Reef Futures is back. From December 6–11, 2026, the Coral Restoration Consortium (CRC) will once again convene the global coral restoration community at Iberostar's Playa Paraíso Resort in Riviera Maya, Mexico. Now in its fifth iteration, Reef Futures remains the only conference dedicated entirely to the practice and science of coral reef restoration and a critical gathering point for a field navigating rapid environmental change.

The CRC is a global network of practitioners, researchers, and partners working to restore coral reef ecosystems. By connecting efforts across regions and disciplines, it has helped shape a more coordinated, collaborative approach to restoration, one that continues to evolve as conditions in the ocean shift.

This year, the Consortium will again partner with the Iberostar Group through its Wave of Change initiative, focused on responsible tourism—from eliminating single-use plastics to advancing nature-based solutions and sustainable seafood practices.

Reef Futures is more than a conference—it's a working space for a global community under pressure. "Reef Futures is where the field comes together to take stock on what's working, what isn't, and where we go next," says Tom Moore. "Whether you're new to restoration or have been in it for decades, it offers something increasingly rare: the time and space to learn directly from the people doing the work."

In 2026, that exchange takes on a new dimension with the introduction of the *Solutions Expo*, marking a significant evolution in how Reef Futures brings people together. Designed as a single, dynamic hub, the Expo will connect practitioners with the tools, technologies, and ideas shaping restoration today. From low-tech approaches developed in reef-dependent communities to emerging innovations in monitoring and scaling, participants will be able to explore solutions up close, testing methods, engaging with developers, and learning directly from peers.

The Conference Center at Iberostar Playa Paraiso Resort, Riviera Maya - the hub of knowledge exchange at Reef Futures.

At its core is a simple but urgent principle: innovation must be accessible. Under the theme *Innovation for All: Ensuring Equitable, Accessible, and Locally Driven Coral Reef Restoration*, the Expo will spotlight approaches that can be adapted and sustained across diverse contexts—particularly in regions where reefs matter most.

The week begins with workshops and an opening reception on Sunday, followed by plenary and concurrent sessions, hands-on training, poster presentations, and the return of the *Reefs to Reels* Film Festival. Content spans disciplines—from propagation and out-planting to policy, engineering, and community engagement—and is shaped directly by the global community through its submissions.

That commitment to inclusion extends beyond the program itself. At Reef Futures 2024, more than 100 scholarships enabled practitioners, researchers, and students from around the world to attend, contributing to a global gathering of participants from 64 countries. By lowering barriers to access, the conference ensures that those most connected to - and dependent on - reef ecosystems are not only present, but able to contribute, shape discussions, and lead the future of restoration. Applications for Reef Futures 2026 scholarships are now open.

Because in a rapidly changing ocean, the future of coral reefs will depend not just on what we know, but on how quickly we can work together to put it into practice.

Join the community at Reef Futures 2026.

Visit reeffutures.com to learn more!

Images below, left to right: a) Hands-on learning at Reef Futures. b) Collaboration starts in-person during breaks between conference sessions. c) The poster session at Reef Futures 2024.

REEFLECTIONS

From Reef Science to Reef Action

Arthur Lyon Dahl

email: dahla@bluewin.ch

The author, from his book "In Pursuit of Hope" (2019)

As a budding marine botanist, my interest in coral reefs began as a Visiting Postdoctoral Research Associate at the National Museum of Natural History, Smithsonian Institution in Washington, D.C. in 1969. With no ocean nearby, it seemed logical to go south to the tropics. I originally intended to work at the Smithsonian Tropical Research Institute in Panama, but the Governor of American Samoa asked for help in understanding the environmental problems of his territory, so I went there and surveyed the reefs around the islands. I found in the Smithsonian library a voluminous report of the Carnegie Institution's expedition to American Samoa led by Alfred Mayor in 1917-1920 (see Mayor 1918), with detailed descriptions of a quantitative transect survey across the reef in Pago Pago harbour. I was able to relocate the site of the transect, and repeat the survey twice that decade, so as to study the reef dynamics. This has since been followed up (Birkeland et al. 2013), providing almost a century of data about that particular reef.

One other interesting experience that initiated my interest in global environmental governance was the opportunity to represent the Bahá'í International Community at the 1972 United Nations Conference on the Human Environment in Stockholm, the meeting that founded the United Nations Environment Programme (UNEP). Since my faith tradition, the Bahá'í Faith, emphasizes unity in diversity, I wanted to understand what nature could teach us that might be relevant to human society. So I set out to study the complex ecosystem that is a coral reef.

There were two other young coral reef scientists at the Smithsonian at the time: geologist Ian Macintyre (a past ICRS President and Darwin Medal winner) and zoologist Klaus Rützler. Along with Steve Smith, we organised an NSF-funded research project, Comparative Investigations of Tropical Reef Ecosystems (CITRE), involving 80 reef specialists, intending to build a quantitative systems model of the coral reef ecosystem. We held a workshop on Glover's Reef off Belize, and mapped out a grid of 104 compartments, with diagrams of the expected interactions among all the compartments, and then engaged with a modelling team at MIT to prepare a dynamic systems model. With Arnfried Antonius (probably the first person to begin describing then evident coral reef diseases), I dove on coral reefs all over the world looking for the best locations for data collection. We published our conceptual work in the *Atoll Research Bulletin* in 1974, but could not go further. However, we did establish a research laboratory on Carrie Bow

Pago Pago in American Samoa, where Mayor completed his historic reef transect during 1917-1920.

Cay on the Belize Barrier Reef to continue the work and this lab continues to operate today. This was an exciting time in coral reef research, networking with scientists around the world.

This work was an early application of the rapidly evolving field of complex systems science being enabled by new information technologies. This is particularly appropriate to understand both the resilience and vulnerability of the coral reef ecosystem with thousands of species and high integration. The computer modelling team at MIT that we worked with had just published, in 1972, a highly influential report for the Club of Rome on ***The Limits to Growth***, with scenarios showing that unlimited growth in the economy, population, resource use and pollution would lead to the collapse of civilisation in the mid-21st century. All of my subsequent work was guided by this framework of systems thinking, understanding the relationships between all of the parts, the flows of energy and information, the dynamics over time, and the role of rules and values, governance and other outside factors in determining system behaviour.

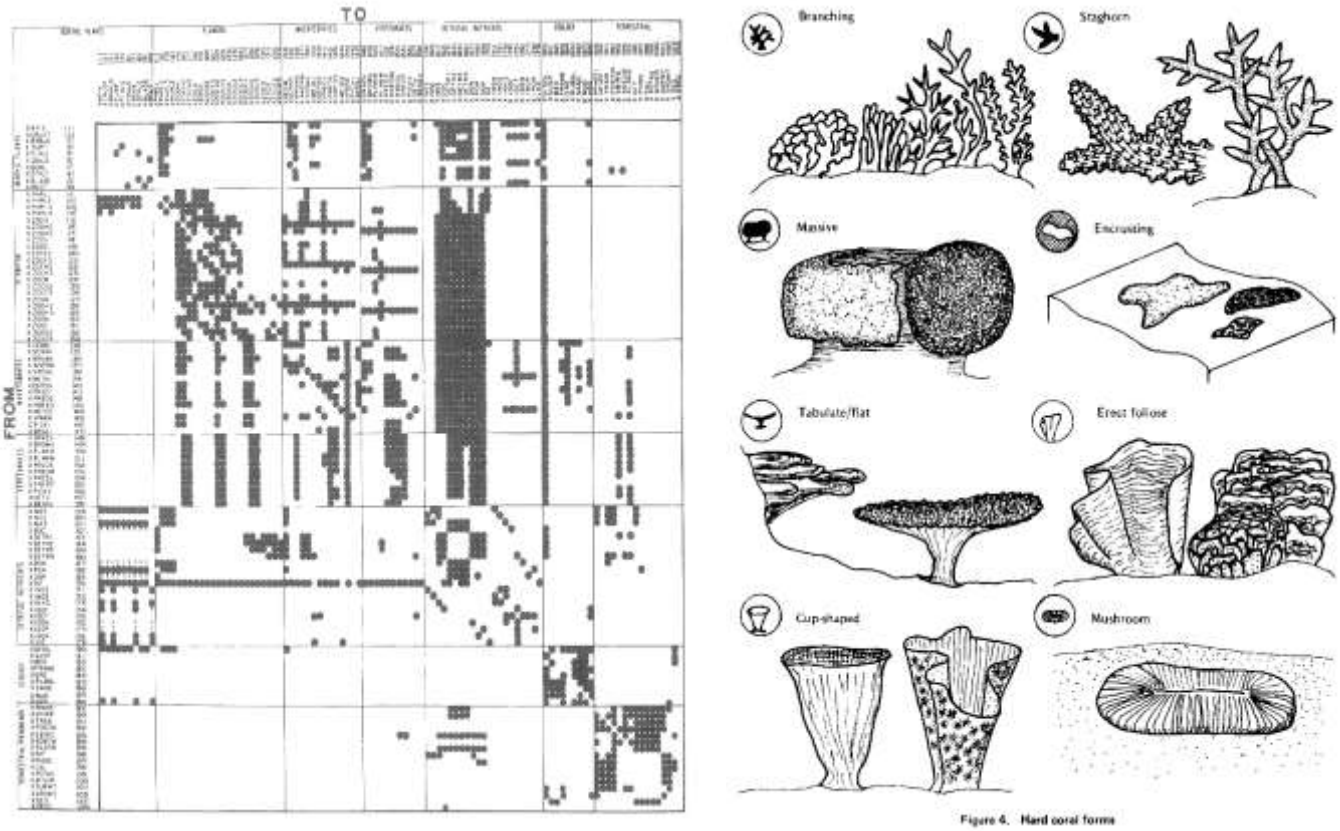
Left, participants at the Glover's Reef workshop. Right, working in the PRINUL undersea laboratory (1972).

Another interesting opportunity from those years was to be an Aquanaut studying reef algal ecology in a two-week saturation diving mission in the Puerto Rico Inter-National Undersea Laboratory (PRINUL), 20 meters down on the base of a coral reef. I noticed a huge difference between a two-hour visit and two weeks' residence. The fish got to know us and would follow us around. One significant result of my continuing work on marine algae was a paper showing how the coral reef community created a large functional surface area many times its horizontal surface, which enabled the reef system to both absorb more light and catch more food (Dahl 1973). I was learning the advantages of complex systems science as a tool for a more integrated and functional perspective on such a complex ecosystem.

At about this time, I also had the opportunity to attend the memorable Second International Symposium on Coral Reefs, held on the cruise ship *M.S. Marco Polo*, as she sailed up and down along the Great Barrier Reef of Australia. We had a post-symposium field trip to visit reef habitats in Fiji, staying in a local village on an outer island. Subsequently, I was also able to examine reef sites in Guam, Palau and Hawaii. This research was my introduction to complex systems thinking for unity in diversity based on cooperation and symbioses, which I extended to human systems and the challenges of global governance later in my career.

The early 1970s also saw the rise of the environmental movement around the world and increasing evidence of environmental damage and the need for management action. I had already experienced the Santa Barbara oil spill in 1969, and lectured at the first Earth Day in Washington, D.C. in 1970. Since childhood, I had dreamed with my Bahá'í values of being of service in poor developing countries. That opportunity came in 1974, when the South Pacific Commission in New Caledonia (SPC, now the Secretariat of the Pacific Community) offered me the post of Regional Ecological Adviser to all 22 Pacific Island countries and territories. I chose action over research, resigned from the museum, and moved to Noumea.

That first year, I visited almost all of the Pacific Island countries to determine their needs, and was also able to visit organizations like UNEP in Nairobi, the International Union for the Conservation of Nature (IUCN) in Switzerland, and others in the United States. For the next eight years, I assisted island countries with everything from primary school curricula to creating national parks and reserves, training



Left, expected interactions among compartments in the model. Right, coral life-forms proposed for reef monitoring work.

environmental planners, surveying the different ecosystems of the region, organizing scientific meetings, adopting a Convention on Conservation of Nature, and finally planning and launching the South Pacific Regional Environment Programme (SPREP), adopted by UNEP as a Regional Seas Programme, that eventually separated from SPC to become its own intergovernmental organization, the Secretariat of the Pacific Regional Environment Programme, based in Apia, Samoa.

During this work I learned a lot about the Indigenous Knowledge of local people, that was often far ahead of Western science. A first example came to light after the Solomon Islands government asked me to investigate a fisheries management problem in the Langa Langa Lagoon, on the island of Malaita. The fishermen lived in villages constructed on artificial islands in the lagoon, and made local traditional money from different shells, including one with a band of orange across it that was subject to overfishing. The local Bahá'ís took me to meet the old pagan priest who traditionally managed the shell fishery. He did this by placing taboos on different parts of the lagoon until he received pigs to sacrifice. Then, after holding traditional ceremonies, he would lift the taboo on collecting shells in one section of the lagoon. With more pigs, he would lift the taboo on another section of the lagoon. Normally, each taboo would last 4-5 years, enough time for the shells to reach the right size to harvest. Thus, the periodic taboos served as an excellent fisheries management technique.

Pigs, in local custom, had great value; they were the equivalent of a "gold standard" in traditional money. However, since World War II, most of the villagers had become Christian or Bahá'í and so no longer believed in giving pigs for sacrifice. So the priest had kept the taboo in place for 30 years, and the system had broken down. I met with the fishermen, explained the wisdom behind the traditional taboo system, and encouraged them to close and open parts of the lagoon to shell collecting in the same way, so as to maintain the productivity of the resource.

The Pacific Islands and their indigenous inhabitants have been fortunate to retain many of their traditional cultures and worldviews despite the heavy impact of colonisation. I was able to live more than a decade among islanders at a time when many island countries were newly independent, allowing me to appreciate deeply what they could offer to the world, which resonated with my own Bahá'í spiritual tradition. For the Pacific peoples, the environment is not something external, but is part of their own being. On my first visit to Kiribati, the government arranged my programme, but the local Bahá'ís, to respect their

custom, took me first to the primary village on the atoll, where I explained to the chiefs the purpose of my visit and was welcomed in customary fashion. As a result, when I went out to start my field work, the word had gone ahead that I had respect for custom, and was not just another outside expert. My educational materials and training programmes for environmental professionals included indigenous knowledge and perspectives and called for their preservation. I believe that much of my impact in the region over the years was because I earned the trust of the indigenous peoples.

Research sites photographed in the 1970s. Left, Munda in the Solomon Islands. Right, Upoloa, in Samoa.

In 1977, I was able to participate in the Third International Coral Reef Symposium in Miami, Florida, with a paper on monitoring man's impact on Pacific Island reefs (Dahl 1977). Another paper with Austin Lamberts described what we had learned from our reef monitoring in American Samoa and our resurvey of Mayor's 1917 transect, demonstrating the major changes in coral cover that can occur in response to environmental impacts (Dahl & Lamberts 1977). To make scientific methods more accessible to reef users for participatory science, I organized and directed an Expert Meeting on Coral Reef Monitoring, on Motupore Island, Papua New Guinea, which led to a first simple *Coral Reef Monitoring Handbook* (Dahl 1981b), which was reprinted by UNEP in their Methods for Marine Pollution Studies series, becoming widely used. Soon enough, the 4th International Coral Reef Symposium came around (in Manila, Philippines) and I published a widely cited paper on monitoring coral reefs for urban impact (Dahl 1981a). Perhaps of even greater significance, I became a founding member of ICRS (then the International Society for Reef Studies).

My efforts to build governmental interest in environmental management culminated in 1982 when I organized and directed a ministerial-level *Conference on the Human Environment in the South Pacific* in Rarotonga, Cook Islands, as the political launch of the Pacific Regional Environment Programme. While the small island countries had too few human resources for all the scientific competencies necessary for environmental management, together they could pool resources to achieve a critical mass. A decade later I was able to scale this to the global level.

One of the most meaningful experiences during my years in the Pacific Islands was to discover and then support, across many island cultures, indigenous traditional knowledge of the island environment and its natural resources. While much has been lost under colonisation, there is still great wisdom that is highly relevant to achieving a sustainable future in limited island environments. Living in New Caledonia for more than a decade, and cultivating a respectful relationship with the Kanak people (assisted by my many Bahá'í friends among them) I was able to prepare an account of traditional environmental management knowledge (Dahl 1985a), as well as review the challenge of conserving and managing coral reef ecosystems (Dahl 1985b).

At the 5th International Coral Reef Congress in Tahiti in 1985, I organised and chaired a symposium on the *Protection and Conservation of the Reef Environment, A Gamble on the Future*. This led to publication with Michel Pichon of both an introduction to the symposium (Dahl & Pichon 1985), and the symposium conclusions (Dahl 1985b). Likely in consequence, in 1986, UNEP asked me to help re-establish its Regional Seas Programme as the Oceans and Coastal Areas Programme Activity Centre in Nairobi, Kenya, after its transfer from Geneva. Subsequently, I became Deputy Director of the UNEP Oceans and Coastal Areas

Programme, helping countries around the world to protect their oceans and coastal areas, and supervising Regional Seas Programmes involving 140 countries around the Mediterranean, the Red Sea, the Persian/Arabian Gulf, East Africa, West Africa, South Asia, South-East Asia, my own programme in the South Pacific, the South-East Pacific along Latin America, and the Caribbean.

When the UN was organizing the United Nations Conference on Environment and Development (UNCED), the so-called "**Rio Earth Summit**" of 1992, I was seconded to the secretariat and was responsible for the drafting and negotiation of Chapter 17 of its action plan *Agenda 21* on the "Protection of the oceans, all kinds of seas, and coastal areas and the protection, rational use and development of their living resources" (UNCED 1992). I was specifically requested to include a section on Small Island Developing States (SIDS), helping to launch the concept. While island countries had individually seemed marginal at the United Nations, together they represented over forty votes in the General Assembly and found an important place at the table that has continued until today. My experience in enabling islands to see what they had in common across the Pacific could now be applied at a global level. Since most SIDS have coral reefs and are threatened by climate change-linked coral bleaching and sea level rise, they have become important global actors for reef protection.

My career took a broader turn in 1992, when I moved to Geneva as Coordinator of the UN System-Wide Earthwatch, and also became Deputy Assistant Executive Director of the UNEP Division of Early Warning and Assessment. One responsibility was to develop indicators of sustainable development that governments could use to measure progress, so I helped to lead that process, both within the UN, and through the then influential Scientific Committee on Problems of the Environment (SCOPE). This became my major activity over the next decade and beyond.

In the UNEP office in Nairobi, 1991

Another interesting project in which I became heavily involved was the South Pacific Biodiversity Conservation Programme funded by the Global Environment Facility, helping 14 Pacific Island countries to develop locally managed protected areas. In 1993, I was invited to prepare a keystone paper on land-based pollution and integrated coastal management (Dahl 1993) for a special issue of *Marine Policy* on UNCED's marine agenda and the challenges of its implementation. With the rapid expansion of satellite remote sensing, there was a growing need to improve the coherence of many national satellite programmes and promote the scientific use and assessment of the resulting imagery. Thus, I helped lead the development of integrated global observing strategies, including for coral reefs, leading eventually to the formation of the intergovernmental Group on Earth Observation (GEO). As a result, I also became a member of the Steering Committee of the Global Ocean Observing System (GOOS), a participant in the Sponsors Group for the First Integrated Global Observing Strategy (IGOS) Partners Meeting, and a participant in the GESAMP Working Group on Marine Environmental Assessments.

Finally, in career terms, in November 2000, I was named Director of a new UNEP Coral Reef Unit, a post I occupied until my retirement in 2002. This involved designing and launching an International Coral Reef Action Network (ICRAN) linking coral reef scientists, NGOs and interested governments. This led to participation in the International Coral Reef Initiative (ICRI) Coordination and Planning Committee (CPC) meeting in Noumea, New Caledonia. Meanwhile, I was able to attend the 7th, 8th and 9th International Coral Reef Symposia, and participate in further committees and programmes. The ICRAN, ICRI Regional Workshop, and IGOS meetings continued in Cancun, Mexico, while NCORE held a Workshop on the Future of Decision-support for Coral Reef Management in Miami, Florida. Some of the outcomes I wrote up as "IGOS Coral Reef Theme" in *Reef Encounter* in 2002 (Dahl 2002a).

The Rio Earth Summit was followed ten years later, in Johannesburg, South Africa, by another highly significant international meeting - the 2002 ***World Summit on Sustainable Development***. I represented ICRAN as a type-two partnership for coral reefs, featuring collaboration between the UN and the scientific community. A major event in 2005 was the participation of organisations at the Mauritius International Meeting on further implementation of the Programme of Action for Small Island Developing States, where

I chaired a side event for ICRI. There I participated in the presentation of the South Pacific Applied Geoscience Commission (SOPAC) Environmental Vulnerability Index, a methodology that demonstrated the particular vulnerability of small islands. In 2008 , I attended the International Coral Reef Symposium in Fort Lauderdale, Florida, for what was effectively my last opportunity to be directly involved with coral reefs. The rest of my career has been concerned with sustainability indicators, small islands, climate change, environmental assessment, values-based indicators, and measurements of wellbeing. Most recently, I have focussed on global environmental governance, since in the absence of strong governance, climate change is accelerating, coral reef ecosystems are collapsing, and biodiversity faces an existential crisis.

Looking back on all these coral reef activities over almost forty years, I was fortunate to be able to contribute to bridging basic science with government policy, and with action in the water. Too often academic research is published in scientific journals or technical reports to which government policymakers have little access. Research findings of global significance may seem very distant to those dealing with practical problems on their local reefs. There is a vital need for those who know the science and participate in research to also learn how to communicate the key findings of their work to governments and administrators in a language the latter can understand. At the same time, international conventions and agreements need to be drafted to be cohesive with and responsive to scientific realities. The urgency of actions to save what we still can of coral reef ecosystems needs to be communicated to leaders and the general public, for there is a wide gap between government agreements to implement a range of actions and the practical implementation of those actions. Coral reef specialists have an important role in demonstrating that actions can produce visible results for the common good.

Reefs now are nothing like those I knew in the 1970s. But they are examples of complex systems that demonstrate how close cooperation, symbioses and integration of many diverse components and functions can achieve high productivity and resilience in a circular economy, including a place and a constructive role for every organism, however seemingly insignificant. This really is a model for human society in our globalised world. In my life I have tried to build on these lessons, going from direct reef studies through motivating national action, up the causal chain of threats to reefs, eventually working to reform the United Nations system, in the hope of securing an effective mandate for global legislation that can bring the Planet Earth back within acceptable system boundaries. Hopefully this will enable both coral reef survival and regeneration on the one hand, and sustainable human wellbeing on the other. Perhaps my efforts will inspire others to rise to the occasion in this time of coral reef crisis.

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REEF CURRENTS

Revising Corals of the World - Taxonomy, Evolution, Diversity

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Introduction

We are currently in the process of finalising a major revision of our coral taxonomy website www.coralsoftheworld.org. The website, first released in 2016, was developed to provide a continuing upgrade of the original three volume book *Corals of the World*, published by two of us (Veron with Stafford-Smith) twenty-six years ago (Fig. 1). Since then, much has changed. In particular, molecular studies, made possible by extraordinary advances in methodology over the last decade, have led to changing views of the relationships between many taxa. Despite these advances, morphological descriptions remain basic to species accounts, and morphological descriptions are likely to remain the means by which taxonomists, students, coral ecologists and reef managers identify the corals they encounter.

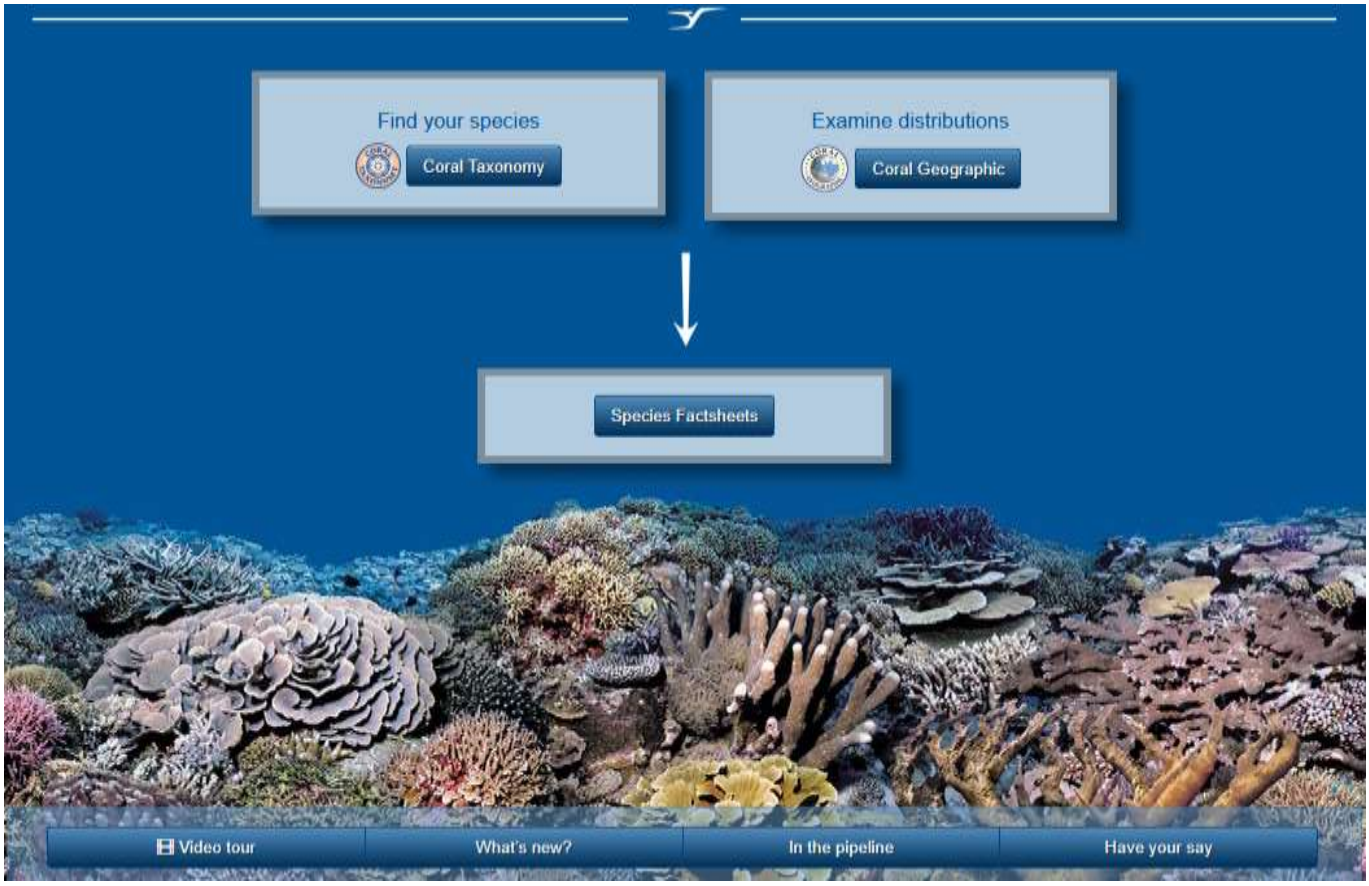

Figure 1. The familiar welcome page of our Corals of the World website. First released in 2016, to provide a continuing upgrade of our original three volume Corals of the World, the site is undergoing extensive revision to incorporate new knowledge and understanding of the relationships between taxa.

Accordingly, we published (November, 2025) in the journal Diversity (https://www.mdpi.com/1424-2818/17/12/823) a paper reviewing the principles that we have adopted in our revision of coral taxonomy, and the evidence we have for doing so. The rapid development of molecular tools and their taxonomic implications have required significant assessment for the approximately 900 taxa we presently recognise. We need to consider that while in many genera, significant hybridisation may occur in parts of their range, many molecular studies have also distinguished multiple genetic lineages within species as currently delineated. In response to these developments, we are now categorising all taxa as "valid", "probably valid" or "possibly valid", providing users with a comprehensive assessment of each biological entity. The website will include multiple factsheets for each taxon covering description, expanded imagery, taxonomy and nomenclature, distribution and variability. Here we summarise the main points in our review, both as a means of informing readers of our work, and in order to encourage discussion of our general conclusions and specific decisions. Please see the more detailed description of this work in our 2025 review (Veron et al. 2025).

Background

The central concept in modern coral taxonomy is reticulate evolution (Fig. 2), which describes a mechanism for the origination of 'species' through the continual intermixing of ancestral lineages forming a network of changing genetic interconnections rather than stable hierarchical trees. As a result, species, however defined, are not discrete units but rather are components of continua with variable genetic, morphological, and geographic boundaries and, further, there are no stable sub-species divisions (variously called sibling species, hybrids, subspecies and lineages).

Hybridisation and introgression are key processes maintaining reticulated networks, making polyphyletic species (those with mixed evolutionary origins) potentially the norm rather than the exception (see Fig. 3). This creates 'grey zones' of speciation where taxonomic divisions are uncertain and gene flow is ongoing. Just as most experienced terrestrial taxonomists identify their species from much more than simple morphology, this article highlights the importance of distinguishing between the 'biological entity' (usually based on thousands of field encounters and skeletal analyses of specimens from varying habitats and/or geographic regions) and what are frequently termed 'morphospecies', which are commonly based on type specimens or a small collection from one or a few localities.

Themes

Our review has four central themes, highlighting the importance of:

1. integrating information from all relevant sources when considering any taxonomic change;
2. maintaining the status quo when evidence from different sources conflicts;
3. foundational molecular studies (most yet to be undertaken) to provide context for understanding genetic variability and species boundaries;
4. understanding the consequences of reticulate evolution when assessing the results of molecular data.

The Main Subjects

This many concepts are more effectively conveyed through images than words, so in the review article we have made extensive use of photographs to illustrate issues or taxa.

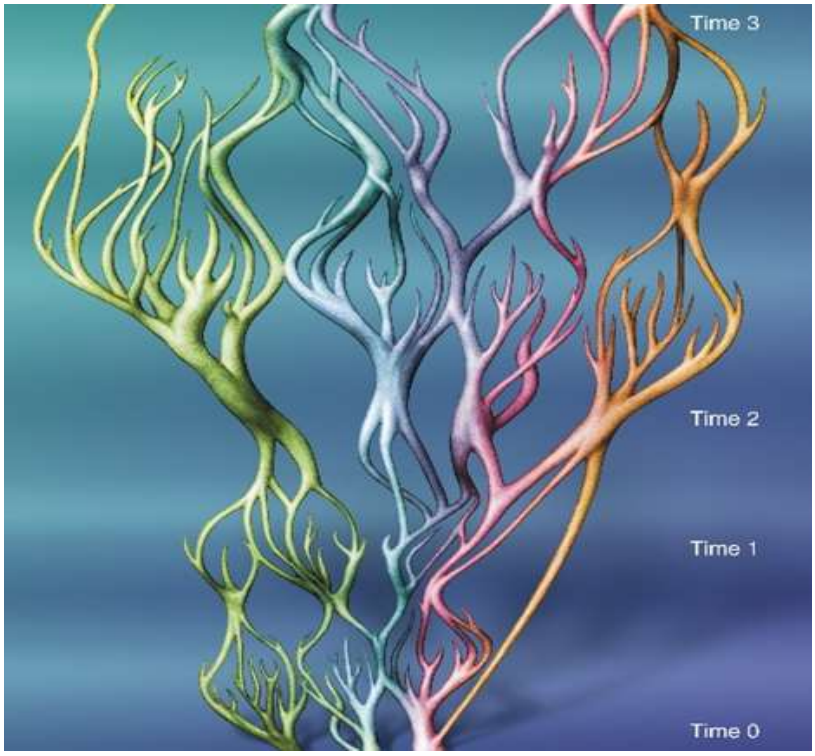

Figure 2. A hypothetical view of reticulate evolutionary change within a group of genetically linked taxa through time. At the bottom (Time 0), the group forms three distinct species each of which is widely dispersed by strong currents. At Time 1 the group forms many indistinct small species units that are geographically isolated because currents are weak. At Time 2, the group forms four species that are again widely dispersed by strong currents. Over the long geological interval to Time 3, the group has been repackaged several times. From Veron (2000).

Specifically, the review addresses:

- The value of field studies that capture environment-correlated and geographic variations. These are illustrated from different points of view. We use *Stylophora* as a case example.
- The differences between nomenclature (a human construct) and taxonomy (which endeavours to reflect nature's organisation).
- The value of co-occurrence as an aid for taxonomy.
- The use and misuse of synonyms that create serial errors stemming from historical publications.
- Undue reliance on type specimens as a basis for taxonomic decisions and the role of nomenclatural websites in perpetuating these problems.
- The premature and misleading use of the term 'cryptic species' when, in most cases the terms 'cryptic variant' or 'cryptic lineage' are more appropriate. We give explanatory examples.
- The prevalence of publications on molecular taxonomy that commence by claiming that their results displace morphological taxonomy. We find that most such claims are premature and not well supported. We give illustrative examples.
- The shuffles, between generic designations, of species where there are incongruent findings between morphological and molecular taxonomies. We illustrate these shuffles and give reasons for not accepting most of them.
- Species-level changes where recent molecular designations fall within the known variability of existing species. Again, we illustrate these findings and give reasons for not accepting them.
- Information processing in taxonomy, describing potential errors from cladistics, Bayesian inference, DNA methodology, morphometrics and microstructure analyses. We give explanatory examples.
- Instances where named species derived from morphological studies are unambiguously used in molecular studies, suggesting that most differences between the two taxonomies are nomenclatural and not about the entities themselves. We list many such species.
- Reasons why conflicts may exist between the two taxonomies. The tendency to draw inferences beyond the scope of individual studies is proving destabilising, creating concern among those working to assess and mitigate the impacts of climate change on coral reefs.

Figure 3. A possible hybrid between *Seriatopora hystrix* and an unknown species, observed by one of us (ET) in the Northern Red Sea, Saudi Arabia. *Seriatopora hystrix*, with much finer branches, occurs at the same locality.

In addition to serving as a review, this article provides context for the Factsheets and linked documentation about each of the species included in CoralsOfTheWorld.org (2026 in prep.).

Concluding Remarks

1. All taxonomy, morphological or molecular, must ultimately be grounded in the reality of the reef, including the complexities arising from the interactions of habitat, geography, oceanography, selection and reticulation.

2. The tools available to investigate the genetic aspects of coral taxonomy, at local, regional and metapopulation levels, continue to develop rapidly and will increasingly support a solid information base.

3. Reefs have by far the greatest biodiversity of all marine ecosystems and, as such, are one of the foundational keystones of the natural world.

4. Taxonomy is the signpost that all other pursuits and endeavours in the natural world, scientific or not, depend on. With the global deterioration of reef corals, it is critical that coral taxonomy is fit for such an essential purpose.

Discussion and Feedback

We welcome feedback on our review of coral taxonomy as published in Diversity and on the views summarised here. We invite readers to respond to our work, either by writing brief items for publication here in the next issue of Reef Encounter, or by submitting to us (at j.veron@coralreefresearch.com) additions, comments or corrections for inclusion in a reiteration of our review to be published on our website (2026). All contributions that make a difference will be acknowledged, subject to correspondents providing permission to cite such personal communications.

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REEF CURRENTS

Coral Reefs at a Global Crossroads: Insights from the GCRMN

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Introduction: The Global Coral Reef Monitoring Network

Coral reefs are recognised for their ecological, social and economic importance, supporting biodiversity, livelihoods and coastal protection across tropical and subtropical regions. Despite this recognition, developing robust assessments on the status, trends, and health at regional and global scales remains challenging. Reefs are monitored through a wide range of methods and indicators, often shaped by local priorities, capacities and available resources. Differences in monitoring protocols, uneven geographic coverage, restrictive data-sharing practices, and variable long-term monitoring capacity have limited the production of comprehensive large-scale syntheses on coral reef status and trends.

In response to these challenges, the Global Coral Reef Monitoring Network (GCRMN) was established in 1995 as an operational network of the International Coral Reef Initiative (ICRI), currently hosted at the Australian Institute of Marine Science (AIMS). The GCRMN was designed to strengthen the link between science and decision-making by ensuring that coral reef monitoring data are not only collected, but synthesised, interpreted and communicated in ways that are meaningful at regional and global scales. The GCRMN was established with three primary goals, with capacity building as a fourth, overarching priority:

1. Improve understanding of coral reef status and trends, globally and regionally.
2. Analyse and communicate biophysical, social and economic trends in coral reefs, providing science-based recommendations in support of raising awareness, management and policy development.
3. Enable and facilitate greater use of coral reef data, including in research.
4. Build human and technical capacity to collect, analyse and report biophysical and socio-economic data on coral reefs.

From its inception, the GCRMN has operated as a network of networks. It does not collect primary data itself, but works through partnerships with scientists, governments, regional organisations and practitioners who monitor reefs locally and nationally. Through publicised standardisation and integration processes (Wicquart et al. 2022) and transparent analytical approaches, the GCRMN transforms thousands of individual surveys into coherent regional and global assessments. This approach allows contributors to retain ownership and control of their data, while enabling collective analysis that is comparable across multiple scales.

The Network's flagship products are the *Status of Coral Reefs of the World* reports, with regional assessments and thematic products also developed. The GCRMN operates through 10 regional nodes, each reflecting distinct ecological, social and governance contexts, and these regional nodes underpin the suite of outputs that include regional status and trend assessments generated by the GCRMN. Together, these products provide a structured, multi-scale picture of coral reef condition, designed to inform local management, national policy, and international processes under biodiversity, climate and ocean governance frameworks.

As climate change accelerates and local pressures persist, the importance of sustained, comparable monitoring has never been greater. Recent regional assessments of the Pacific and the Caribbean, alongside the ongoing development of the Status of Coral Reefs of the World: 2025, illustrate both the scale of change underway and the collective effort required to understand it.

2. Regional Assessments

2.1 Status and Trends of Coral Reefs of the Pacific: 1980–2023

The GCRMN Pacific region contains 26% of the world's coral reefs (65,255 km^2), spanning from Palau in the East to Pitcairn in the West, and encompasses extraordinary ecological, social and cultural diversity. From remote atolls to densely populated islands, Pacific reefs support livelihoods, protect coastlines and underpin cultural identity. This scale and diversity not only present unique challenges for monitoring but also make the Pacific an essential region for understanding how reefs respond to both global climate drivers and local management.

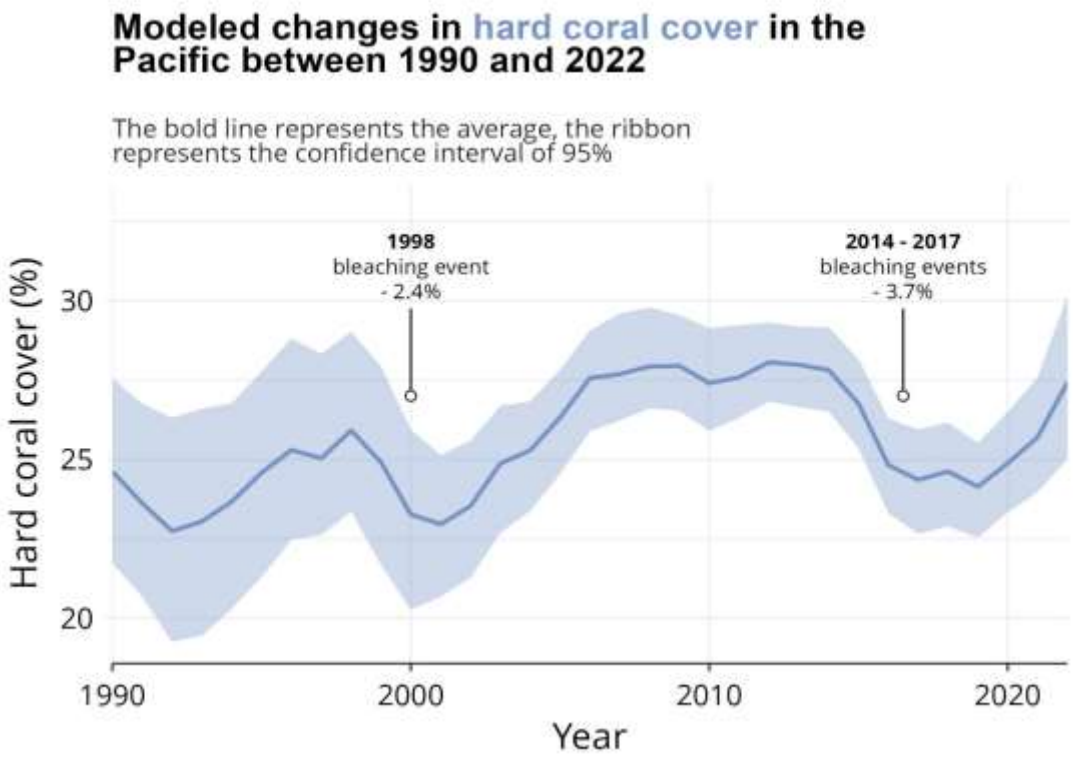

Figure 1. Modelled hard coral cover (%) throughout the GCRMN Pacific region from 1990 – 2022 (Wicquart et al. 2025a).

The *Status and Trends of Coral Reefs in the Pacific: 1980–2023* (Wicquart et al., 2025a) represents the most comprehensive synthesis of coral reef monitoring data for the region to date. The assessment draws on more than 15,000 surveys from over 8,000 sites across 30 countries and territories, compiled through a highly collaborative process involving scientists, regional organisations, national coordinators and local monitoring programs. Considerable effort was invested in standardising and integrating data collected through different methods and at different times, reflecting the realities of long-term monitoring across such a large and diverse region.

At the scale of the Pacific region as a whole, the assessment shows that average hard coral cover remained relatively stable at approximately 25% between 1990 and 2022 (Fig. 1). However, this apparent stability masks important temporal fluctuations and spatial variability.

Coral cover declined during major bleaching events, including an overall reduction of 2.4% during the first Global Coral Bleaching Event (GCBE) in 1998, and a further decline of approximately 3.7% during the prolonged 2014 - 2017 third GCBE. Recovery following these events typically took several years, underscoring both the sensitivity of Pacific reefs to thermal stress and their capacity, under certain conditions, to seemingly recover.

It is important to note, however, that while the results of the GCRMN Pacific report indicate relative stability in hard coral cover, those of the previous global report (Souter et al., 2021) suggest a decline. These discrepancies likely arise from differences in the modelling approaches used to derive trends, as well as in how data limitations are addressed. Indeed, given the vast spatial scale of the Pacific region, the largest within the GCRMN, monitoring sites are unevenly distributed across space and time, and several subregions remain under-monitored. This underscores the critical need to establish more robust, long-term monitoring sites across the region.

Beyond changes in total coral cover, the assessment documents shifts in reef assemblage composition that have important ecological implications. In many parts of the Pacific, coral communities are gradually shifting away from structurally complex branching species towards more massive and stress-tolerant forms. While these taxa may be better able to withstand heat stress, their increasing prevalence reduces three-dimensional habitat complexity, a change that impacts reef-associated biodiversity as well as ecosystem services such as fisheries productivity and coastal protection.

The report also identifies broader environmental trends shaping reef conditions across the Pacific. Satellite data were used to estimate the long-term change in daily sea surface temperatures. Sea surface temperatures over coral reef areas increased by approximately 0.8°C between the mid-1980s and early 2020s, contributing to more frequent and intense marine heatwaves. Macroalgal cover increased modestly at the regional scale, while crustose coralline algae, which are important for coral recruitment, showed limited gains. At the same time, the number of people living close to reefs has increased in many Pacific countries and territories, potentially intensifying local pressures related to pollution, fishing and coastal development, particularly in nearshore areas.

Importantly, much of the dataset underpinning the Pacific assessment predates the peak impacts of the ongoing Fourth Global Coral Bleaching Event - declared in April 2024. As such, the report provides a critical baseline against which future change can be measured. It also reinforces the value of long-term monitoring in detecting not only decline, but recovery dynamics and thresholds beyond which recovery may become less likely.

These findings were launched at the Third United Nations Ocean Conference (UNOC-3) in Nice in June 2025, alongside high-level events that brought together Pacific leaders, scientists and changemakers. These events highlighted both the relative persistence of Pacific reefs to date and the growing risks they face, reinforcing calls for urgent global action on climate change alongside sustained investment in regional monitoring and management capacity.

2.2 Status and Trends of Caribbean Coral Reefs: 1970–2024

The Caribbean is one of the most intensively monitored coral reef regions globally, with data records extending back to the early 1970s. This long history of observation provides a rare opportunity to examine reef change over multiple decades, capturing both abrupt disturbance events and the cumulative effects of chronic pressures. The *Status and Trends of Caribbean Coral Reefs: 1970 - 2024* (Wicquart et al., 2025b) builds on previous historic assessments (i.e., Jackson et al., 2014; Souter et al., 2021) and this exceptional evidence base permits us to deliver the most comprehensive regional assessment to date.

The report was developed over a two-year collaborative period and involved more than 300 contributors across 44 countries and territories. It synthesises over 23,000 surveys from almost 14,000 sites collected between 1973 and 2024. Advanced statistical and machine-learning approaches were applied to address spatial and temporal gaps in the monitoring record, enabling robust estimation of long-term regional trends despite uneven monitoring effort.

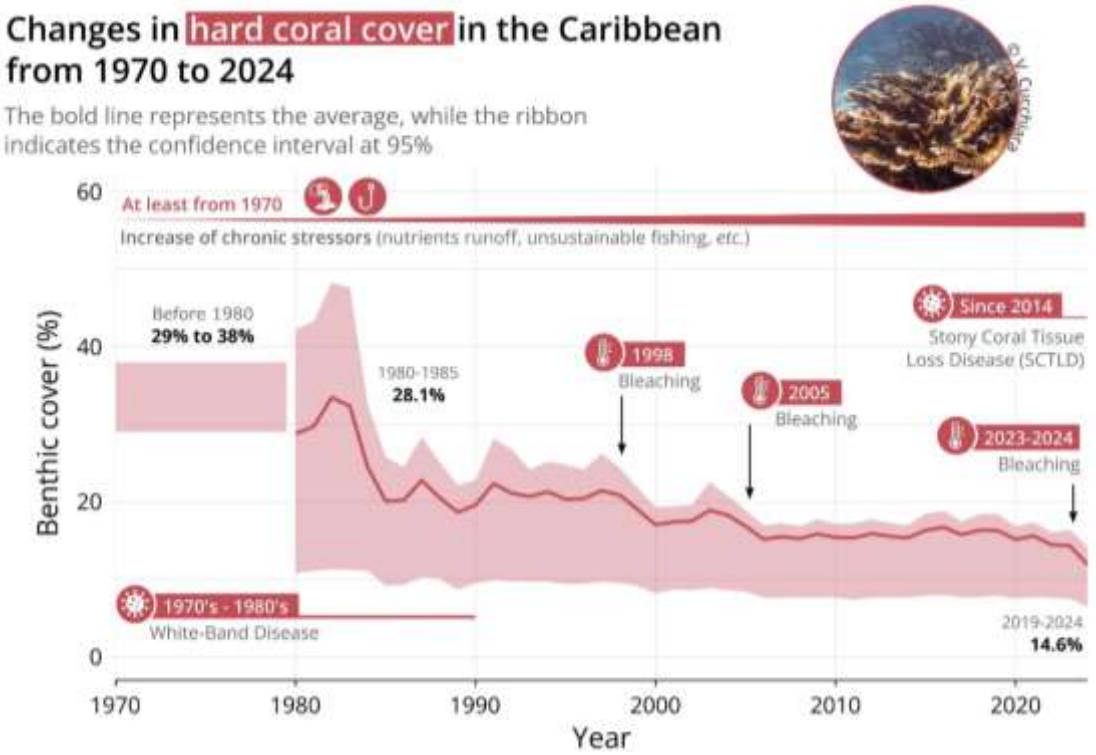

Figure 2. Modelled hard coral cover (%) throughout the GCRMN Caribbean region from 1980 – 2024 (Wicquart et al. 2025b).

At the regional scale, the results reveal a marked and sustained decline in reef condition. Average hard coral cover decreased from approximately 28% in the early 1980s to around 15% by 2019 - 2024, representing a relative decline of 48% (Fig. 2), but with large variations within the region. This decline was not linear,

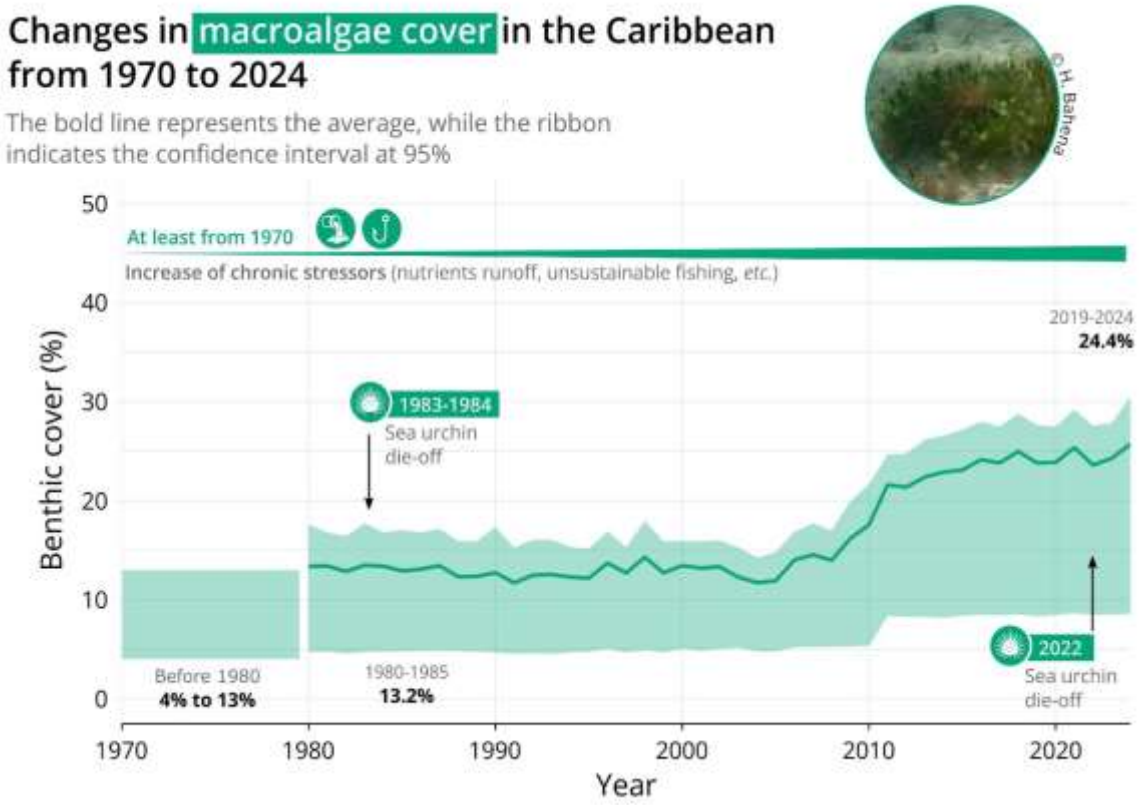

Figure 3. Modelled macroalgae cover benthic composition (%) throughout the GCRMN Caribbean region from 1980 – 2024 (Wicquart et al. 2025b).

however. Major losses coincided with region-wide disturbance events, including sharp declines associated with the 1998, 2005 and 2023 - 2024 bleaching events, as well as with widespread disease outbreaks.

In parallel with the loss of coral cover, the benthic assemblage composition of Caribbean reefs has shifted substantially. Macroalgal cover increased from 13% in the early 1980s to approximately 24% in recent years, an increase of around 85% (Fig. 3). This change is closely linked to declines in herbivory, driven by overfishing of key herbivorous fishes and repeated mass mortality events of the long-spined sea urchin *Diadema antillarum*, as well as by declining water quality associated with coastal development and land-based sources of pollution.

The assessment also documents significant reorganisation within coral assemblages. Branching *Acropora* species, which dominated many Caribbean reefs in the 1970s, have remained at low abundances since the 1980s, averaging less than 2% cover. In contrast, more stress-tolerant massive corals, including *Orbicella spp.* and *Porites spp.*, now make up a greater proportion of remaining coral cover. While these taxa contribute to persistence under stress, the loss of branching corals has greatly reduced structural complexity, with implications for reef-associated biodiversity and fisheries productivity. The introduction of non-indigenous soft coral species has further contributed to the shift in benthic assemblages, as they outcompete native hard coral species in several locations.

Climate-driven pressures intensified over the same period. Mean sea surface temperature over Caribbean reef areas increased by approximately 1.1°C between the mid-1980s and 2024, corresponding to a warming rate of around 0.27°C per decade. Marine heatwaves have become more frequent, intense and prolonged, amplifying bleaching risk and interacting with disease and local stressors to undermine recovery potential.

In parallel, Caribbean coral reefs have also been increasingly exposed to intense tropical storms, with more than 170 hurricanes passing within 100 km of reef systems since 1980, causing episodic structural damage.

Caribbean reefs are also subject to particularly high levels of direct human impacts. Within the region, the number of people living within 20 km of a coral reef increased by nearly 28% between 2000 and 2020, adding an estimated 13 million people. This proximity of greater numbers of people intensifies pressures related to fishing, pollution and coastal development, while simultaneously increasing dependence on reef ecosystem services for food security, livelihoods, tourism and coastal protection.

Despite the severity of these trends, the report highlights important spatial variation and includes evidence that outcomes are not uniform. Reefs located within some marine protected areas that are well-managed, or where herbivores are protected and water quality has improved, tend to exhibit higher coral cover, lower macroalgal dominance and greater resistance to disturbance. These examples demonstrate that while climate change is a dominant driver of regional decline, local and regional management actions have the potential to influence reef health trajectories.

The Caribbean assessment was launched through a public webinar on December 9th, 2025, which attracted over 400 participants from across the region and beyond. The level of engagement reflected both the seriousness of the findings and the demand for regionally led data-driven assessments. The report now provides a critical quantitative foundation to support regional cooperation and the implementation of global commitments, including those under the Kunming–Montreal Global Biodiversity Framework (GBF).

2.3 Collective recommendations

Despite their very different ecological, social and governance contexts, the Caribbean and Pacific assessments converge on a clear set of priorities for sustaining coral reefs. Both reports emphasise that increased global action to address the drivers of climate change is essential. Ocean warming is now the dominant driver of coral loss, and without rapid and sustained reductions in greenhouse gas emissions, local and regional management efforts will increasingly be overwhelmed.

At the same time, both assessments demonstrate that local action still matters. Reducing chronic pressures such as overfishing, declining water quality and poorly managed coastal development can strengthen reef conditions and improve resistance and recovery following disturbance. Protecting key functional groups, particularly herbivores, emerges as a shared priority, as does tackling land-based sources of pollution that would otherwise favour macroalgal dominance and suppress coral recruitment.

Strengthening area-based management is another common recommendation. Well-designed and effectively managed marine protected areas, alongside other area-based conservation measures and customary or locally managed systems, are consistently associated with better ecological outcomes, such as the establishment of the Red Hind Bank Marine Conservation District (MCD), and the protection of Fish Spawning Aggregations for Nassau Grouper recovery in the US Virgin Islands. Both reports highlight the importance of ecological connectivity, enforcement, and equitable governance in determining whether protected areas deliver real benefits.

Sustained investment in long-term monitoring underpins all other actions. Comparable, high-quality data are essential for detecting change, evaluating management effectiveness and informing adaptive responses. Both regions emphasise the need to maintain and expand monitoring capacity, standardise key indicators, and ensure data are used to support decision-making at multiple scales.

Finally, both assessments recognise a growing role for restoration, but stress that it must be embedded within broader management frameworks. Restoration cannot substitute for emissions reductions or environmental stress mitigation, but when strategically applied, as part of a wider conservation and management plan, it has the ability to support recovery, enhance resilience and deliver social and economic benefits.

3. Towards the Status of Coral Reefs of the World: 2025

Building on recent regional assessments, the GCRMN is currently developing the *Status of Coral Reefs of the World: 2025*, its seventh global assessment. This forthcoming report will represent the largest and most comprehensive synthesis of coral reef monitoring data assembled to date by the GCRMN, drawing together evidence from across all 10 regions of the Network.

The global database underpinning the report currently includes data from 39,437 sites and 90,669 surveys, spanning 124 countries, territories and economies (Fig. 4) - a three-fold increase in sites represented compared to GCRMN's sixth global assessment (Souter et al., 2021). More than 600 contributors have been involved in this effort, reflecting an unprecedented level of global collaboration among scientists, institutions and monitoring programmes.

The *Status of Coral Reefs of the World: 2025* is due to be released in late-2026, with significant effort focused on building a robust, policy-relevant evidence base. The assessment aims to provide a coherent and comparable picture of coral reef condition and trajectories at global and regional scales, creating a shared reference point for governments, practitioners and international organisations. To further the report's scientific rigour, the International Coral Reef Society (ICRS) will provide an external peer review of the report, covering both the main text, and the statistical and analytical approaches used to assess the global dataset.

A key objective of the global report is to support policy alignment and implementation. The findings will contribute to reporting against targets under the GBF, the UN's Sustainable Development Goals, and IUCN-Res-037 (Fourth global coral bleaching event: urgent action to reduce the risk of catastrophic loss of the world's coral reefs), as well as UNEP/EA.7/Res.1 (Resolution on accelerating global actions to promote the climate resilience of coral reefs). This includes the need to integrate reefs into national climate and

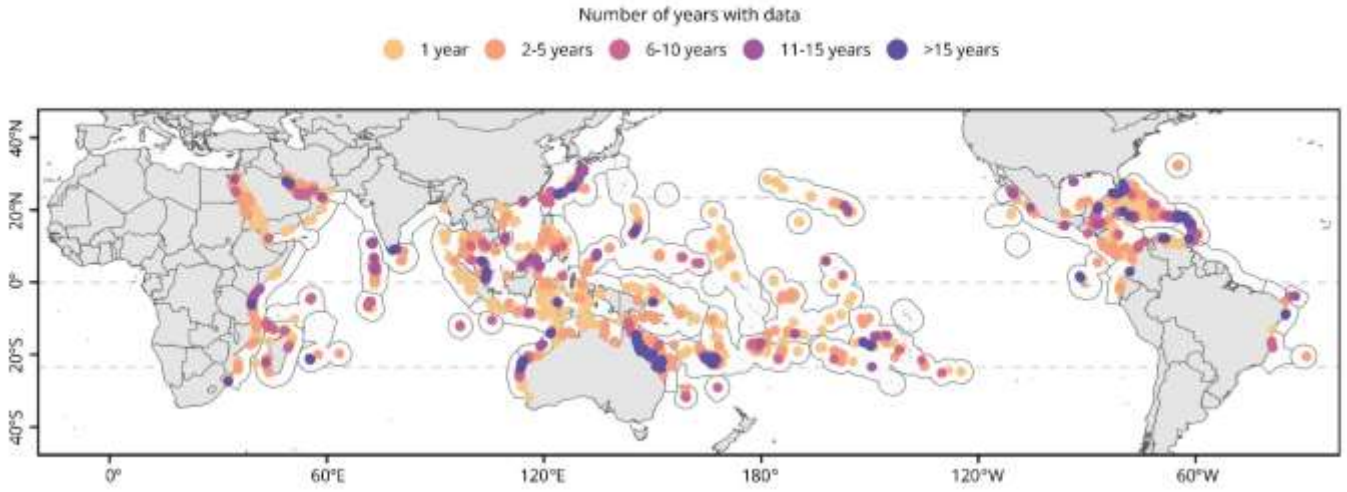

Figure 4. Map of the distribution of benthic cover monitoring sites for which data are included within the gcrmndb_benthos synthetic dataset. Light grey polygons represent economic exclusive zones. Colours correspond to the number of years with monitoring data.

biodiversity strategies, reduce local pressures, strengthen area-based management, scale-up monitoring, and mobilise sustainable finance.

Strong data governance underpins the global assessment process. Contributors retain ownership and control of their data, while transparent analytical workflows and shared code repositories support reproducibility and trust (https://github.com/GCRMN). This approach ensures that the global synthesis is both scientifically robust and socially legitimate, reinforcing long-term participation in the network.

The *Status of Coral Reefs of the World: 2025* will serve as an essential reference point, as the world passes the half-way point (from 2020) of the 2030 agenda, informing international policy dialogues under biodiversity, climate and ocean frameworks, and supporting adaptive management in an era of rapid environmental change.

4. Conclusion: From Data to Action

Recent regional assessments coordinated through the GCRMN provide a clear picture of how coral reefs are changing across very different contexts. In many regions, including the Caribbean, long-term decline has been severe. In others, such as parts of the Pacific, reefs have shown greater persistence, albeit with clear signs of emerging stress and reorganisation. Together, these assessments underscore both the seriousness of the situation and the diversity of reef trajectories worldwide.

Importantly, this is not a story of inevitable collapse. The evidence consistently shows that where local pressures are reduced, where management is effective, and where communities are engaged, reefs are more likely to persist and, in some cases, recover. These examples of resilience and recovery do not negate the overriding threat posed by climate change, but they do demonstrate that action matters and that outcomes are not predetermined.

The purpose of the GCRMN is not simply to document trends, but to provide the evidence needed to inform better decisions. By transforming local monitoring into comparable, policy-relevant knowledge, the network helps identify where interventions are working, where they are not, and where investment and action are most urgently needed.

Coral reefs are in a precarious state globally but abandoning them as lost causes would be both scientifically unjustified and ethically indefensible. Sustained monitoring, informed management, and decisive policy action can still shape future trajectories. The challenge now is to act on the evidence, at the pace and scale that the situation demands.

The GCRMN expresses its deep gratitude to its financial supporters, partners and the dedicated members of the network to whom the work undertaken at global, regional and national scales would not be possible.
www.gcrmn.net

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REEF LIVES

An Interview with Michel Pichon

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The following are excerpts from an interview I was privileged to have with Michel Pichon, about his long career and experiences in coral reef science, in the run up to the upcoming ICRS conference in Auckland, New Zealand. Michel expects to be there and is believed to be the only person who will have attended all sixteen International Coral Reef Symposia, from the very first held at Mandapan Camp, in southern India, in January 1969, to the most recent held in Bremen, Germany.

As background, while Michel was raised and educated in France, from where he undertook pioneering work on coral communities in Madagascar and other parts of the Indian Ocean, subsequently he worked for more than 25 years in Australia, first as a professor at James Cook University, and then as deputy director of the Australian Institute of Marine Sciences, both in Townsville, Queensland. He has served as a council member of ICRS, of which he was an early member, and as President of the French Coral Reef Association. He has published more than 180 scientific papers and seven volumes on the corals of different reef regions, including the Great Barrier Reef, the Gulf of Aden and French Polynesia, and been awarded many honours.

Elis: So what got you into coral reef science?

Michel: It started from a series of lectures by Professor Jean-Marie Peres, the director of the Station Marine d'Endoume in Marseilles. He was telling us: "we know next to nothing in terms of modern ecology, as far as coral reefs are concerned, particularly in terms of synecology… not only how the individual organisms live, but why do they live together in that particular type of environment?"

Some other students and I went to see him and said "well, we got your message, would there be a space for us [to work on coral reef ecology]?" Eventually, he called us to his office with some suggestions. One was in Madagascar. There were some very interesting reefs in Tulear, in the southwest, which I think were very briefly referred to by some of the early naturalists. Prof. Peres was setting up a lab there, and said it could be a place for me to do research for a thesis.

Michel working off Tulear, Madagascar in

In high school, I had been awarded a book on the beauty of the sea as a prize. And there were lots of very nice pictures of corals. So my motivation was probably also an aesthetic attraction to the corals themselves. When Prof. Peres proposed that I go that route, I said yes, quite enthusiastically. I'm still interested in the science and aesthetics, or artistic aspects, of the corals themselves.

A colleague and I left Marseille for the newly founded research station in Madagascar in August 1961

Michel with Jacques Cousteau on the Great Barrier Reef (1987)

and spent 6-7 months there. Other scientists there were working on topics like sponges and lagoon seawater chemistry, and we all got along together in a very nice way. So credit should be given to Prof. Peres, for founding the station, and being so strongly supportive and highly competent.

Around that time, I also worked in Sri Lanka, after the International Coral Reef Symposium (in India), and I got to study some corals which were collected by Jacques Cousteau's Calypso expedition from Nicobar Island in the Eastern Indian Ocean.

Elis: And was that the first International Coral Reef Society meeting?

Michel: That was actually before the International Coral Reef Society was formed. It was just a decision to have an international coral reef symposium. That was way back in 1969. It was in a station of the Indian Fisheries Office, in the southern tip of India. There were about 50 scientists, and half of them were Indians. It was a good selection of people who really were interested in coral reefs, from all over the world.

The conference went so well, that it was decided it should become an ongoing event. The second one took place in Australia. Actually, it was a ship-borne conference, taking us from almost the north of the Great Barrier Reef to the south. There were only about 200-250 delegates, so we could charter a ship. And since then we had conferences just about every 4 years in various places. Traditionally the conferences were in places where we could also do field trips.

Elis: What was the first conference like?

Michel: Compared to today, the set-up was very primitive. We had a building used for both accommodation and meetings and in front was a big sand terrace. I remember one evening, Georg Scheer and his wife, Annelise, started dancing the traditional Vienna Waltz, and most of us tried to follow! That was fantastic to see. We spent a lot of time together, which created some really strong links between people. We became really good friends. There was no competition that I could feel, which is quite different from now, where there is a huge amount of competition in coral reef science.

But that's probably unavoidable. Because we are no longer 50, but maybe 2500. That also creates technical and logistical problems: how to hold such large meetings? Very few places are in a position to organize such large symposia. So, I'm a bit anxious about what might happen next. A similar thing happened with the Congress of Zoology after World War II. It finally disappeared because it grew too big. I am concerned we might have to split into more specialized conferences. And this has already started in some ways. The first four or five symposia were 50/50 biology and geology. Now the geology has almost disappeared. So, we might have to think seriously how best we can split these congresses, which are still very useful. There is lots of excellent research, I am not denying that. But we have to make sure we don't lose the whole picture of the coral reef ecosystem: what is the future of coral reefs?

Elis: And was it otherwise similar? People giving presentations and things like that?

Michel: Absolutely. The format was pretty much the same. At the beginning, posters were not really popular, but over time posters have been recognized as quite an effective way to communicate with fellow scientists. They are there for the week. You can go and see them whenever you want. You can talk to the author because they are in your mind. So I think it's a good addition. Increasing the poster numbers is generally no problem.

Elis: Was there a keynote speaker at the first one?

Michel: No. It was, I would say, a group of friends. We knew what we had published before. So it was really "let's see what we can do, let's get something started." So we all had some interesting communication and presentations. But nobody was given preference. I'm not in favour of having a keynote speaker.

Elis: It must have been amazing to see this huge community develop from such a small number

Michel: Yes, and also to see the science being discussed changing over time. As I said, in the beginning there was biology and geology. The first few symposia, there was quite a bit on the crown-of-thorns starfish, including special sessions. That more or less disappeared after the Manila symposium (the 4th) in 1981. Then there was more focus on trying to find out how a reef works in terms of organic carbon, so reef metabolism became fashionable. And I think it should have been more than a fashion, because it's very important for their future. We haven't talked about that aspect as much since around the time of the Panama symposium (the 8th) in 1996. Since then, we have talked more about genetics and the micro-environment. It's part of the way science evolves, I guess.

Elis: Has coral science itself changed much over your career?

Michel: Yes, enormously. Identifying the species on the reef became a taxonomic specialty for a number of us. Unfortunately, we (taxonomists) are getting old, and we are not being replaced as much as we would have hoped. In many museums now, there are lots of taxa for which there are no more taxonomic specialists, including corals.

For me, after understanding reef composition, the second development was to ask how these organisms live together. And why are the organisms in this reef zone different from those on other parts of the reef? Environmental factors do play a constant role in what we do. This eventually led me to study what I call a unifying factor, which is carbon flow in the reef environment. It's quite a complex chemical problem. We wanted to see how CO_2 is channelled through trophic levels and organisms. Some reefs are net producers of oxygen, some reefs are net consumers; they don't all have the same balance. Reef metabolism is no longer as well studied, yet it is important because it can help with understanding how reefs need to be protected.

Also, quite often now, funding calls ask for an educational aspect, how we will transfer knowledge to the younger generation. And now, at sea, we often have with us a high school teacher or a reporter from the local newspaper. And that's where the Citizen Science Association I have been working with works remarkably well. The earlier that kids are brought into the picture, the more they will be effective and efficient guardians of the reef. I think that's important, and more accepted now. In the old days, we didn't even think of that.

Elis: And have the reefs themselves changed much?

Michel: When I was working in the Indian Ocean in the 1960s, and Jacques Cousteau was there, I was asking him about the reefs, because he had been to the Indian Ocean in the 1950s. And he said "the reefs I have seen in the fifties and the reefs I see now in the late sixties, they are quite different; we are going the wrong way." So even in that time span, he could see they were different.

My first trip there was from August 1961 to February 1962, but I went back in 2009. And I could have cried. I couldn't recognise it. It was distressing, but at the same time, no matter how bad the reefs, I think there is still some hope. We probably have the means and the will to go back to the situation of, let's say, maybe a century ago. If we play our cards rights, they can be saved. But the margin for error is quite limited. We don't have time to waste, and I wouldn't be surprised if the reefs, in a hundred years' time, are quite different from what they are today or were 50 years ago.

Michel at Osprey Reef, on the GBR in 1987 getting ready for a submersible survey

Elis: What other questions in coral science do you like to think about?

Michel: My major concerns, interests, and enthusiasm for reefs, have changed over the years, which I think is good. More recently, I have been working on mesophotic reefs in French Polynesia, and also with the Citizen Science Association in Mayotte in the Western Indian Ocean. Very little is known about the mesophotic environment. There are a lot of calcifying algae, gorgonians, soft corals, sponges. But there are few taxonomists, few people looking at how they form communities. So there are plenty of unknowns, beyond just the corals. Back in 1960, Prof. Peres told us we know nothing about the reefs. We could say the same thing in 2026 about the mesophotic reefs. There are a huge number of interesting problems to solve for whoever is interested. At the next ICRS, I hope to see young scientists getting a bit away from DNA – I am not against genetics, it's essential and we need to use it – but to go back to the basics, who is there, who lives with whom, how do they make assemblages, in mesophotic reef communities? That I find exciting for the younger generation. And we still don't know whether corals that we find in the mesophotic can reproduce enough to re-seed shallow water reefs, whether the larvae can be transported at the right place and time.

I would like also to look a bit more at the microbiome. Not only the zooxanthellae, but lots of other primitive organisms like archaea that live in coral, and I am pretty sure they play an important role, for instance in corals using dissolved organic carbon. With lack of light, zooxanthellae don't produce much. So what replaces them? I would also like to look more closely at the role of intra-reef zooplankton and phytoplankton, how these two groups, which are poorly known, affect the reef functioning. So there are plenty of new avenues to be explored.

Elis: And what does a healthy reef look like to you?

Michel: Uh [laughs] … high diversity, high abundance of everything, including fish. But corals and fish would be the two markers.

But what happens when the reef degrades: decrease in diversity, decrease in abundance, and then the physiological aspects, which are essentially growth and reproduction, go down. And you can measure that, it's quite visible.

But one problem is that degraded reefs can still be beautiful, which can make degradation harder to notice. Not everywhere or not necessarily where they were before. But if you just look at the Great

Barrier Reef. It is not uniform north to south. If you look at these parameters - coral diversity, abundance, capacity to reproduce, and also things like bleaching effects, and abundance of crown-of-thorns starfish, you find that there is no synchrony at all. Some parts of the reef will be in good shape, and the next 300 kilometres will be in bad shape. In some sections you might have the most magnificent reef with plenty of color, plenty of corals, high diversity, plenty of fish, big fish, small fish, sharks……elsewhere it is quite different. The point is, in some instances, you cannot generalize on a large scale. Admittedly, I mean, things like global change, by definition are global, we cannot escape it. But the effects of global change might not be the same everywhere. For instance, heat waves, these may vary with space, time and ocean circulation. So, we cannot be complacent. But we also cannot put one label on everything, saying it's done, it's dead.

Elis: And are you in the water often still?

Michel: I am no longer allowed to dive professionally - I had the regular diving medical test only a few years ago, and passed with flying colors. But when I was getting close to 80, the hyperbaric medic said, "okay, but from a professional standpoint, we cannot give you the green light because we have no idea what are the effects of hyperbaric pressure on people your age." I was not happy with that, but okay, I've done my bit, quite a bit, of very nice diving.

Elis: So you have always enjoyed diving?

Michel: I did, yeah. Diving in the reef environment is always something special because, it's my area of expertise, and you always think about it, and ask yourself questions. It can be a bit boring diving elsewhere. I like the aesthetics and complexity of the reef system. There's nothing like it in the ocean. I am sure that a specialist of another environment might disagree. But I've never felt like I'd like to do something else. The flame is still there.

Diving in New Caledonia (2006)

Elis: Can you remember your first dive?

Michel: Well, my very first dive was in Marseille, just below the institute, but that was when I was learning. I was taught to dive by Albert Falco, who was Cousteau's chief diver on the Calypso in the early 1960s. It was interesting, it was with the old gear, which has disappeared over the past 50 years: the twin flexible hose, one stage regulator. You would breathe as much water as you would breathe air. You could turn on your side in order to blow out the water which had managed to enter into those big air hoses. There were some interesting memories of that. And then when I went to Tulear, we were pretty much on our own, so we had to learn about how to maintain our regulators, and the air compressor, which was a very simple one.

Elis: I'd like to finish by returning to aesthetics, which you mentioned a few times. How strongly

do you think reef aesthetics is connected to coral reef science?

Processing fresh coral samples, Polynesia (2018)

Michel: I think the artistic aspect of the reef is becoming more important. I believe that for the first time, at ICRS in Auckland, there will be a session on coral reefs and the arts – something I like to see. Because, as I said, I have always been interested in that. And the progress of technology, such as microphotography, and scanning electron microscopy, allows us to look in more detail at the components, and this also has an appeal from an aesthetic and artistic standpoint. It's challenging to realize that a living being can do such beautiful things which may remain invisible to humans. But now we can uncover them; and help people appreciate the uniqueness of coral reefs better. I think we should play that card. Because lots of people are interested.

We also now have more and more artists in residence joining research vessels and research programmes. We currently have an artist who is using glass, metal, drawings and watercolor - I mean why not? I am really keen to see what will happen in Auckland. It should be encouraged. It has a place in trying to gain better knowledge and conscience of what coral reefs are.

The future of coral reefs is in the hands of younger generations. That's why I think it's important to have these meetings. To remind them that the overall picture is also important. I support the science wholeheartedly. But the general, more humanist - if you like - approach to science, is important too.

Elis: Is there anything else you'd like to add?

Michel: Just that, I would say on the whole, the coral reef scientific community is doing a good job.

Elis: Well, thank you for your time.

Michel: My pleasure.

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UNFCCC CONFERENCE of the PARTIES 30

Back from COP30 in Belém, Brazil: Heart of the Amazon

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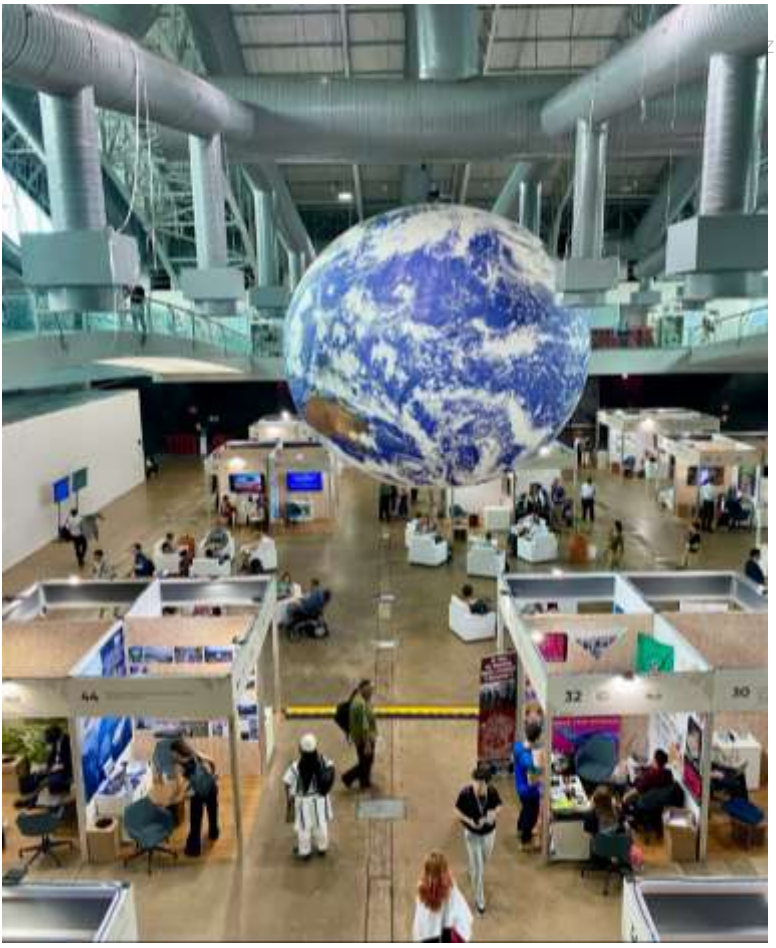
The 30th Conference of the Parties (COP30) to the United Nations Framework Convention on Climate Change (UNFCCC) convened this past November in Belém, Brazil, drawing global attention to one of the world's most critical and climate-vulnerable regions. Scientists, policymakers, Indigenous leaders, civil society organizations and youth, all gathered to confront accelerating climate risks and advance solutions rooted in science, equity, and local knowledge.

The ICRS delegation this year was composed of myself (Dr. Mariana Rocha de Souza), an ICRS officer and researcher at the University of Hawaii, and Dr. Barbara Pinheiro, a researcher from the University Federal de Sâo Paulo. This marked ICRS's fifth COP, at which the Society continued its efforts to elevate the ocean–climate agenda, emphasizing the urgent need to protect coral reefs as global temperatures rise.

COP (the Conference of the Parties) is the annual UN climate summit where nearly every nation negotiates climate commitments, assesses progress, and advances global climate action. This year's gathering brought together representatives from more than 190 countries - though the United States did not participate - in order to advance implementation of the Paris Agreement. The urgency of the moment was unmistakable in Belém. Delegates navigated extreme heat, intense Amazonian rains, and even a dramatic fire at the venue - experiences that symbolically underscored the escalating impacts of climate change. While COP discussions have historically focused on land-based mitigation and adaptation, the presence of researchers advocating for ocean issues has become increasingly important. Coral reefs are among the world's most climate-vulnerable ecosystems, and decisions made at COP directly shape their future.

Representing ICRS on the Global Stage

Both Barbara Pinheiro and I spoke on behalf of ICRS and of coral reefs at a series of meetings and workshops during COP30. On 12 November, Barbara spoke at the UN Brazil Pavilion in an event marking the opening of COP30 Justice and Human Rights Days. The session highlighted warnings from the 2025 Global Tipping Points Report, which concluded that warm-water coral reefs are nearing their thermal limits and facing unprecedented die-off. Other looming tipping points include potential Amazon rainforest collapse and polar ice destabilization. These changes threaten not only ecosystems, but also fundamental human rights, including the rights to life, health, food, water, culture, and a healthy environment. Dr. Pinheiro joined scientists, Indigenous leaders, youth representatives, legal experts, and human rights defenders to discuss how international law and global governance must evolve - especially in light of recent climate-related advisory opinions from the International Court of Justice (ICJ) and the International Tribunal for the Law of the Sea (ITTLOS) - to prevent irreversible harm and better protect communities already experiencing slow-onset impacts.



ICRS representatives at events advocating for coral reefs and microbial ecosystems. Others shown include Thelma Krug, coordinator of the COP30 scientific council (in centre top right image) and UN Special Envoy for the Ocean, Peter Thompson (at left of bottom right image).

On 17 November, Barbara attended the launch of the Brazilian Coral Coalition. Aligned with the "Coral Breakthrough" initiative from COP28 and the UN Climate Change agenda, the coalition will focus on conserving, restoring, and enhancing Brazil's coral reefs. It aims to mitigate threats, such as pollution, coastal development, and overfishing; expand protected areas; support innovative restoration efforts targeting 30% of degraded reefs by 2030; and mobilize public and private resources for coral conservation.

I was able to speak at five events during COP30—four within the UN-accredited Blue Zone and one open to the public - sharing insights on coral reef science, resilience, and the integration of traditional and local knowledge into global climate policy. On 17 November, I participated in an event at the newly established Planetary Science Pavilion, a science-policy platform mandated by the COP30 Presidency and led by Johan Rockström and Carlos Nobre. Alongside speakers such as Katja Matthes (GEOMAR), Margaret Leinen (Scripps Institution of Oceanography), and David Obura (IPBES), I highlighted the vulnerability of tropical coral reefs and the importance of embedding ocean science in climate decision-making.

On the evening of 18 November, I joined a public film screening, organized by Projeto Conservaçåo Recifal and ReefBank at the Araya Climate Hub, a museum in Belém, featuring a documentary on a recent mass bleaching event in northern Brazil. The event drew a diverse audience of students and community members, sparking an engaged discussion about climate impacts and the future of coral reefs.

On 19 November, I spoke at a high-level event hosted by Brazil's Ministry of Environment and Climate Change and WWF-Brazil. The session underscored that coral reefs are vital to biodiversity, food security, coastal protection, and cultural identity, and are at the frontlines of the climate crisis. Speakers outlined pathways to accelerate commitments from COP30 to COP31, emphasizing reef-positive finance, inclusive governance, scientific innovation, and Indigenous and local knowledge. Representatives from Brazil, Palau, Indonesia, and Fiji shared approaches to strengthening reef resilience through innovative financing, restoration science, and community-led action. The session closed with remarks from Peter Thomson, UN Special Envoy for the Ocean, reaffirming that safeguarding coral reefs is essential for a just and sustainable future.

Later that day, I also spoke at an event titled *Advocating for the Invisible Microbial Majority That Underpins a Healthy Planet*. The session highlighted the essential role of microbes as the unseen biological foundation of ecosystems on land and in the ocean. These microorganisms recycle nutrients, fuel roughly half of global carbon fixation, and sustain the ecosystem services that support forests, fisheries, and coral reefs. The discussion centred on how to better advocate for this invisible yet indispensable planetary network. Speakers included Elizabeth Kujawinski (Woods Hole Oceanographic Institution) and Sonya Dyhrman (Columbia University), who underscored the need to integrate microbial science into sustainability and climate decision-making.

Later that same day, I participated in an official COP30 side event examining how ocean sectors are adapting to rapid environmental and geopolitical change. The session explored how sustainable ocean planning, emerging marine technologies, and evolving ocean finance can be designed to avoid unintended consequences and ensure equitable benefits for the Global South, small island developing states (SIDS), and least developed countries (LDCs). The event, hosted by Plymouth Marine Laboratory, the Delta Electronics Foundation, ICRS, and Partnership for

Observation of the Global Ocean (POGO), brought together scientists, policymakers, and practitioners working to strengthen ocean resilience in our rapidly changing world.

Outcomes from COP30

With global emissions still rising and climate-related disasters intensifying, COP30 aimed to chart clear pathways to deliver on past pledges and set the world on a safer trajectory. A major question lingered: how would countries address short-comings in achievement in their next round of nationally determined contributions (NDCs)? While many hoped for a decisive commitment to phase out fossil fuels and halt deforestation, late negotiations - blocked by a handful of petrostates - prevented consensus. The final text was only able to include voluntary initiatives, although the Brazilian Presidency nevertheless signalled its intention to advance fossil fuel and deforestation roadmaps outside the formal negotiation process.

There were, however, meaningful advances:

- **Adaptation finance tripled**, marking a significant win for climate-vulnerable nations.
- **New mechanisms for financing the low-carbon transition** were outlined.
- For the first time, **trade policies** were formally acknowledged as tools for climate action.
- A new **tropical forest conservation fund** was launched.
- Indigenous Peoples and local communities received unprecedented recognition. This COP saw the largest Indigenous participation to date.

Notably, actions focusing on the ocean saw major progress:

- The **Ocean Breakthrough Dashboard -** the first global tool to track ocean-climate progress - was launched.
- **The Blue NDC Challenge**, led by Brazil and France, encouraged countries to integrate the ocean into their NDCs and 17 nations immediately committed.
- A new **One Ocean Partnership** aims to mobilize **$20 billion**, restore **20 million hectares** of marine and coastal ecosystems, and generate **20 million blue jobs**.

Despite these steps forward, in her closing speech, Brazilian Environment Minister Marina Silva expressed deep disappointment that the final document did not mention fossil fuels - the primary drivers of climate change. Her remarks echoed widespread frustration that the negotiations fell short of addressing the root causes of the crisis. Yet amid these challenges, progress was driven by those who refused to give up: Indigenous communities, youth, environmental defenders, scientists, and civil society organizations, who collectively pushed the process forward. COP is never an endpoint - it is part of a continuous effort to drive global climate action. COP30 made clear that while formal negotiations may falter, transformative change is increasingly led from the ground up.

ICRS at the UN Ocean Conference 2025

Elevating Coral Reef Science on the Global Stage

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The United Nations Ocean Conference (UNOC) is the UN's flagship global gathering dedicated to advancing ocean action under Sustainable Development Goal 14: Life Below Water. Held every three years, it brings together heads of state, ministers, scientists, NGOs, civil society, and international organizations to accelerate commitments, forge partnerships, and scale solutions for ocean health.

UNOC was established following the Rio+20 Conference and the adoption of the 2030 Agenda, which recognized that achieving SDG 14 would require unprecedented political momentum and international cooperation. The first conference took place in New York in 2017, followed by Lisbon in 2022, each growing in importance as threats to marine ecosystems intensify—from warming seas and ocean acidification to biodiversity loss, plastic pollution, and the increasing vulnerability of coastal communities.

In June 2025, thousands of participants gathered in Nice, France, for the third United Nations Ocean Conference (UNOC 3), co-hosted by France and Costa Rica. This year's conference placed particular emphasis on scaling science-based action and strengthening the links between ocean governance, climate policy, and sustainable development.

UNOC 3 featured a two-part structure. The scientific segment, the One Ocean Science Congress (OOSC, 4–6 June), convened the global research community to share the latest advances in ocean science. Christian Voolstra, President of the International Coral Reef Society (ICRS), presented "Rebuilding Reefs: Adapting Restoration Approaches to Meet Global Challenges," highlighting how standardized, evidence-based frameworks can enhance coral-reef restoration and guide conservation decisions under accelerating climate change.

This was followed by the high-level UN Ocean Conference (9–13 June), where heads of state, policymakers, NGOs, and financial actors translated scientific insights into

Nice (France) harbour, with worried Polar Bear

international commitments. Discussions centered on advancing SDG 14, strengthening marine biodiversity protection, regulating high-risk activities such as deep-sea mining, and mobilizing sustainable financing for ocean action. By directly linking a global science congress with a major diplomatic forum, UNOC 3 underscored a core message: credible ocean policy must be grounded in robust scientific evidence - "without science, there is no future." Protecting the world's marine ecosystems will require coordinated action across research, governance, and society.

Left, the author and colleagues routing for corals. Right, David Obura addresses the ICRS led event.

The 2025 conference focused on the theme *"Accelerating action and mobilizing all actors to conserve and sustainably use the ocean."* Both meeting weeks convened heads of state, ministers, scientists, Indigenous leaders, NGOs, private sector actors, and civil society to assess global progress, share knowledge, and forge commitments for ocean action. The conference also featured ten Ocean Action Panels that addressed key targets under SDG 14, from reducing marine pollution and restoring coastal ecosystems to increasing scientific cooperation and leveraging climate-biodiversity-ocean interlinkages.

The outcomes of this process culminated in the **Nice Ocean Action Plan**, a political declaration aimed at driving coordinated global action. For the International Coral Reef Society (ICRS), UNOC represents a critical opportunity to ensure that coral reefs, and the science that supports them, are visible within one of the most influential policy arenas for the global ocean

A major success for ICRS was the acquisition of official Blue Zone accreditation, granting the Society access to UNOC's central negotiations and high-level spaces. This accreditation ensured that coral reef science was represented where global policies, partnerships, and commitments are shaped—an essential step given the accelerating threats facing reefs. ICRS had 5 members attending with the ICRS accreditation: Mariana Rocha de Souza (University of Hawaii, ICRS Recording Secretary), Tali Verdi (Coral Reef Consortium), Luiz Rocha (California Academy of

Science), Keisha Bahr (Texas A&M University-Corpus Christi, ICRS council member) and Simon Harding (ICRS Conservation Committee Co-chair and council member).

Under UNOC guidelines, each accredited organization could lead one event and partner in others. ICRS used this structure to maximize its visibility and influence, leading one official event and partnering in three additional sessions. ICRS was involved in events in both the Blue Zone and Green Zone of the conference, with the latter having the ICRI-led #ForCoral Pavilion where multiple coral reef-related events took place over the two weeks.

Partnership Event with CORDAP and ICRI (9 June)

As a partner, ICRS joined a collaborative session with CORDAP and ICRI "Paving the way to solve the global coral crisis" focused on aligning global coral protection initiatives. I spoke in a high-level panel on strengthening collaboration across the coral reef community. Other panelists included Tom Dallison (International Coral Reef Initiative), Just Cebrian (G20 Coral Research & Development Platform - CORDAP), Angelique Brathwaite (Global Fund for Coral Reefs), Siam Chair (WAVE- a collective action platform), and Felipe Cousteau. We discussed how global partnerships and networks can scale up reef resilience efforts.

Keisha Bahr talks about ocean acidification and ICRS

Ocean Acidification Session (10 June)

ICRS was invited as a partner in a high-profile UN Ocean Conference session on ocean acidification (OA), at which Dr. Keisha Bahr represented the society and highlighted the foundational work that ICRS scientists are leading in order to enable us to understand and address the impacts of ocean acidification on coral reefs and reef-dependent communities. The session convened an impressive range of contributors—including representatives from global OA observing networks, intergovernmental agencies, philanthropy, finance, media, and major scientific initiatives—underscoring that meaningful progress on OA requires broad, cross-sector collaboration. Discussions emphasized both the urgent need for sustained funding and the importance of inclusive, equitable partnerships that elevate diverse expertise from local communities to international institutions. As Keisha shared during the event *"Protecting our ocean requires every sector at the table—sharing knowledge, aligning resources, and working together toward solutions none of us can achieve alone".* She left the conference encouraged by the strong collective commitment to action and the growing urgency to collaborate and communicate across sectors to advance science, support communities, and safeguard the future of our ocean.

ICRS led event: Bridging Science and Policy for Coral Reef Conservation (10 June)

On June 10th ICRS hosted a high-profile panel entitled *"Bridging Science and Policy for Coral Reef*

Conservation: Strengthening Resilience and Action." The session featured speakers including David Obura (CORDIO East Africa), Ana Giró Petersen (Healthy Reefs for Healthy People), Manuel Mejia (Coral Reef Alliance), Paubert Tsimanaoraty Mahatante (Minister of Blue Economy, Madagascar), Khadija Stewart (Peace Boat), and Susana Cardenas Dias (University of Quito). The discussion highlighted the importance of science-based decision-making, equitable governance, and sustained investment in reef resilience.

Coral Restoration Solutions Session with Coral Restoration Consortium (11 June)

In partnership with the Coral Restoration Consortium (CRC), the International Coral Reef Society (ICRS) contributed to a high-energy session showcasing science-based coral restoration solutions. The event drew strong engagement from practitioners, researchers, policymakers, and youth leaders, underscoring the growing global momentum behind coral reef recovery efforts.

Other Coral Reef Events

From June 2nd to 13th The #ForCoral Pavilion in the Green Zone of the conference (La Baleine) held a wide range of coral reef-related events. One notable instance was a WCS-led session on wastewater pollution management to increase coral reef resilience (June 12). The event provided examples of both local and regional approaches to pollution management. It highlighted the use of coastal pollution toolkits as well as the need for standardised monitoring. It also considered implementation challenges such as treatment costs and the level of coordination required for effective action.

Looking Ahead

All in all, the ICRS delegates to UNOC 3 believe they did as much as was possible to highlight the cause of coral reefs in the face of climate change, and to promote the aims of the Society. As we look ahead to the next cycle of ocean and climate negotiations, ICRS remains committed to ensuring that coral reefs—and the people who depend on them - are fully represented. We intend to pursue these aims with scientific rigor, in high ambition, and in effective collaboration[5].

[5] Useful summaries of the achievements of UNOC 3 can be found on the following website pages: UN ocean summit in Nice closes with wave of commitments https://news.un.org/en/story/2025/06/1164381; Nice Ocean Action Plan signals political will for global action to protect the ocean https://www.un.org/sustainabledevelopment/blog/2025/06/closing-press-release-2025-unoc/

CONFERENCE REPORTS

Shifting Trends in the Mexican Coral Reef Conferences (2000–2024) in the Context of a Global Coral Reef Crisis

Research results on Mexican coral reefs were previously presented at various conferences, including those focused on zoology, ichthyology, and oceanography. This changed in the year 2000, when the First National Coral Reef Conference was held in the port city of Veracruz, in Veracruz state. At the following conference—held in Puerto Ángel, Oaxaca, in 2003—the event was renamed to its current title, the *Congreso Mexicano de Arrecifes Coralinos* (CMAC, Mexican Coral Reef Conference), and the formation of the *Sociedad Mexicana de Arrecifes Coralinos* (SOMAC, Mexican Coral Reef Society) was proposed. SOMAC was officially established on 28th January, 2005. The third congress (held in Cancún, Quintana Roo, in 2006) was jointly organized by the host institutions and SOMAC, a model that has continued ever since.

	City	State	Year	Oral	Poster	Total	% Poster	O:P	Days	Rooms	P per day	P per room
1	Veracruz	Veracruz	2000	71	20	**91**	22	3.6	4	2	17.8	8.9
2	Puerto Ángel	Oaxaca	2003	58	13	**71**	18	4.5	3	2	19.3	9.7
3	Cancún	QR	2006	51	111	**162**	69	0.5	3	1	17.0	17.0
4	La Paz	BCS	2007	46	49	**95**	52	0.9	3	1	15.3	15.3
5	Tuxpan	Veracruz	2009	78	53	**131**	40	1.5	3	1	26.0	26.0
6	Ensenada	BC	2011	36	90	**126**	71	0.4	3	1	12.0	12.0
7	Mérida	Yucatán	2013*	149	106	**255**	42	1.4	4	3	37.3	12.4
8	PV	Jalisco	2015	60	51	**111**	46	1.2	4	1	15.0	15.0
9	Chetumal	QR	2017	59	110	**169**	65	0.5	3	1	19.7	19.7
10	Manzanillo	Colima	2019	82	99	**181**	55	0.8	4	1	20.5	20.5
11	Veracruz	Veracruz	2022*	125	80	**205**	39	1.6	4	2	31.3	15.6
12	Ensenada	Baja California	2024*	82	217	**299**	73	0.4	4	1	20.5	20.5
			TOTAL	**897**	**999**	**1896**	53					
			mean	75	83	158	49	1	4	1	21	16
			MIN	36	13	71	18	0	3	1	12	9
			MAX	149	217	299	73	4	4	3	37	26

Table 1. Data from the Mexican Coral Reef Conferences (CMAC) held from 2000 to 2024. The columns labeled "Oral" (Oral presentation) and "Poster" indicate the number of presentations delivered in each format during each conference, along with the total number of scientific contributions. The "% Poster" column represents the percentage of presentations delivered as posters relative to the total. The "O:P" ratio shows the proportion between oral and poster presentations, allowing for the analysis of trends in presentation formats over time. The last four columns provide logistical details for each congress: the duration of the event (in days), the number of rooms used for oral presentations, and the average number of presentations per day and per room. These data help contextualize the structure of the conferences, the intensity of academic activities, and the evolution in the organization of these key scientific meetings for the Mexican coral reef research community. Abbreviations: BC: Baja California, BCS: Baja California Sur, PV: Puerto Vallarta, QR: Quintana Roo. Note: The bottom row includes total values where applicable, as well as the average, minimum, and maximum for each column. MIN: minimum value; MAX: maximum value. * indicates was also the Pan-American Congress (CPAC).

After 25 years and twelve conferences, CMAC has become the main meeting point for researchers, decision-makers, and students interested in coral reefs in Mexico. These gatherings have witnessed significant changes in terms of attendees, participating institutions, and especially the scientific topics of interest—reflecting the historical context at each time. Furthermore, these conferences illustrate the remarkable growth of coral reef science in Mexico and now represent a historical archive of great relevance.

SOMAC has played a key role in advancing research, conservation, and management efforts for coral reefs in Mexico for 20 years after its foundation. The main purpose was to unite scientists, students, and decision-makers interested in the study and protection of Mexico's coral reefs. The organization focuses primarily on scientific research conducted by its members and promotes interdisciplinary collaboration to address the pressing environmental challenges affecting these ecosystems.

Currently, SOMAC has approximately 260 active members, the majority of whom are students, followed by researchers working in most of the academic institutions along Mexico's coasts, as well as some based in inland cities such as Mexico City, Guadalajara, and Morelia. Some members are also affiliated with government and non-governmental organizations. Since 2020, SOMAC has served as the Mexican chapter of the International Coral Reef Society (ICRS), providing access to funding and student travel grants to support conference participation. Several SOMAC members also hold membership in the ICRS.
Over the years, SOMAC has actively disseminated knowledge on coral reef ecology, biodiversity, and resilience. Its members collaborate with national and international institutions, to better understand reef processes and organisms

	City	State	Year	Men	Women	TOTAL	Authors per work	M:W
1	Veracruz	Veracruz	2000	112	70	**182**	2.0	1.6
2	Puerto Ángel	Oaxaca	2003	83	37	**120**	1.7	2.2
3	Cancún	QR	2006	222	104	**326**	2.0	2.1
4	La Paz	BCS	2007	116	76	**192**	2.0	1.5
5	Tuxpan	Veracruz	2009	219	112	**331**	2.5	2.0
6	Ensenada	BC	2011	185	89	**274**	2.2	2.1
7	Mérida	Yucatán	2013	395	261	**656**	2.6	1.5
8	PV	Jalisco	2015	153	115	**268**	2.4	1.3
9	Chetumal	QR	2017	271	185	**456**	2.7	1.5
10	Manzanillo	Colima	2019	257	193	**450**	2.5	1.3
11	Veracruz	Veracruz	2022	273	219	**492**	2.4	1.2
12	Ensenada	Baja California	2024	298	322	**620**	2.1	0.9
			TOTAL	**2584**	**1783**	**4367**	2.3	1.4
			average	215	149	364	2	2
			MIN	83	37	120	1.7	0.9
			MAX	395	322	656	2.7	2.2

Table 2. Data from the Mexican Coral Reef Conferences held from 2000 to 2024. The columns for men and women indicate the number of participants in the presented works by gender at each conference, along with the corresponding total. The "Authors per work" column shows the average number of authors per contribution in each congress. The M:W column represents the male-to-female ratio (a value close to one indicates near gender parity).

Participants at the 12th CMAC meeting, which took place in Ensenada, Baja California

and to implement conservation strategies. One of SOMAC's most significant accomplishments has been the organization of the Mexican Coral Reef Conferences, which have become a key gathering for the scientific community and other stakeholders. CMAC is Mexico's most important conference focused on coral reefs. To date, 12 CMACs have been held across different locations, alternating between the Pacific and Atlantic coasts, including the Gulf of Mexico and the Caribbean. A comprehensive analysis of the first 11 conferences is available in Medina-Rosas (2023). With wider international participation, CMACs have also hosted three Pan-American Coral Reef Congresses (CPACs), with attendees from Latin America, Europe, and the United States. Presentations are primarily in Spanish, though English contributions are also included.

The 12th CMAC took place in Ensenada, Baja California in 2024, and implemented a zero-waste policy, eliminating use of single-use plastics. The congress featured live-streamed sessions and included a total of 299 presentations—82 oral and 217 posters—the highest number of posters in CMAC history. This shifted the presentation format ratio to 0.4, an unprecedented change (Table 1). Oral presentations were delivered in a single room over four days, while posters were displayed throughout the congress in a dedicated area (Table 1). As in previous years, students (undergraduate and graduate) formed the majority of participants, followed by professionals, including researchers and staff from national and international organizations. Participants represented 10 countries: Mexico, Cuba, Costa Rica, United States, Colombia, Puerto Rico, Ecuador, Brazil, Portugal, and the United Kingdom.

A notable milestone was reached at that conference when, for the first time in CMAC history, women were the majority among presenters. This shift in gender representation (previously $r^2 = 0.44$; now $r^2 = 0.56$) resulted in a male-to-female ratio of 0.9 (Table 2). This breakthrough in gender parity was also highlighted in the prologue of the CMAC 2022 special issue published in the journal Hidrobiológica (Vol. 33, No. 2, 2023). Although this conference ranked second in total attendance, it was the first to achieve this gender balance. This is especially

significant in light of the global "leaky pipeline" phenomenon, whereby women disproportionately leave careers in the natural sciences (Grogan 2018). Encouragingly, Mexico is becoming a leading example of increasing female participation in scientific research (UNESCO 2015), particularly in coral reef science, as demonstrated by the 12th CMAC.

One of the keynote speakers. Dr. Fiorenza Micheli (Stanford University), addressed ecological and human connectivity in tropical marine environments in the context of biodiversity conservation and food security.

The keynote speakers at the congress included: **Andrea Grottoli** (Ohio State University), who presented advances in coral feeding strategies and technological solutions; **Sean Connolly** (Smithsonian Tropical Research Institute, Panama), who discussed patterns of abundance and biodiversity on Indo-Pacific reefs through ecological and diversity system frameworks; **Fiorenza Micheli** (Stanford University), who addressed ecological and human connectivity in tropical marine environments in the context of biodiversity conservation and food security; and **Fabián Rodríguez** (University of Guadalajara), who presented his work on the taxonomic and functional diversity of coral reef ecosystems, from microbial communities to entire ecosystems.

This line-up maintained gender and national diversity, with two female and two male speakers—three from international institutions and one from Mexico. As with attendees no previous CMAC has featured more women than men among keynote speakers (Medina-Rosas 2023, Table 4).

Five thematic areas were covered during the congress:

- Genomics and physiology of reef organisms
- Communities and populations in coral reefs (the largest session, accounting for nearly half of all presentations)
- Socio-ecosystems
- Physics, chemistry, and innovation in coral reef science
- Temperate reefs—featured for the first time as a separate session
- The number and topics of sessions have varied across CMACs (Medina-Rosas 2023, Table 5).

The Ensenada CMAC was held in April 2024, coinciding with the National Oceanic and Atmospheric Administration (NOAA) recognising the fourth global coral bleaching event—the second within a decade (NOAA 2024). This event affected reefs in the Atlantic, Pacific, and Indian Oceans, including Florida, the Caribbean, Brazil, the Eastern Tropical Pacific (including Mexico, Costa Rica, Panama, and Colombia), the Great Barrier Reef, and vast areas of the South Pacific.

The 13th CMAC and 4th CPAC were scheduled for October 2025 in Cozumel, Quintana Roo, marking a return to the biennial schedule (in odd years), which had been disrupted by the COVID-19 pandemic. This timing avoids overlap with the International Coral Reef Symposium (ICRS), held every four years. The congress provided a forum for presenting recent research on the effects of the current bleaching event and broader advances in coral reef science in Mexico and other countries across the American continent. The next ICRS will take place in Auckland, New Zealand, from July 19–24, 2026, under the theme "Working together to ensure a future for coral reefs."

Each event of CMAC has addressed critical topics such as coral bleaching, reef degradation, disease outbreaks, and ecological restoration strategies. Rising ocean temperatures have intensified mass coral bleaching events, further weakening reef ecosystems. Mexican coral reefs have recently shown alarming signs of degradation, underscoring the need for continuous monitoring and research.

In this context, the work of SOMAC and the CMAC is more important than ever. Science, conservation, and collective action are essential to protect these ecosystems and ensure their persistence for future generations. Through strengthened collaboration networks, evidence-based policy implementation, and active societal engagement, SOMAC remains a cornerstone in the understanding and conservation of coral reefs in Mexico.

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"The Battle of the Century". Dr. Andrés Lopez-Perez (UAM, left) and Dr. Lorenzo Álvarez-Filip (UNAM, right) debated the respective merits of Caribbean and Pacific Ocean coral reefs.

Cambios en las tendencias de los Congresos Mexicanos de Arrecifes Coralinos (2000-2024) en el contexto de crisis mundial arrecifal

In keeping with our aim of making Reef Encounter increasingly multi-cultural, as well as international, we are including the Spanish version of the text of the preceding report (ed.)

Los resultados de las investigaciones sobre arrecifes coralinos en México se presentaban anteriormente en diferentes congresos, incluidos los de zoología, ictiología y oceanografía. Esto cambió en el año 2000, cuando el Primer Congreso Nacional de Arrecifes Coralinos se realizó en Veracruz, Veracruz. En el siguiente congreso, llevado a cabo en Puerto Ángel, Oaxaca en 2003, el evento fue renombrado a su nombre actual, el Congreso Mexicano de Arrecifes Coralinos (CMAC), y se propuso la formación de la Sociedad Mexicana de Arrecifes Coralinos (SOMAC). La SOMAC se constituyó oficialmente en enero 28 de 2005. La coordinación del tercer congreso, celebrado en Cancún, Quintana Roo, en 2006, fue organizada por la institución sede y la SOMAC, un modelo que ha continuado desde entonces.

Después de 25 años y doce ediciones, el CMAC se ha convertido en el principal punto de encuentro para investigadores, tomadores de decisiones y estudiantes interesados en los arrecifes coralinos de México. Estas reuniones han atestiguado cambios significativos en términos de personas e instituciones participantes, y especialmente los temas científicos revisados, lo que ha reflejado el contexto histórico en cada ocasión. Además, estos congresos ilustran el gran crecimiento de la ciencia sobre arrecifes coralinos en México, y ahora representan un archivo histórico de gran relevancia.

La SOMAC ha jugado un papel clave en el avance de la investigación, conservación y esfuerzos de manejo en los arrecifes coralinos en México después de 20 años de su fundación. El propósito principal es unir a los científicos, estudiantes y autoridades interesados en el estudio y protección de los arrecifes coralinos de México. Su labor se ha enfocado principalmente en la investigación científica, a través de los proyectos y estudios de sus miembros, así como promover la cooperación interdisciplinaria para enfrentar los desafíos ambientales que afectan estos ecosistemas. Actualmente la SOMAC cuenta con aproximadamente 260 miembros, la mayoría estudiantes, seguido de investigadores que trabajan en las instituciones del litoral mexicano, así como algunas ubicadas en ciudades que no están en la costa, como la Ciudad de México, Guadalajara y Morelia. Algunos miembros también están afiliados a organizaciones gubernamentales y no gubernamentales. Desde 2020 la SOMAC es un capítulo de la Sociedad Internacional de Arrecifes Coralinos (ICRS, por sus siglas en inglés), lo que ha permitido contar con fondos y apoyos para realizar los congresos y apoyar con becas a estudiantes. Varios miembros de la SOMAC también son parte de la ICRS.

A lo largo de los años, la SOMAC ha trabajado en la difusión del conocimiento sobre la ecología, biodiversidad y resiliencia de los arrecifes, donde los miembros de diversas instituciones nacionales e internacionales colaboran para lograr un mejor entendimiento de los procesos y organismos arrecifales, además de la implementación de estrategias de conservación. Uno de los logros más significativos de SOMAC ha sido la organización de los Congresos Mexicanos de Arrecifes Coralinos (CMAC), eventos que se han consolidado como un punto de encuentro clave para la comunidad científica, así como diversas organizaciones e instituciones. Los CMAC son las reuniones

más relevantes en México sobre estos ecosistemas, y se han realizado doce congresos en diferentes sitios del país, alternando sedes en la costa del Pacífico y el Atlántico, en el Golfo de México y Caribe. Para conocer la historia de los congresos se puede revisar el análisis realizado después de las primeras once ediciones (Medina-Rosas 2023). Los CMAC también han incluido ya tres reuniones panamericanas (CPAC), debido a que hay participación de investigadores y estudiantes de países latinoamericanos y europeos, así como de Estados Unidos. Los trabajos se presentan en español y también son bienvenidos en inglés.

El doceavo CMAC se realizó en Ensenada, Baja California, y se logró mantener una política de cero desechos sin usar plásticos de un solo uso, se incluyó la transmisión en vivo de todo el evento, y se presentaron un total de 299 trabajos: 82 de forma oral y 217 posters, la mayor cantidad de posters que se han presentado en los congresos, un valor que cambió la proporción (0.4) en cuanto a la forma de presentar trabajos como nunca se había tenido anteriormente (Tabla 1). Estos valores se dieron ya que las presentaciones orales se realizaron en una sola sala durante cuatro días, y los posters se presentaron a lo largo de los cuatro días del congreso (Tabla 1). Como en todos los congresos, la mayor cantidad de participantes fue de estudiantes, tanto de licenciatura como posgrado, y después los profesionales, incluidos investigadores y trabajadores de diversas organizaciones nacionales e internacionales. En esta ocasión participaron personas de diez países: México, Cuba, Costa Rica, Estados Unidos, Colombia, Puerto Rico, Ecuador, Brasil, Portugal, y Reino Unido.

Un dato digno de remarcar, como se había observado en la tendencia en los congresos anteriores (Medina-Rosas 2023), pero ahora si cumplido, es que por primera vez en la historia de los CMAC, el número de mujeres en los trabajos presentados fue mayor que los hombres, con un cambio en la tendencia (r^2 = 0.44 anteriormente, y ahora 0.56) (Tabla 2). Nunca se había logrado la paridad, y ahora la tasa de hombres y mujeres fue menor a uno (0.9, donde el valor mayor de uno equivale a un número mayor de hombres, y si es menor a uno, el número mayor corresponde a las mujeres) (Tabla 2). En el suplemento especial del CMAC de 2022, publicado en la revista Hidrobiológica (2023, volumen 33, número 2), se pudieron observar también estos números, como bien fue mencionado en el prólogo. El 12CMAC fue el segundo en cantidad de personas que participaron, pero el primero en lograr este cambio en la proporción de géneros participantes. Esta situación a nivel nacional y mundial es relevante, donde la fuga en la tubería (*leaky pipeline*), con respecto a mujeres que estudian y realizan investigación en ciencias naturales (Grogan 2018), puede mejorar, con México como uno de los ejemplos donde cada vez más mujeres participan en actividades científicas (UNESCO 2015), y como se demostró en este último CMAC, en particular en los ambientes arrecifales.

En cuanto a las conferencias magistrales, Andrea Grotolli, de Ohio State University, presentó resultados sobre tecnología y soluciones de alimentación para corales; Sean Connolly, del Instituto Smithsonian de Investigaciones Tropicales de Panamá, presentó resultados sobre los patrones y dinámicas de abundancia y biodiversidad de los arrecifes del IndoPacífico, considerando conceptos ecológicos y los patrones de sistemas de diversidad; Fiorenza Micheli, de la Universidad de Stanford, habló sobre las conexiones ecológicas y humanas en diferentes ambientes tropicales relacionadas con la conservación de biodiversidad y protección para la seguridad de los alimentos y protección de áreas marinas; y Fabián Rodríguez, de la Universidad de Guadalajara, habló en su conferencia sobre la diversidad taxonómica y funcional de ecosistemas coralinos a través de sus estudios a diferentes escalas, desde micro

organismos, como bacterias, pasando por corales, hasta ecosistemas. Esto significa que participaron dos mujeres y dos hombres, tres de nacionalidad extranjera y un mexicano, valores similares a los que se han tenido en otros CMAC. Nunca ha habido un número mayor de mujeres en conferencias magistrales (Medina-Rosas 2023, Tabla 4).

En el congreso se consideraron cinco temáticas: genómica y fisiología de organismos arrecifales; comunidades y poblaciones en arrecifes coralinos (que concentró el mayor número de trabajos, casi la mitad); socioecosistemas; física, química e innovación en arrecifes coralinos y, por primera vez como sesión en un CMAC, arrecifes templados. Las sesiones en cada CMAC han variado en cuanto a cantidad y temas (Medina-Rosas 2023, Tabla 5).

El CMAC de Ensenada se realizó en abril de 2024, justo cuando la Administración Nacional Oceánica y Atmosférica de Estados Unidos (NOAA) confirmó el cuarto evento global de blanqueamiento de corales, el segundo en menos de una década (NOAA 2024). Este fenómeno afectó arrecifes en el Atlántico, Pacífico e Índico, incluyendo regiones como Florida, el Mar Caribe, Brasil, el Pacífico Tropical Oriental (con sitios afectados en México, Costa Rica, Panamá y Colombia), la Gran Barrera de Coral en Australia, y amplias zonas del Pacífico Sur.

El treceavo CMAC y cuarto CPAC fue programado para octubre de 2025 en Cozumel, Quintana Roo, lo que permite retomar el ciclo bianual (en años nones), interrumpido por la pandemia de COVID, y que evita el traslape con el Simposio Internacional de Arrecifes Coralinos (International Coral Reef Symposium), que se realiza cada cuatro años en diferentes lugares del mundo. Pero además, proporciona el espacio para presentar los resultados de los estudios realizados sobre los efectos del blanqueamiento sucedido recientemente, así como los últimos avances encontrados en los ambientes arrecifales de México y otros países de América. El próximo congreso internacional se realizará en 2026 en Auckland, Nueva Zelanda, del 19 al 24 de julio, donde se presentarán trabajos bajo el lema trabajando juntos para asegurar un futuro para los arrecifes coralinos.

Cada evento del CMAC ha abordado temas cruciales como el impacto del blanqueamiento coralino, el deterioro de la calidad del ambientes arrecifales, las enfermedades y las estrategias de restauración ecológica. El aumento de las temperaturas oceánicas ha provocado eventos masivos de blanqueamiento coralino, exacerbando su vulnerabilidad. Los arrecifes coralinos en México han mostrado signos alarmantes de degradación recientemente, por lo que es necesario dar seguimiento a los estudios y resultados obtenidos.

Ante este panorama, la labor de la SOMAC y los Congresos Mexicanos de Arrecifes Coralinos es más relevante que nunca. La ciencia, la conservación y la acción colectiva son esenciales para mejorar la protección de estos ecosistemas y garantizar su persistencia para las futuras generaciones. A través del fortalecimiento de redes de colaboración, la aplicación de políticas basadas en evidencia y el involucramiento de la sociedad, la SOMAC continúa siendo un pilar fundamental en el entendimiento y conservación de los arrecifes coralinos en México.

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Home to Brazil - Personal in Belém

I really have been extremely fortunate that this was my fourth time being able to represent the International Coral Reef Society at a major international COP (Conference of the Parties); but, for me, attending COP30 in Belém, this occasion felt somewhat different. As a Brazilian, it felt special - personal. I found myself cheering for everything to go well: for the outcomes to be strong, for the air conditioning not to fail, for the international community to see my country at its best.

In the weeks leading up to the conference, Brazil's political climate was tense. President Luiz Inácio Lula da Silva was under constant scrutiny from right-wing media, much of it fueled by supporters of former President Bolsonaro. Depending on which news outlet you followed, you would hear about all the progress and preparation, or endless criticism and predictions of failure. Some outlets even complained about the price of food at the venue, calling it "exorbitant," clearly without ever having attended any other COP. It often felt like parts of the media were rooting for the event to be a complete failure.

And yet, it wasn't. Yes, there were hiccups: delays in setting up pavilions on day one, the air conditioning not being strong enough early on, and even a fire that forced an evacuation. But despite all of this, COP30 delivered - substantively, politically, and culturally.

One of the most remarkable aspects of this COP was the enormous participation of civil society. Traditionally, COPs have had only two main areas: the Blue Zone (for UN-accredited parties and observers) and the Green Zone (a public-access area linked to the negotiations). Belém transformed this model entirely. The city hosted *hundreds* of events across multiple venues - film screenings, panels, exhibitions, workshops - allowing the whole city to "live" the COP. People were exposed to conversations about climate change, sustainable agriculture, deforestation, ocean health, finance, and so much more.

There were also thematic "COPs" spread across the city. One of the most powerful was the Aldeia COP, named after the traditional homes of Indigenous peoples in Brazil. This COP became a vibrant gathering place for thousands of Indigenous leaders from across the world - the largest Indigenous presence at any COP to date. Majés (women leaders) led blessings and cultural ceremonies; there were dances, discussions, and powerful expressions of identity and resistance.

The People's Summit was another major space, bringing together social movements from across the world. Discussions there centered on equity, climate justice, and the vital role of civil society in holding governments accountable. Beyond that were the Free Zone, Yellow Zone, Enzone, City COP, Para House, and Casa dos Oceanos (a dedicated space focusing on oceans), each offering its own portals into climate topics and community engagement.

COP30 was everywhere in Brazil. It dominated national news. Celebrities, activists, and public figures traveled to Belém. For once, a COP didn't feel distant or exclusive. Even if not everyone had access to the Blue Zone, people were participating, learning, and experiencing the conference in real time. I genuinely believe this will have lasting impacts - Belém and Brazil now have a clearer understanding of what a COP is, why it matters, and how climate decisions are made on a global scale.

And the people of Belém… they were extraordinary. Welcoming, proud, eager to share their culture - whether through food, dance, music, or conversation. Every night there were cultural events: carimbó, brega, performances in public squares. The city felt alive.

I was also able to see up close how hard the COP Presidency worked to make this a meaningful, ambitious conference. They launched the *Mutirão* and the *Mapa do Caminho*, a bold roadmap for phasing out fossil fuels—something that, incredibly, has still not been formally embraced after 30 COPs. Most countries applauded the proposal, but in the final days, Saudi Arabia, China, and Russia blocked it. Because all COP outcomes require consensus, fossil fuel phase-out language was removed. But the story didn't end there. A coalition of countries agreed to meet again next year in Colombia to continue the discussion - essentially creating a follow-up meeting among selected countries focused specifically on phasing out fossil fuels.

For me, COP30 was not just a political moment - it was an emotional one. It showcased a Brazil that is engaged, creative, culturally rich, and determined to be part of global climate solutions. As a Brazilian representing coral reef science on an international stage, it was an experience I'll never forget.

I am most grateful to the Society for providing this opportunity to represent our community.

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The Coral Futures Academy:

capacity building for Micronesian communities to undertake climate-smart coral restoration

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Coral reefs are highly diverse habitats that provide a wide range of ecosystem services, including coastal protection, fisheries support, and cultural and economic benefits to coastal communities (Woodhead et al. 2019). However, reefs worldwide are increasingly threatened by multiple disturbances arising from both local pressures, such as overfishing and coastal development, and climate-driven stressors, particularly marine heatwaves associated with global climate change (Spalding & Brown 2015). Yet, many restoration practices fail to integrate climate resilience into their reef restoration projects, thus missing a critical opportunity to restore reefs using future-facing corals that could ensure restoration efforts and goals are achieved for decades to come. In the face of these challenges, locally led coral restoration efforts are also increasingly recognized as essential for enhancing the scale, effectiveness, and long-term sustainability of restoration initiatives, as they leverage local ecological knowledge, build community stewardship, and strengthen socio-ecological resilience in reef-dependent communities (Trialfhianty & Saudi 2017, Wambugu et al. 2025).

With these ideas in mind, the Coral Futures Academy (CFA) was established, as part of an initiative funded by the G20 Coral Research and Development Accelerator Platform (CORDAP), entitled *"Scaling up identification, protection, and local management of coral reefs resistant to future climate stress."* This project is a global partnership among The Nature Conservancy Micronesia and Polynesia, Dr. Courtney Klepac of the Palumbi Lab at Stanford University, the Palau International Coral Reef Center (PICRC) (Republic of Palau), the Marshall Islands Conservation Society (Republic of the Marshall Islands), and the Conservation Society of Pohnpei (Federated States of Micronesia). Through CFA, the project aims to build the capacity of local community members across Micronesia by equipping them with the training, tools, skills, and knowledge needed to conduct climate-smart coral restoration activities in their respective countries. In addition, CFA seeks to establish a regional network of partners in Micronesia and beyond, a network that can facilitate knowledge exchange to guide and strengthen restoration efforts across the region.

The Coral Futures Academy (CFA) was first crafted by Dr. Courtney Klepac and has been piloted in Palau, where local researchers from the Palau International Coral Reef Center (PICRC) were trained in standardized protocols created by the CFA framework. Specifically, CFA methods leverage widespread inter- and intraspecific variation in heat tolerance to identify coral colonies with a higher likelihood of survival (see Klepac et al., 2024). Once identified, these resilient corals can be used to stock climate-resilient coral nurseries. In Palau, with the cooperation of the local government and community volunteers, two restoration sites have been established, in Ngaraard and in Ngarchelong, both located in northern Babeldaob, the largest island in Palau. These sites were chosen because natural reef recovery has failed to

Figure 1. a (left) CFA Palau team leader Dawnette Olsudong attaching newly collected coral fragments to the "waiting room" table nursery. B (right) The right panel shows MARS reef stars used by the CFA team in Palau as nurseries for heat-tested corals, which are currently under continued monitoring.

materialize more than two decades after typhoon damage.

The CFA framework operates over a typical work week, and activities involve the collection of fragments from source colonies, as well as coral bleaching experiments. The CFA–PICRC team identified a source reef from which numerous coral colonies were collected from multiple coral species for restoration activities and experimental assays. Larger fragments are attached to *in situ* nurseries (the 'waiting room'), while four smaller fragments are transported to the PICRC laboratory for heat tolerance testing (Figure 1a). Heat stress assays conducted over four days can quantify variation in coral thermal tolerance. By the end of each weekly assay, corals are assigned heat tolerance rankings: high (upper 25%), medium (middle 50%) or low (bottom 25%). Colonies maintained in the 'waiting room' are moved to defined racks at the restoration site, tagged based on rankings, and are regularly monitored to validate laboratory results under field conditions (Figure 1b).

To date, the CFA team in Palau has tested more than 1,000 coral colonies. These thermally characterized corals represent a potentially climate-resilient source stock for outplanting at degraded reef sites requiring restoration. However, another key benefit to this approach is that it can be used with virtually any coral species. Already colonies from 24 different species with a range of growth morphologies have been tested. As a result, there are two main benefits to the restoration system – heat resilient corals from many species increase both the climate resilience of these reefs, and their fundamental biodiversity.

Training and hands-on learning

In 2025, CFA hosted a series of workshops attended by participants from Palau, the Federated States of Micronesia, the Marshall Islands, and Nauru (Figure 2). These workshops provided training on protocols for heat testing corals for restoration and covered additional topics including characterizing climate resilience in corals, the selection of donor and source sites, as well as broader discussions on coral restoration strategies.

In Majuro, Marshall Islands, the Marshall Islands Conservation Society has established a heat testing facility and has also started a few trials on heat tolerance testing. They have also set up multiple nurseries that will serve as heat-resistant stock for upcoming restoration projects. In Pohnpei, Federated States of Micronesia, table nurseries have been established, while the local team is finalizing the location for a heat testing facility. In Palau, in addition to the establishment of nurseries for heat-tested corals, the CFA team has implemented additional restoration activities to match CFA objectives, including the use of

Figure 2. (Top) Participants of the first Coral Futures Academy (CFA) workshop, held at the Palau International Coral Reef Center in February 2025. The event was attended by CFA members from the Nature Conservancy Polynesia and Micronesia, the Marshall Islands Conservation society, the Government of Nauru, Palau International Coral Center, and Standford University. (Bottom) Participants of the follow-up CFA workshop conducted in Pohnpei, Federated States of Micronesia, in April 2025. Participants included representatives of different local organizations in Pohnpei, including the Conservation Society of Pohnpei.

fragments of opportunity and MARS reef stars (www.buildingcoral.com). Fragments of opportunity do not have the resilience benefits or the biodiversity scope that CFA corals provide, so they provide good tests for the significance of heat testing in a restoration situation. These activities have engaged local stakeholders, aiming to foster community stewardship and strengthen long-term support for coral restoration in the region.

Another aim of the CFA is to create a network of coral restoration practitioners, providing a platform for exchanging ideas and learning from one another's experiences, even across different political jurisdictions. Since the project was initially piloted in Palau, the local team there has accumulated more experience, which now serves to provide baseline knowledge for operations at other restoration sites. As part of this network, CFA team leaders from partner countries were invited in July 2025 to a coral restoration workshop, which was organized by the Palau International Coral Reef Center, Newcastle University, and the Nature Conservancy Polynesia and Micronesia, and funded by the Great Barrier Reef Foundation (Figure 3). This workshop was a significant event for CFA members, as it provided hands-on training in various coral restoration methodologies, facilitated

Figure 3. Scenes from the coral restoration workshop organized by the Palau International Coral Reef Center and Newcastle University. (Top) CFA members from the Marshall Islands and Federated States of Micronesia learning how to use Coral Clips® developed by the Coral Nurture Program. (Bottom) Workshop participants observing the deployment of reef stars, developed by the MARS Assisted Reef Restoration System (MARRS).

by experts from the organizations that developed these approaches, including the Coralassist Lab at Newcastle University, SECORE International, Mars Assisted Reef Restoration system, and the Coral Nurture Program. The knowledge and skills gained from these activities are expected to support CFA members in planning and implementing climate-smart coral restoration in their respective regions.

The need for future-facing restoration

As global temperatures continue to rise, identifying heat-tolerant corals for use in coral restoration has become increasingly valuable. Although a few reefs around the world have so far been spared by recent global bleaching events, the global temperature is rising at record-breaking levels each year, such that in the next decades, reefs globally will experience annual bleaching stress. Moreover, coastal development is increasing across many remote islands, increasing the chances of local reef degradation. Given this, it is very important to prepare ourselves, especially at the local stakeholder level, with the capacity to perform climate-smart restoration protocols. Although restoration alone cannot save our reefs, this work has the potential to buy us time, when implemented in parallel with other conservation strategies (e.g., reduction of local disturbances). Thus, most importantly, we continue to call for strengthened and immediate efforts to reduce carbon emissions so as to mitigate the escalating impacts of climate change.

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Evidence of Acropora Settlement Emerges from Florida Nursery-Based Spawning Research

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During the largest coral spawning event in years, researchers in the Florida Keys documented rare settlement of endangered Acropora juveniles following nursery-based spawning and larval experiments, offering new insight into long-standing recruitment failures.

Researchers from around the United States, working in the world's largest offshore coral nursery, have capitalized on the healthiest mass spawning event of endangered staghorn coral (*Acropora cervicornis*) by testing novel methods for on-site fertilization, settlement, and grow-out of the next generation of Florida's corals. Underpinned by Coral Restoration Foundation (CRF) and conducted at its Tavernier Coral Nursery, this work aims to ensure that critical genetic diversity can be returned to Florida's coral reefs through future restoration efforts. A key goal was to determine whether coral larvae produced under current ocean conditions could successfully settle and survive - since newly-settled corals have been conspicuously absent from Florida reefs for decades.

After poor environmental conditions during the global mass coral bleaching event in 2023 and 2024 hampered coral spawning research, the scale of this summer's spawn was an encouraging sign for species on the brink of extinction. "We lost a lot of corals in 2023 and 2024," says CRF Science Program Manager Alex Neufeld, "and the corals that did survive were too stressed to spawn with any consistency or viability during those summers. The fact that we saw such a massive number of healthy corals spawning in 2025 didn't just give us the opportunity to conduct some important new research; it also showed us that these corals aren't ready to toss in the towel just yet."

CRF spawning research this year was focused on a question fundamental to coral restoration efforts in Florida: *Why don't we see juvenile Acropora corals on Florida reefs?* Corals in the genus *Acropora*, the branching corals, are the keystone reef-building species in the Caribbean, but their numbers in the wild have declined precipitously in recent years, to the point of functional extinction. As CRF Restoration Program Manager Phanor Montoya-Maya points out, "We can return all the corals we want to our restoration sites. But if those corals don't reproduce and create future generations of corals, the reefs will never recover on their own."

Because juvenile corals are small and often settle miles from their parents' reefs following a spawning event, they can be difficult to track and monitor. However, most researchers agree that new *Acropora* "recruits" have not been seen in the Florida Keys for several decades. As Phanor Montoya-Maya explains: "The coral reproductive cycle has many nuanced steps. From spawning, to fertilization, to larval development and dispersal, to settlement, and then surviving as tiny initial clusters of polyps, there are a lot of potential hurdles in the natural process of creating new corals. One or more of these steps could be failing right now, and that's why we never see *Acropora* recruits in the Florida Keys."

To effectively test hypotheses about where reproductive breakdowns may be occurring, CRF partnered with researchers from the Shedd Aquarium, the University of Miami, the University of Hawai'i, and others. Together, the team of scientists boarded the Shedd Aquarium's 60-foot liveaboard research vessel *Coral Reef II* for a two-week expedition based at the Tavernier Coral Nursery and surrounding Florida Keys reefs. From this floating laboratory, the crew were able to mimic, support, and directly monitor many stages in the natural coral reproductive cycle.

During the two weeks in August, over 120 colonies of *Acropora cervicornis*, three colonies of *Acropora prolifera*, and one colony of *Acropora palmata* were observed spawning and monitored for timing and quantification of gametes released. Many additional colonies spawned throughout the various sections of the Tavernier Coral Nursery but were not formally documented. This year marked the first time that *A. palmata* (elkhorn coral) was observed spawning in the CRF *in situ* nursery system, indicating that this slow-growing species still retains its reproductive capacity within Florida's restoration community.

Even more exciting was the observation of fused staghorn coral (*A. prolifera*) spawning in a nursery setting – a first for this species anywhere in the Caribbean. Fused staghorn, the natural hybrid that results from cross-breeding between *A. cervicornis* and *A. palmata* in the wild, has long been a potential candidate for active reef restoration projects. However, questions about its long-term viability and ecological role on Caribbean reefs have limited its use to date. The CRF observation of spawning *A. prolifera* lends support to the argument that fused staghorn could merit the same restoration considerations as either of its parent species.

With their research partners on board the *Coral Reef II*, the CRF spawning team prioritized the collection and assisted fertilization of *A. cervicornis*. Small nets with attached vials were placed over large, genetically diverse staghorn colonies staged on the seafloor of the underwater nursery. As the colonies spawned night after night, scientists collected the gametes that accumulated in the vials and transported them to the main deck of the *Coral Reef II*, where live wells of circulating seawater awaited. There, gametes from different genotypes of staghorn coral were combined to enable fertilization. The resulting coral larvae were then allowed to drift in the moving water for several days, just as they would naturally disperse in open-ocean currents.

Following this period of larval development, batches of larvae were used in a series of experiments to assess their health and viability. First, some larvae were subjected to rapidly increasing water temperatures to determine the thermal tolerance of the new generation. Next, some larvae were inoculated with different strains of heat-tolerant algal symbionts. Finally, a portion of the larvae were introduced to various ceramic and silica structures within the nursery, to encourage settlement and metamorphosis from free-swimming larvae into sessile coral juveniles.

Remarkably, some three months after the spawning work concluded, the CRF spawning team returned to the settlement tiles in the nursery and discovered that a half dozen staghorn coral larvae, no larger than the head of a pushpin, had settled and were growing on the structures. As Alex Neufeld commented "This was an incredible discovery for us, because it tells us so much about what is still possible for this species in the current ocean environment. For example, we know that the gametes that our adult corals produce are viable and can create larvae that are healthy enough to settle and grow. We also now know that our ocean water chemistry is not necessarily a barrier to creating new baby corals. There are more specifics to tease apart, to be sure, but this spawning season represents a huge step forward for our coral restoration efforts."

Spawning heads of staghorn *Acropora* attached to a "Coral Tree" structure as used in the Coral Reef Foundation Tavernier Coral Nursery - the largest open ocean coral nursery in the world. Credit CRF.

Images clockwise from top left. a) preparing the tent structures that are to be placed over the coral heads for gamete collection, b) close-up of a spawning colony of *A. cervicornis*, c) restoration program manager Phanor Montoya Maya collecting a vial of staghorn gametes, d) gametes accumulated at the end of a collection vial, e) team members from the collaborating organisations working with the culture facilities aboard the Shedd Aquarium's vessel *Coral Reef II*. Photo credits CRF.

Coral Restoration Activities Deliver Immediate Economic Boost

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Our Florida Keys case study shows ecosystem restoration work stimulates the local economy, in addition to providing long-term environmental benefits.

A peer-reviewed study recently published in Restoration Ecology (Winters & Rothwell 2026) shows that coral restoration efforts not only help secure the future of coral reefs but also provide immediate economic benefits to local communities, comparable to those generated by other local industries. The research, led by Dr. R. Scott Winters (CEO of Coral Restoration Foundation™ (CRF)) and Madeline Rothwell (CRF Impact Coordinator), demonstrates that investments in coral restoration can stimulate local economies by supporting jobs, small businesses, and community resilience, regardless of whether restored reefs deliver ecological benefits in future years.

As Scott Winters has commented: "Coral reefs are vanishing at an unprecedented pace, but restoration is buying us time. What this study shows - and for the first time, quantifies - is that coral restoration activity is also an economic engine. Every dollar invested in coral restoration work translates to *more than* a dollar of spending within the local community right away."

Using economic impact modelling, the study examined economic activity in the Florida Keys between 2018 and 2022. Researchers found that each dollar invested in CRF activities directly generated between $1.20 and $1.40 in local economic activity. Even during the COVID-19 shutdowns, when tourism collapsed, coral restoration operations continued and became relatively more important to the Keys' economy. Hence, coral restoration activities contributed to the community's economic resilience during this time.

As Madeline Rothwell has explained: "Coral restoration is about more than planting corals. It creates jobs, sustains local businesses, provides alternate income streams for local communities, and keeps money flowing even during economic downturns. The economic resilience provided by coral restoration is a benefit that has been overlooked in policy and funding discussions to date, and it warrants recognition when discussing the benefits of this kind of work."

The paper distinguishes between two sources of socio-economic benefit from restoration:

The Activity: The act of restoration itself injects money into the economy immediately by hiring staff, operating boats, maintaining nurseries, partnering with dive shops, and more. This influx of direct funding also generates secondary effects as its ripples through the local economy.

The Outcomes: If restoration is ecologically successful, recovering reefs can support fisheries and tourism, and future generations can enjoy restored ecosystem services.

The study emphasizes that both the immediate activity and the longer-term outcomes are important and should be considered by communities, funders, and governments when making decisions about coral restoration programs.

The findings carry three major implications for how coral restoration should be designed, funded, and evaluated:

1. **Local goals matter most.** Local communities are affected differently by the

loss of coral reefs. Consequently, the needs and priorities for different communities may vary, and they may define restoration "success" differently. Universal metrics for ecological and socio-economic outcomes may not always be appropriate, as they fail to reflect local needs.

2. **Beneficiaries must be clear.** Economic stimulus may benefit today's businesses and workers, whereas ecological recovery primarily benefits future generations. Projects should explicitly state who is expected to benefit from restoration and on what timescale.
3. **Restoration can function as economic stimulus.** Like road-building or habitat conservation jobs programs, restoration spending should be recognized in government decisions on economic recovery and public investment. This has the potential to open new sources of funding for coral restoration projects.

"Too often, reef restoration is judged only by whether corals survive years into the future," said Winters. "This paper shows that the work itself, what we are doing today, has real value for communities right now. That's pivotal for how we think about funding, policy, and how we measure the 'success' of coral restoration activities."

Globally, nearly one billion people depend on coral reefs for food, income, and coastal protection. Yet reefs are under accelerating threat from climate change, pollution, and overexploitation. While large-scale reef recovery will ultimately require climate action, the study underscores that restoration projects can also deliver important short- to medium-term benefits to local communities most impacted by the degradation of their reefs.

By quantifying economic returns, the authors hope to broaden the conversation about how and why coral restoration is funded and judged on its merits. Governments and international development agencies that already use ecological restoration as a tool for economic stimulus may now look to coral restoration projects as part of those strategies. "This study gives policymakers another reason to support restoration," said Rothwell. "It's not just about ecology. It's about jobs, resilience, and people's livelihoods."

Reference

Winters RS, Rothwell MH (2026) Coral restoration as economic stimulus: a case study from the Florida Keys (United States). Restor Ecol 34: e70204
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REEF EDGE

Positive behavioral interactions in reef fish communities: an example from Florida Keys National Marine Sanctuary (NW Atlantic)

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"To keep every cog and wheel is the first precaution of intelligent tinkering" Aldo Leopold (1949)

Introduction

Aldo Leopold's advice about "intelligent tinkering" in a "community of interdependent parts" has been a fundamental principle in applied ecology for conservation and restoration of communities (e.g., Bohnsack 2003, Murcia and Aronson 2014). To effectively design and implement conservation and restoration strategies for ecosystems, we must consider the interacting elements that contribute to the whole network. While corals, as foundation species, are central to the restoration of coral reefs, we must also factor in the complex fabric of species interactions that are characteristic of coral reef ecosystems (Kaufman et al. 2023). This includes the community of fishes that inhabit coral reefs. Here we demonstrate an approach for identifying facilitative behavioral interactions (commensal and mutualistic) of reef fish species in a complex web of mixed-species foragers (e.g., Auster and Lindholm 2008, Auster et al. 2013, 2019). We propose that such information, especially as a time series, can be used to inform assessments and strategies for coral reef ecosystem restoration and sustainability.

We used a dataset of pair-wise fish species interactions from mixed-species foraging groups on Florida Keys reefs (i.e., Conch Reef region inclusive of Conch, Molasses, Pickles, Davis, French reefs) collected from 7-20 October 2010 during a mission at the Aquarius Undersea Laboratory. Divers conducted surveys along 50 m transects to quantify positive mixed-species behavioral foraging and

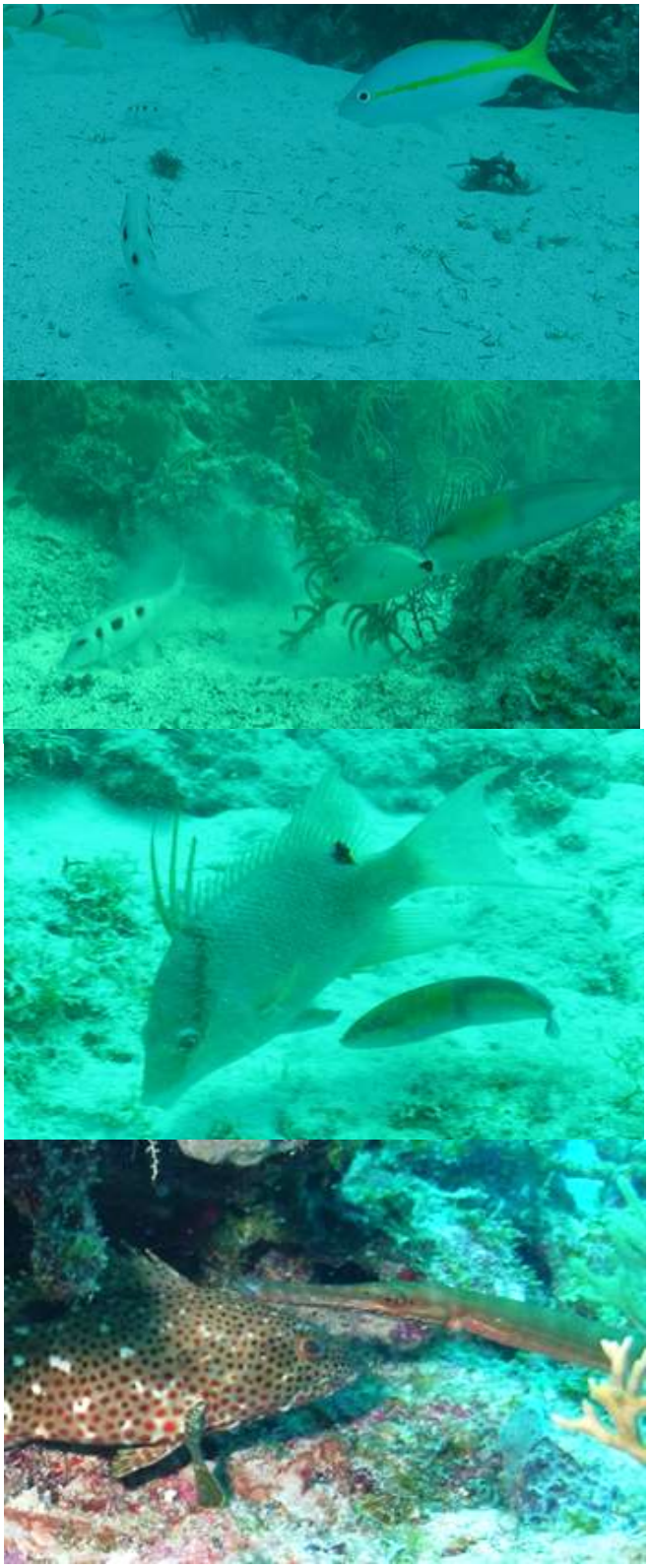

Figure 1. Examples of mixed-species groups with focal species and followers. Top: Two spotted goatfish *Pseudupeneus maculatus* followed by a yellowtail snapper *Ocyurus chrysurus* and painted wrasse *Halichoeres caudalis.* Second from top: Spotted goatfish followed by butter hamlet *Hypoplectrus unicolor* and yellowhead wrasse *Halichoeres garnoti.* Second from bottom: Hogfish *Lachnolaimus maximus* followed by painted wrasse. Bottom: A rock hind *Epinephelus adscensionis* followed by a trumpetfish *Aulostomus maculatus*.

hunting relationships (Figure 1). Sample units were mixed species bouts (2 or more individuals of 2 or more species exhibiting coordinated search, stalk, and attack behaviors) observed over 92 person-dives (66.36 hrs of observation).

The final data set was composed of 865 mixed-species bouts in a species x sample matrix (mean species per bout = 2.4, median = 2, maximum = 7.0; mean individuals per bout = 13.6, median = 3.0, maximum 1040). Species were assigned to families and trophic guilds (piscivore, invertivore, herbivore) based on numerical trophic indices from Fishbase (Froese and Pauly 2024) to facilitate the interpretation of network statistics and visualizations. Network analyses, including visualizations and the calculations for the number of mixed species links, total occurrences, interaction strength, and eigenvector centrality as well as subsequent visualizations were conducted in R 4.3.1 (R Development Core Team 2023).

Figure 2 is a visualization of paired-species interactions (n=60 species) from all mixed-species groups. Variation in line widths indicates number of bouts with each species pair. Table 1 lists the top 25% of species (n=15) identified by total number of mixed-species links. The dominant taxa found in multiple mixed species groups represent a diversity of families and range of trophic guilds found in the reef fish community. These results demonstrate that positive interactions occur within mixed species hunting groups, even when searching for diverse types of prey (inferred from trophic guild). A subsequent analysis included only those bouts that included piscivores (n=41 species) to examine the presence of higher trophic level predators in the composition of

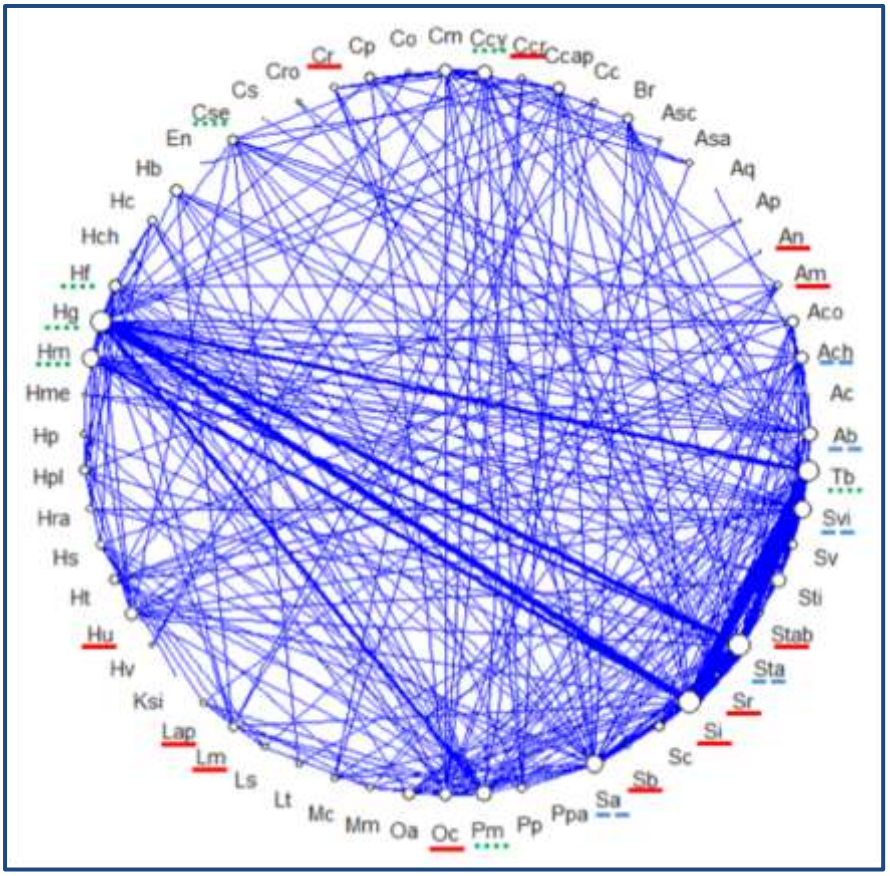

Figure 2. All paired interactions from mixed-species groups across all trophic levels (Each node represents a species with letter code. Node diameter represents the relative value of total occurrences. Line width linking species-pairs is relative to number of bouts. Lines beneath some species represent trophic guild of top species listed in Tables 1 and 2 (blue dashed line = primary consumer, green dotted line = secondary consumer, red solid line = piscivore). List of species in figure with abbreviation, scientific name, common name, and trophic level: Ab, Acanthurus bahianus, Ocean surgeonfish, 2.4; Ac, Acanthurus spp., Surgeon, 2.2; Ach, Acanthurus chirurgus, Doctorfish, 2.1; Aco, Acanthurus coeruleus, Blue tang, 2.2; Am, Aulostomus maculatus, Trumpetfish, 4.3; An, Aetobatus narinari, Spotted eagle ray, 4.2; Ap, Acanthostracion polygonium, Honeycomb cowfish, 2.0; Aq, Acanthostracion quadricornis, Scrawled cowfish, 2.7; Asa, Abudefduf saxatilis, Sergeant major, 3.8; Asc, Aluterus schoepfii, Scrawled filefish, 2.0; Br, Bodianus rufus, Spanish hogfish, 3.7; Cc, Calamus calamus, Saucereye porgy, 3.5; Ccap, Chaetodon capistratus, Foureye butterflyfish, 3.4; Ccr, Cephalopholis cruentata, Graysby, 4.3; Ccy, Chromis cyanea, Blue chromis, 3.7; Cm, Chromis multilineata, Brown chromis, 3.0; Co, Chaetodon ocellatus, Spotfin butterflyfish, 3.7; Cp, Clepticus parrae, Creole wrasse, 3.4; Cr, Caranx ruber, Bar jack, 4.3; Cro, Canthigaster rostrata, Sharpnose pufferfish, 3.3; Cs, Chaetodon striatus, Banded butterflyfish, 3.5; Cse, Chaetodon sedentarius, Reef butterflyfish, 3.9; En, Echeneis naucrates, Sharksucker, 3.7; Hb, Halichoeres bivittatus, Slippery dick, 3.8; Hc, Haemulon carbonarium, Caesar grunt, 3.7; Hch, Haemulon chrysargyreum, Smallmouth grunt, 3.5; Hf, Haemulon flavolineatum, French grunt, 3.5; Hg, Hypoplectrus gemma, Blue hamlet, 3.8; Hm, Halichoeres maculipinna, Clown wrasse, 3.3; Hme, Haemulon melanurum, Cottonwick Grunt, 2.2; Hp, Hypoplectrus puella, Barred hamlet, 3.7; Hpl, Haemulon plumierii, White grunt, 3.8; Hra,Halichoeres radiatus, Puddingwife, 3.5; Hs, Haemulon sciurus, Bluestriped grunt, 3.5; Ht, Holacanthus tricolor, Rock beauty, 3.0; Hu, Hypoplectrus unicolor, Butter hamlet, 4.0; Hv, Haemulon vittatum, Boga, 3.3; Ksi, Kyphosus spp., Chub, 2.0; Lap, Lutjanus apodus, Schoolmaster, 4.3; Lm, Lachnolaimus maximus, Hogfish, 4.2; Ls, Lutjanus synagris, Lane snapper, 3.8; Lt, Lactophrys triqueter, Smooth trunkfish, 3.3; Mc, Microspathodon chrysurus, Yellowtail damselfish, 2.1; Mm, Mulloidichthys martinicus, Yellow goatfish, 3.2; Oa, Halichoeres garnoti, Yellowhead wrasse, 3.7; Oc, Ocyurus chrysurus, Yellowtail snapper, 4.0; Pm, Psuedupeneus maculatus, Spotted goatfish, 3.7; Pp, Pomacentrus partitus, Bicolor damselfish, 2.0; Ppa, Pomacanthus paru, French angelfish, 2.8; Sa, Sparisoma atomarium, Greenblotch parrotfish, 2.0; Sb, Sphyraena barracuda, Great barracuda, 4.5; Sc, Scarus coeruleus, Blue parrotfish, 2.8; Si, Synodus intermedius, Sand diver, 4.2; Sr, Scomberomorus regalis, Cero, 4.5; Sta, Scarus taeniopterus, Princess parrotfish, 2.0; Stab, Serranus tabacarius, Tobaccofish, 4.2; Sti, Serranus tigrinus, Harlequin bass, 3.5; Sv, Scarus vetula, Queen parrotfish, 2.0; Svi, Sparisoma viride, Stoplight parrotfish, 2.0; Tb, Thalassoma bifasciatum, Bluehead wrasse, 3.3.)

Table 1. Recruits Top 25% of species observed in mixed-species groups based on the number of mixed species links observed across the reef fish community. Mixed species links are the total number of paired species links derived from all mixed species groups. Total occurrences are the total number of times a species was associated with another species. Strength is the sum of associations of any species with all other species. Eigenvector centrality is a measure of how strongly a species was associated with another species, and the strength of the association of that species with others (e.g. high eigenvector centrality indicates that a species has strong associations with multiple species). See details on network analysis in Auster et al. (2019). Trophic level is based on values in Fishbase as described above. The two-letter abbreviation is used in the network diagrams. Scientific name and common name are listed in the legend of Figure 2.

Common Name	Family	Trophic Level Spp Abbrev	Mixed Species Links	Total occurrences	Strength	Eigenvector Centrality
Blue hamlet	Serranidae	3.8_Hg	28	206	336	0.32
Spotted goatfish	Mullidae	3.7_Pm	27	89	119	0.06
Princess parrotfish	Scaridae	2.0_Sta	26	299	492	0.52
Greenblotch parrotfish	Labridae	2.0_Sa	25	111	179	0.18
Sand diver	Scaridae	4.2_Si	25	406	637	0.58
Bluehead wrasse	Labridae	3.3_Tb	24	238	380	0.43
Stoplight parrotfish	Scaridae	2.0_Svi	22	110	182	0.17
Ocean surgeonfish	Acanthuridae	2.4_Ab	20	43	64	0.04
Yellowtail snapper	Lutjanidae	4.0_Oc	18	30	41	0.01
French grunt	Haemulidae	3.5_Hf	16	19	33	0.01
Clown wrasse	Labridae	3.3_Hm	15	97	163	0.18
Doctorfish	Acanthuridae	2.1_Ach	14	27	37	0.02
Blue chromis	Pomacentridae	2.0_Ccy	14	46	57	0.02
Butter hamlet	Serranidae	4.0_Hu	14	25	37	0.02
Reef butterflyfish	Chaetodontidae	3.9_Cse	13	15	24	0.01

Table 2. Piscivore species in mixed-species groups. See Table 1 legend for details.

Common Name	Family	Trophic Level Spp Abbrev	Mixed Species Links	Total Occurrences	Strength	Eigenvector Centrality
Sand diver	Synodontidae	4.2_Si	25	403	625	0.64
Yellowtail snapper	Lutjanidae	4.0_Oc	18	30	41	0.01
Butter hamlet	Serranidae	4.0_Hu	14	26	40	0.03
Hogfish	Labridae	4.2_Lm	9	14	15	0.01
Trumpetfish	Aulostomidae	4.3_Am	7	6	9	0
Graysby	Epinephelidae	4.3_Ccr	5	6	6	0
Bar jack	Carangidae	4.3_Cr	5	4	7	0
Schoolmaster	Lutjanidae	4.3_Lap	5	3	6	0
Cero	Scombridae	4.5_Sr	4	3	4	0
Tobaccofish	Serranidae	4.2_Stab	4	2	4	0
Great barracuda	Sphyraenidae	4.5_Sb	2	4	4	0
Spotted eagle ray	Aetobatidae	4.2_An	1	1	1	0

mixed species groups (Table 2 lists twelve piscivore species within such groups). While there were fewer associated piscivore links, the interactions show that a diversity of piscivores participated in mixed-species groups to hunt and that benefits accrued to higher trophic level fishes. Piscivores were largely observed as followers rather than focal species in these groups, indicating that taxa in lower trophic guilds were the principal drivers of these associations. Graphical representations of network metrics (mixed species links, strength, total occurrences, eigenvector centrality) and trophic level plotted on species ordered by total occurrences (from highest to lowest) identify both highly connected species and those that have few mixed species interactions (Figure 3). There is a common pattern of dominance for both the community and piscivore-only analyses with multiple trophic levels represented in groups regardless of commonality of species in such groups.

These results demonstrate that mixed species foraging and hunting is a common characteristic of these reef fish communities and that individual groups can include members across trophic guilds (planktivores to piscivores). Such interactions likely increase individual fitness and may have important demographic consequences that have yet to be quantified directly. Network analysis revealed a gradient of interaction complexity across taxa with some species exhibiting dominance based on multiple occurrences in groups.

Identification of key taxa can focus attention for management and monitoring objectives onto dominant species that have recurring roles in these types of interactions. While this demonstration is a snapshot in time, implementation for time series monitoring would provide greater insight into these systems, quantify variation over time linked to habitat variability (see Auster and Lindholm 2008), and include areas subject to natural and human-caused disturbance (e.g., addressing impact response along gradients; Reeds et al. 2018). More work is needed to quantify the interactions between reef fish across trophic levels and the influence of fishes on coral communities

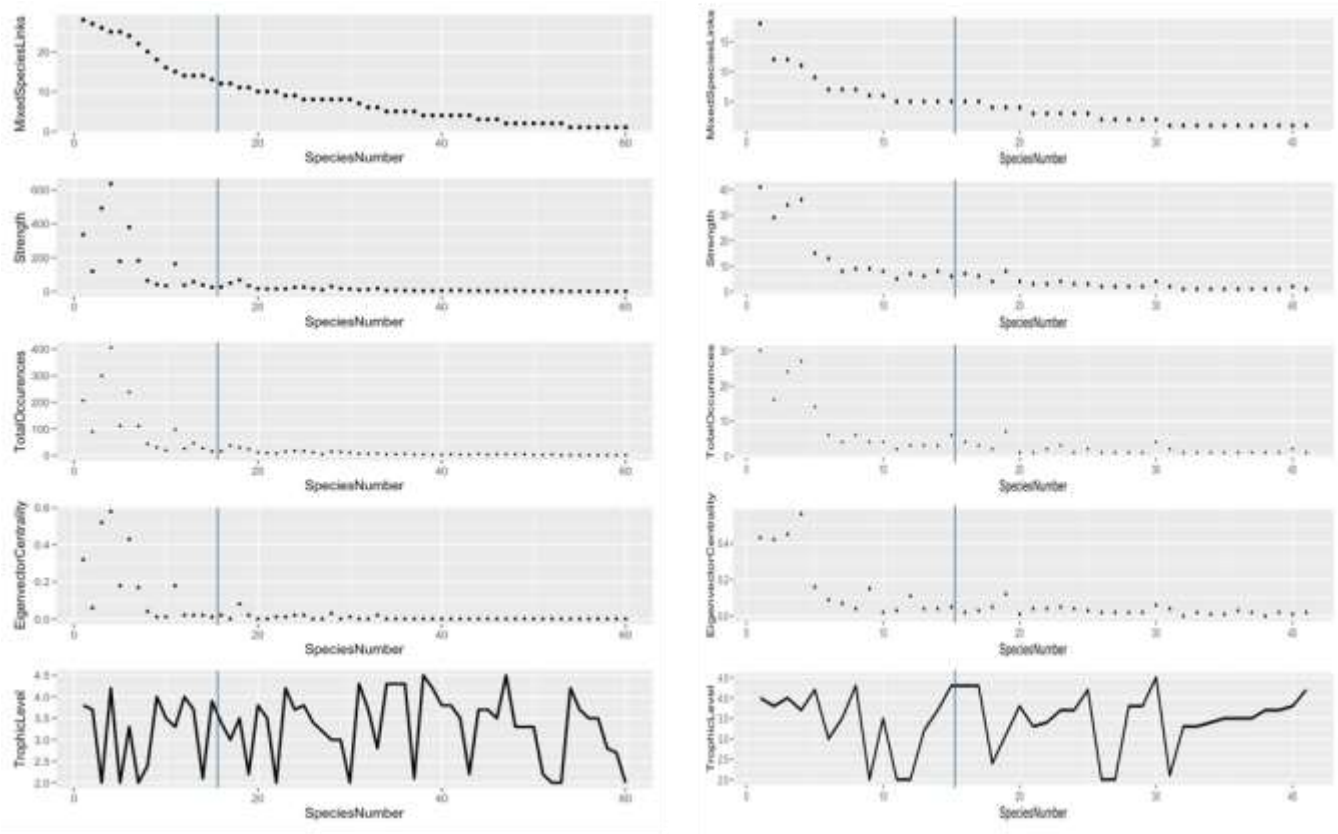

Figure 3. Patterns of network metrics and trophic level (y-axis) plotted on species ranked highest to lowest based on mixed-species links (x-axis). Community interactions left panel and piscivore inclusive groups only in right panel. Vertical lines represent the top 25% (n=15) of species to visualize dominant species based on multiple metrics.

and coral transplants to better inform restoration efforts (e.g. Auster and Cullerton 2024). The behavioral interactions of coral reef fishes are part of the invisible fabric of nature that belies straightforward assessment from standard methods (Auster et al. 2013, Travis et al. 2014,). Indeed, we must understand these interactions to reveal all the pieces that make up the complexity of coral reef ecosystems and assess their role in restoration and conservation.

Acknowledgements

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Benthic Community Assemblages in Temperate and Tropical Natural Analogue Reef Environments

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Introduction

Heightened emissions of CO_2 in our atmosphere are causing a drop in the pH of our oceans, which act as a major carbon sink (Foo et al. 2018). This phenomenon is widely known as ocean acidification (OA). Field studies of this phenomenon, while still lacking, are increasing, especially in natural analogue sites, which are areas containing naturally low pH gradients emulating or exceeding future projections under anthropogenic stressors (Foo et al. 2018). Many studies have looked at the impacts of decreasing pH on marine calcifiers such as scleractinian corals, which are important reef-building organisms (McCulloch et al. 2017, Kurihara et al. 2021, Comeau et al. 2022). However, there are few of studies examining other important competitive benthic organisms including algae, soft corals, zoantharians, and sponges.

Non-scleractinian groups have been hypothesized to have important roles in marine environments under OA, since community shifts from calcifying to non-calcifying communities have been observed in some areas. For example, one study in southern Japan observed a shift in reef communities from hard corals to soft corals with increasing pCO_2 levels (Inoue et al. 2013). Other studies have observed increased abundance of algae (Kroeker et al. 2013), zoantharians (Reimer et al. 2021, Reimer et al. 2023), and sponges (Bell et al. 2013) in stressed environments. Additionally, while some comprehensive benthic surveys have also been conducted (Maggioni et al. 2021, Kurihara et al. 2021), there is still a lack of studies which examine in detail such benthic community assemblages. It is crucial to include those groups that may have abilities to adapt to OA conditions, since some may come to dominate these ecosystems in the future (Agostini et al. 2015, Agostini et al. 2018). Finally, for coral reefs, there are only a handful of natural analogue sites currently being studied, and thus it is important to conduct groundwork assessments of community assemblages focusing on non-scleractinian taxa in these unique regions. Beyond this, it is important to highlight that within these limited studies in these specific environments, research on temperate coral communities remains particularly scarce. Understanding how natural analogue community systems are currently established from tropical to temperate regions can help us further understand how different coral communities may shift in the future.

As a part of a larger project aimed at assessing benthic community assemblages in acidic (elevated CO_2 areas) and ambient control reef sites, we surveyed two natural analogue systems in different climate zones using visual transect surveys and environmental DNA (eDNA): one temperate (mainland Japan) and one tropical (Palau). Although the combination of transect and eDNA surveys to assess reef communities and diversity has been increasingly used in coral reef research, application to elevated CO_2 systems remains limited, especially for resolving differences between benthic community assemblages between elevated CO_2 and control sites. As well, while most natural analogue studies have focused on scleractinian corals or fishes, few studies from coral communities have considered the large range of "other" benthic taxa. This project was primarily driven by the opportunity to study temperate reef communities at Shikine Island in mainland Japan, a relatively understudied natural analogue system, with Palau presented here as a tropical comparison. In this article, we report the preliminary results from our study.

Research Undertaken

Surveys were conducted in natural analogue sites located in Palau, a tropical island nation in the western Pacific (April and September 2023), and at Shikine Island, a temperate volcanic island located in the Izu Islands off mainland Japan (October 2024). While many elevated CO_2 environments are due to CO_2 seeps, Ngerikuul Bay (Nikko Bay) in Palau is unique because its low pH is due to it being a highly isolated semi-enclosed bay with long seawater residence times (Golbuu et al. 2016). The sites on Shikine Island, discovered in 2015 (Agostini et al. 2015), have elevated CO_2 levels because of volcanic CO_2 seeps. Shikine Island is unique as it is within the temperate Izu Arc in Japan, presenting the rare opportunity to examine acidification in temperate coral communities.

Our preliminary results from Palau focus on six sites (three with elevated CO_2 and three controls), while preliminary observations from Shikine Island are presented to provide context as an important temperate analogue and the basis of ongoing work. In Palau, at each site, six 10 m transects were placed at depths between 3-6 m, and photographs were taken 1 m above the transect, every meter. The photo transect data were subsequently analyzed using ImageJ and the point line intercept transect methodology (three transects per site were analyzed for the preliminary results reported here). Organisms were separated into five benthic group categories (scleractinian corals, soft corals, sponges, macroalgae, zoantharians) and were recorded at points 10 cm apart, for a total of 100 points per transect (Figs. 1, 2). To test for differences among sites, a permutational multivariate analysis of variance (PERMANOVA) and principal component analysis (PCA) were performed. Additionally, for eDNA analysis, three 2L water samples were collected on the surface above the transects at each site. Additional 2L water samples were also taken as field and laboratory controls.

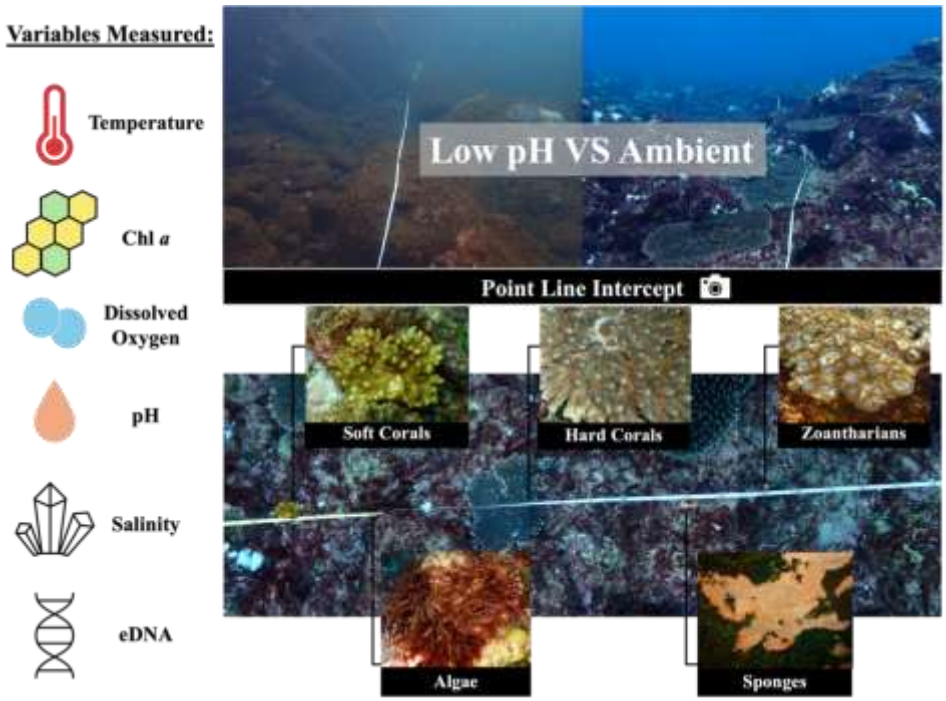
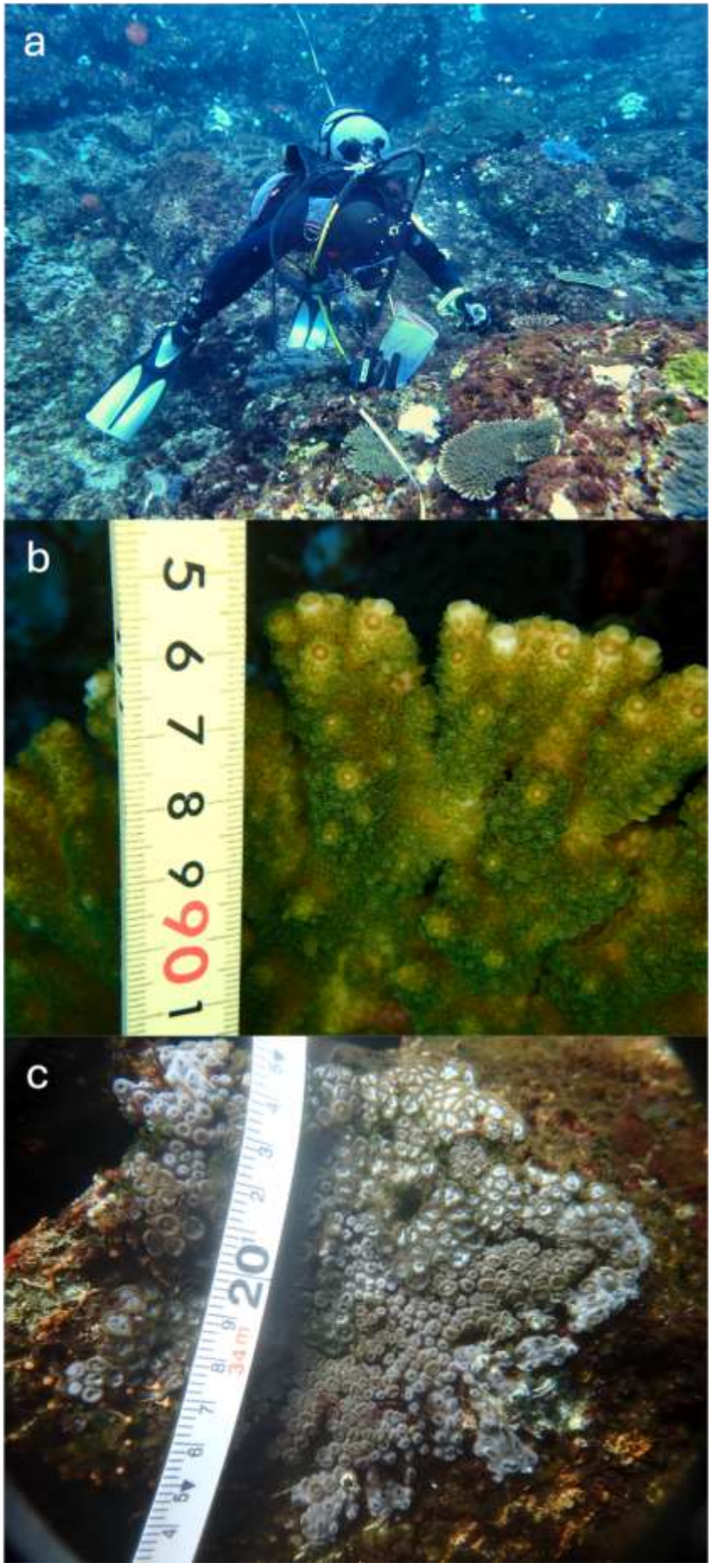


Figure 1. Differences in appearance between low pH and ambient environments at Shikine Island, Japan, are shown, together with the methodologies employed: point line intercept transects (PLIT) and environmental measurements as shown.



Preliminary Results

Preliminary results from Palau showed a significant difference between the benthic groups identified in elevated CO_2 vs control environments (PERMANOVA, p=0.024). Furthermore, the PCA indicated that algae and hydrozoans were more associated with the control environment while the presence of hard corals, sponges, and zoantharians contributed to the variance within the elevated CO_2 environment (Fig. 3).

The most striking differences between the elevated CO_2 and control sites at Shikine Island were differences in the abundances of algae, sponges, and hard corals present between the CO_2 seep sites as compared with the ambient sites (Fig. 1). Hard corals and sponges were much more prevalent outside the elevated CO_2 sites compared to inside, while the acidified zones were dominated by algae and, in the shallows, zoantharians.

Figure 2. Underwater photographs from surveys at Shikine Island, Japan showing a) Ayaka Umeda Paul conducting benthic surveys, b) an example of a hard coral (*Acropora* sp.) close-up image as used for identification, and c) an example of a zoantharian (*Zoanthus* sp.) identified along the transect.

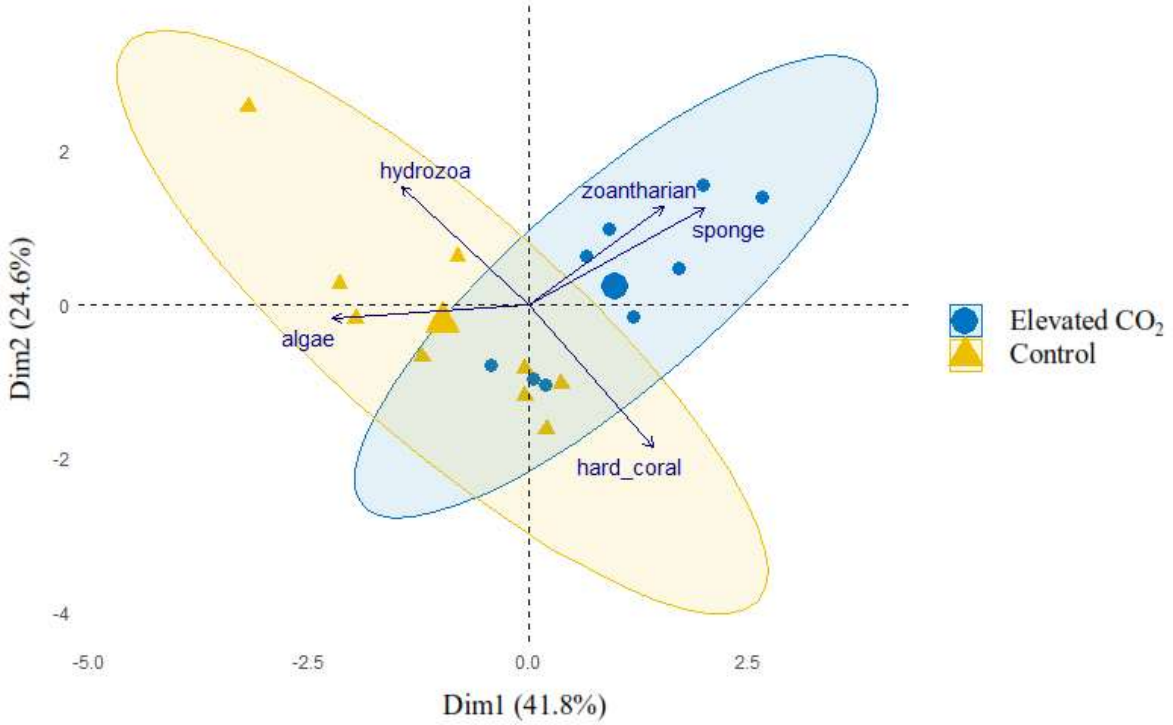


Figure 3. Principal component analysis (PCA) showing variability of benthic groups found in elevated CO_2 and ambient (control) environments in Palau. Dim1 explains 41.8% of variance along the y-axis and Dim2 explains 24.6% of variance along the x-axis, which in total explains 66.4% of the variability in this dataset. Zoantharians, sponges, and hard corals drive variance in elevated CO_2 sites while hydrozoans and algae are shown to drive the variability in control sites.

Discussion and Concluding Remarks

While the presence of sponges and zoantharians in the elevated CO_2 sites we surveyed seems to follow expectations from previous studies, indicating the resilience of these taxa, the abundance of hard corals in Ngerikuul Bay (Nikko Bay) was somewhat unexpected. This prevalence of hard corals could be a product of the unique environment there, because the bay may enable isolation and self-seeding, possibly resulting in scleractinian corals acclimatizing to the unusual conditions (Golbuu et al. 2016). Meanwhile, sponges and zoantharians drive the variability inside the elevated CO_2 bay, indicating their comparable resilience under environmental stressors, and further supporting their role as potential 'winners' in low pH phase shift scenarios (Bell et al. 2018, Reimer et al. 2023). These results indicate how under low pH environmental stressors, sponges and zoantharians could become some of the dominant benthic taxa on future reefs.

From our recent field observations in Shikine, we expect to see slightly different patterns than those observed in Palau. Because the bays with high CO_2 in Shikine provide a more open system than Ngerikuul Bay in Palau, actively allowing exchange between the inside and outside of the bay, hard corals there may not have the opportunity to properly adapt to the different environment, unlike in Ngerikuul Bay. Interestingly, sponges, which were more abundant in the elevated CO_2 bay in Palau, were not so common in Shikine. This could be due to the presence of sediment and lack of a substrate to which sponges could successfully attach, but such hypotheses remain to be confirmed.

Our preliminary results from Palau and initial observations from Shikine show distinct differences in community assemblages between elevated CO_2 environments as compared to nearby ambient control sites, including specifically an increased abundance of "other" benthic taxa besides scleractinian corals under low pH conditions. The results from Palau and Shikine differ to some degree, and the unique features within each of these natural analogue sites may explain some of these differences. However, questions remain about the specific mechanisms that drive the resilience of each taxon. Comparing these results with other natural analogue sites to identify underlying patterns of OA is an important next step of this research. While reef-building hard corals are important to study, it is clear that the prevalences of other benthic taxa are also critical to understanding the possible phase shifts that ecosystems will undergo with OA. The data support the view that sponges, zoantharians, and algae may be among the strongest benthic competitors shaping our reefs in the future.

Acknowledgements

I would like to thank the **International Coral Reef Society** for providing funds to support this project, through a **Ruth Gates Fellowship Award**. Essential support was also provided by the University of Tsukuba, Shimoda Marine Research Center and the International CO_2 Natural Analogues Network (ICONA). I would also like to thank all the collaborators in the natural analogues project, including the Palau International Coral Reef Center (PICRC), the Ravasi Unit at the Okinawa Institute of Science and Technology (OIST), the Kurihara Laboratory from the University of the Ryukyus, Rodolfo-Metalpa Laboratory from the Institut de Recherche Pour le Développement (IRD), and the Molecular Invertebrate Systematics and Ecology (MISE) Laboratory from the University of the Ryukyus.

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REEF RECRUITS

Exploring the Hidden Biodiversity of Deep-Sea Vertical Reefs in the Galápagos

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Background

Ecological transitions from the lower mesophotic zone (80–150 m) into deeper aphotic reef communities (>200 m) remain largely unresolved due to limited sampling and technological constraints. Vertical geomorphologies, such as cliffs, provide unique environmental conditions, including enhanced currents and pronounced topographic heterogeneity, that distinguish them from surrounding seafloor habitats and favour the development of these structurally complex communities (Pearman et al. 2023). Due to their irregular and complex geomorphology, vertical walls often harbour a variety of microhabitats, in addition to those created by foundation species such as corals, which typically thrive in vertical walls (Robert et al. 2017). Furthermore, some of these geomorphological features (Robert et al. 2020), together with their biotic components, may serve as keystone structures, which are habitat components whose presence and spatial configuration disproportionately support species diversity by providing microhabitats or unique resources (Tews et al. 2004). With support of an ICRS graduate fellowship, my (MPH) research explores one of the least-studied reef environments on Earth: deep-sea vertical walls within the Galápagos Marine Reserve (GMR).

Research Objectives

The primary goal of the project is to characterize the diversity, structure, and drivers of epibenthic megafaunal communities inhabiting deep vertical walls (400, 550, and 700 m depths) across the Galápagos Archipelago. A secondary objective is to assess the presence and distribution of Vulnerable Marine Ecosystem (VME) indicator taxa, such as cold-water corals and coral gardens, and to explore their implications for conservation and spatial management.

Data Collection and Methods

This research is based on high-definition ROV imagery collected during the 2023 Schmidt Ocean Institute expedition aboard the R/V *Falkor II*, using

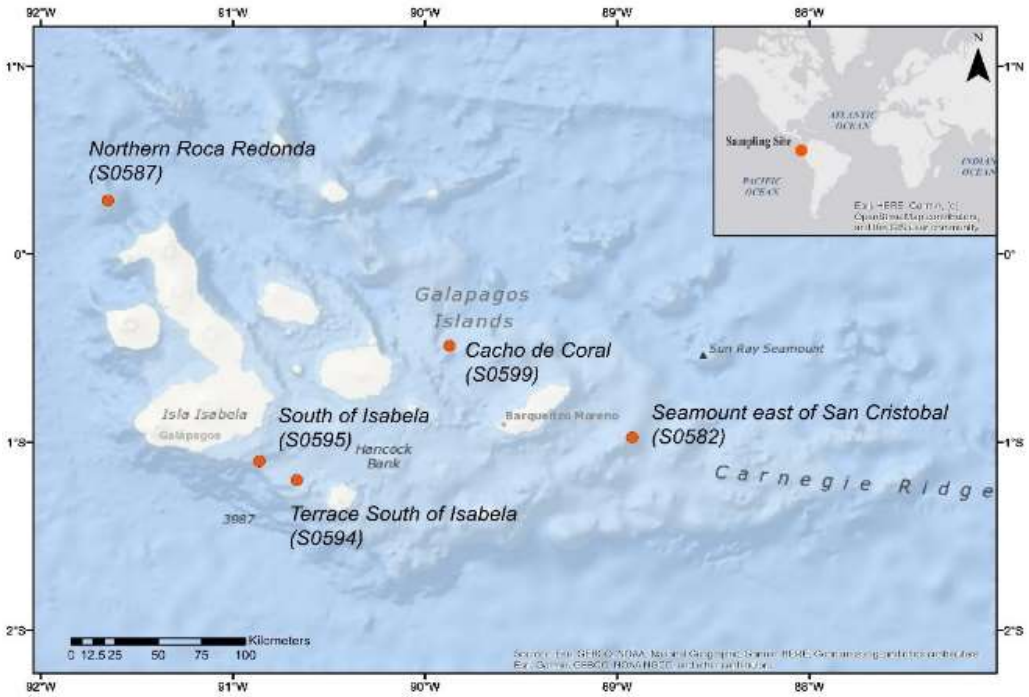
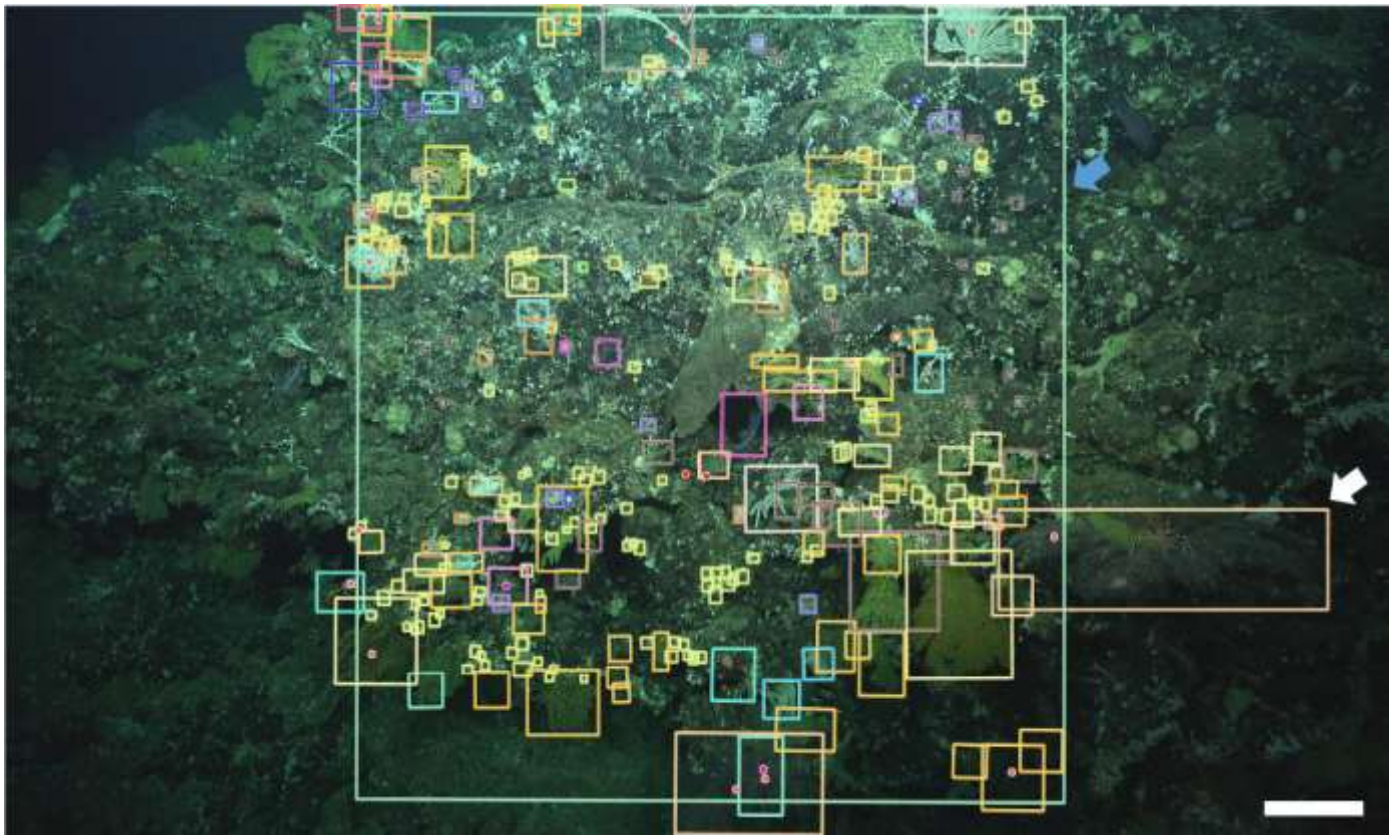


Figure 1. Map of sites surveyed by the ROV SuBastian used for imagery transects across the GMR



the ROV *SuBastian* (Robert et al. 2023). Seven vertical wall transects across four sites in the Galápagos were analyzed (Fig. 1).
A total of 12,458 epibenthic megafaunal individuals were identified and classified into 123 morphospecies. Systematic image annotation was conducted on 448 frames covering ~1,330 m² of vertical habitat, using BIIGLE 2.0 online annotation software (Langenkämper et al. 2017; Fig. 2). Quantitative analyses included rarefaction, beta diversity partitioning, NMDS ordination, hierarchical clustering, and VME indicator assessments

Key Findings to Date

Preliminary results reveal exceptionally high biodiversity for the surveyed area—approximately one morphospecies per square meter, despite the known limitations of image-based taxonomy. Species accumulation curves indicate that sampling was nearly complete across all transects. Community composition varied strongly with depth, substrate type, and site, although these drivers were often confounded at fine spatial scales. Importantly, species turnover, rather than nestedness, dominated beta diversity, suggesting that different depth zones hosted distinct assemblages rather than simple subsets of the same fauna.

A major outcome of this work is the documentation of 31 VME indicator taxa (Fig. 3), including cold-water corals (e.g., *Madrepora oculata*, Caryophylliidae), octocoral gardens, and hydrocoral assemblages. Several transects exceeded 75–95% VME presence, highlighting the conservation significance of these vertical reefs within the GMR.

Broader Implications and Next Steps

This project provides the first comprehensive ecological description of deep-sea vertical reef communities in the Galápagos, addressing a critical knowledge gap in a UNESCO World Heritage Site. The findings underscore the need to explicitly incorporate vertical habitats into deep-sea spatial planning, especially given ongoing artisanal fishing activity in parts of the reserve.

Ongoing work includes finalizing taxonomic validation, refining multivariate analyses, and preparing a peer-reviewed manuscript. In parallel, the annotated image dataset is being organized to support future AI-assisted biodiversity monitoring.

Figure 2. Snapshot of the BIIGLE 2.0 annotations in a vertical wall section.

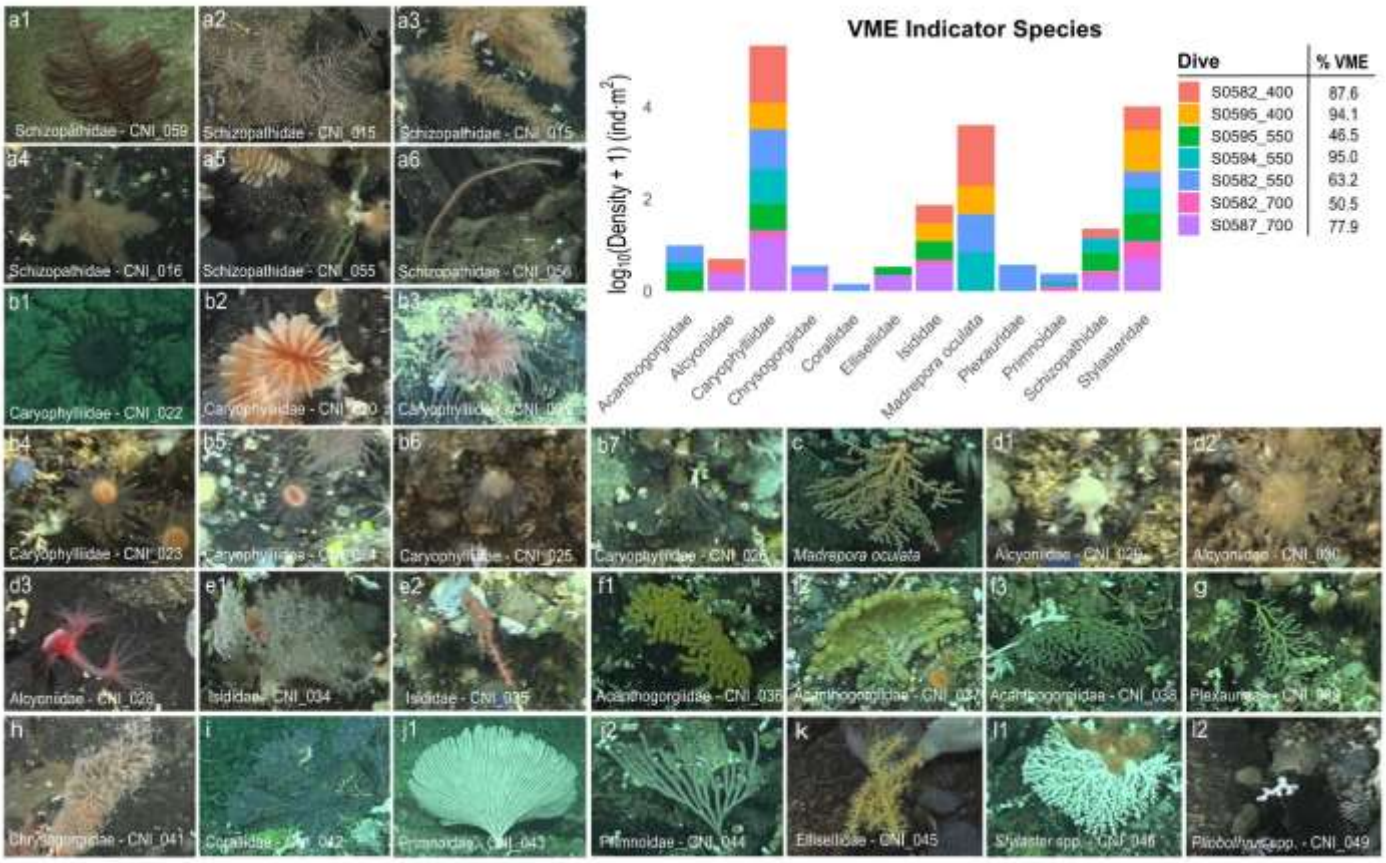


Figure 3. Representative images of identified VME taxa and their morphospecies codes (CNI IDs), alongside a log-transformed stacked bar plot displaying the density (log_{10} (ind·m^2 + 1)) of each VME species across all transects

Through the support of this fellowship, I have been able to combine deep-sea exploration, quantitative ecology, and reef conservation into a single framework, contributing new insights into how reef-like ecosystems persist far beyond the limits of light.

About Manuja Promodya Hendawitharana

Manuja is a Pre Doctoral researcher at the Institut De Ciències Del Mar (ICM) of the Spanish National Research Council (CSIS) and a PhD student at the Universitat de Barcelona.

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Tracing corallivore-mediated nutrient flow on coral reefs: a stable isotope approach

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Background

Fish are major reservoirs of biomass on tropical coral reefs and play central roles in nutrient storage, transformation, and redistribution (Sorokin 1995, Allgeier et al. 2014, Francis & Côté 2018) Their waste products harbour diverse macro- and micro- nutrient profiles, and can influence coral growth, productivity, and potentially thermal tolerance (Chase et al. 2014, Schiettekatte et al. 2023, Shantz et al. 2023, Van Wert et al. 2023). Yet quantifying nutrient transfers between fish and corals remains challenging. Specifically, the fate of nutrients released by fish and their bioavailability to nearby corals remain poorly understood, as no direct methods currently exist to track these flows (Carmignani et al. 2025).

This gap is particularly important in competitive benthic environments, where fish-derived nutrients may support coral persistence or fuel the growth of opportunistic algae (Holbrook et al. 2008, Burkepile et al. 2013; Chase et al. 2014, Shantz et al. 2015).

Developing methods to trace nutrient flows between fish and the benthos is therefore essential for a more integrated understanding of fish contributions to reef productivity and resilience to stress. Stable isotope approaches provide a promising avenue. Pulse-chase experiments using labelled isotopes have been used to track nutrient movement within and between organisms, an approach that may offer quantitative and temporal estimates for fish-mediated nutrient transfers.

Here, we tested the effectiveness of labelled isotopes to track macronutrient flow through a fish-mediated trophic pathway on coral reefs. Specifically, we aimed to trace carbon and nitrogen fluxes from a reef-building coral to a corallivorous fish via consumption, and back from the fish to coral and calcareous algae via expulsion. We hypothesised that enrichment would be detectable at each stage, reflecting rapid digestion and limited assimilation within fish, and the release of nutrients in bioavailable forms (Cox 1986, Holbrook et al. 2008, Schiettekatte et al. 2023).

Research Undertaken

We conducted the laboratory experiment at Heron Island Research Station, Australia, using the coral *Acropora aspera*, the butterflyfish *Chaetodon melannotus*, and the calcareous alga *Halimeda* (Fig. 1).

Coral fragments, fish, and macroalgae were collected from the lagoon and housed in outdoor aquaria, where fish were fasted for 21 hours prior to the experiment. The experiment itself ran for nine hours using natural daylight and comprised three phases:

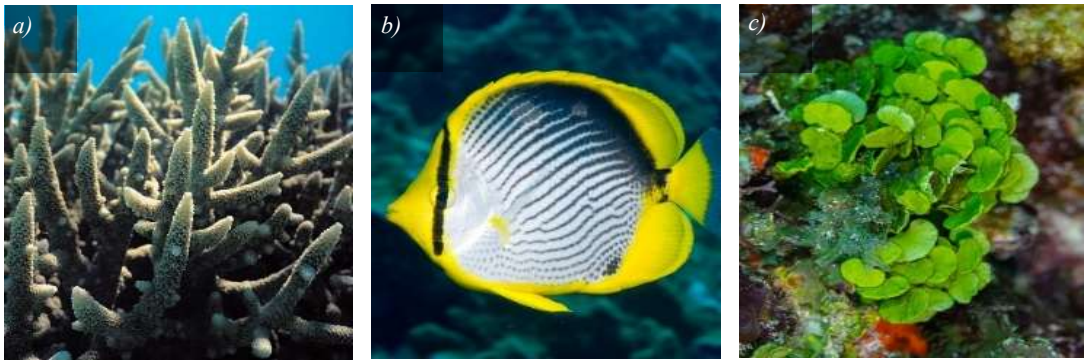

Figure 1. Species used in the experiment. *a) Acropora aspera* (Dana, 1846; photo by Charlie Veron, Corals of the World)*; b)*: *Chaetodon melannotus* (Bloch & Schneider, 1801; photo by Erik Schlögl, iNaturalist). *C) Halimeda sp.* (Lamouroux, 1812; photo by Diego Delso, delso.photo).

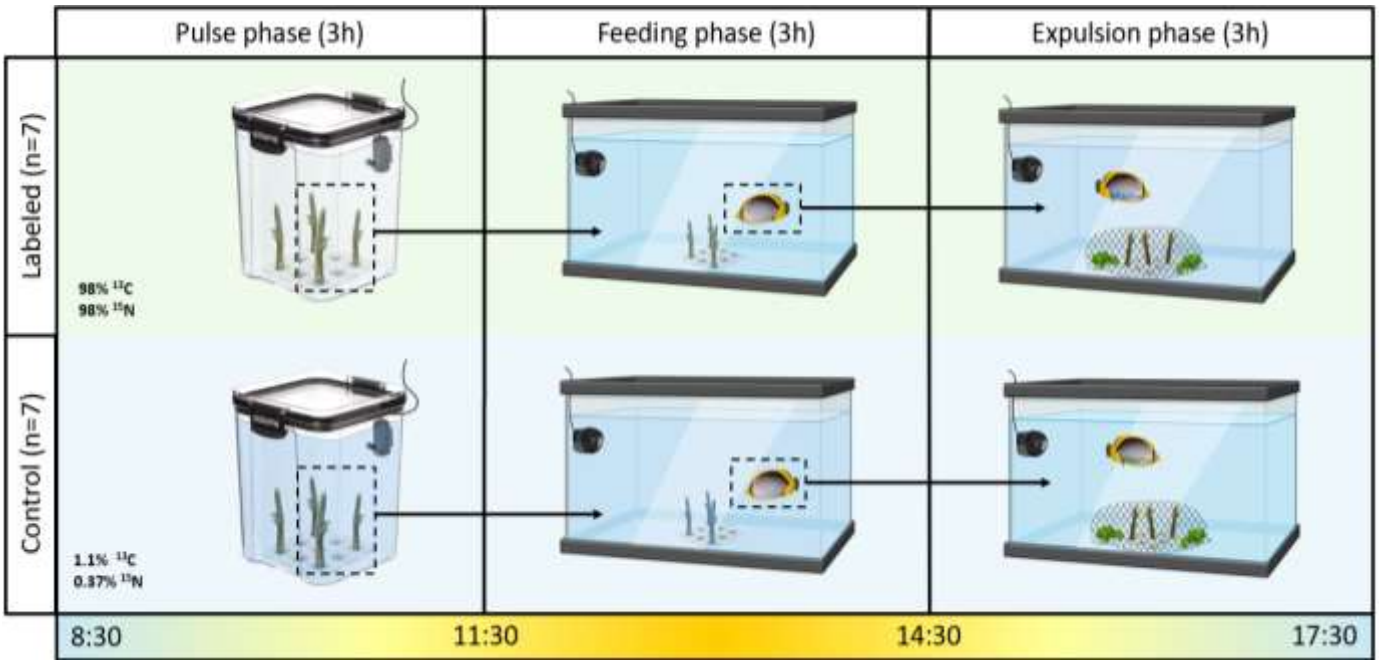

Fig. 2. Diagram of pulse-chase experiment. Pulse incubations used artificial seawater, while feeding and expulsion tanks used lagoon seawater. The colored bar represents approximate phase timing and sunlight intensity. Black dashed boxes with arrows indicate organisms that were moved to the next phase after 3h.

(1) Pulse phase (3h): Corals were incubated in artificial seawater with $^{15}NH_4Cl$ and $NaH^{13}CO_3$ (enriched) or NH_4Cl and $NaHCO_3$ at natural isotopic abundances (control). A subset of fragments was collected at 3 hours to quantify isotopic uptake.

(2) Feeding phase (3h): The remaining incubated coral fragments were introduced to aquaria containing individual butterflyfish, and feeding rates were recorded using a GoPro video camera.

(3) Expulsion phase (3 h): Fish were transferred to aquaria containing non-labelled coral fragments and *Halimeda*. These organisms were exposed to fish-derived waste but protected from feeding with a wire dome. Coral and algae samples were collected at 1.5 and 3 hours. Fish were then euthanised and dissected to collect stomach content, faeces and tissue (Fig. 2).

All samples were freeze-dried, ground, and analysed for $\delta^{13}C$ and $\delta^{15}N$ enrichment.

Summary of Results

From the pulse phase, both coral tissue and Symbiodiniaceae showed strong enrichment in ^{13}C and ^{15}N, confirming effective assimilation of labelled nutrients (Fig. 3).

In the fish samples, the stomach contents of fish that fed on labelled corals showed a trend of higher ^{13}C and ^{15}N enrichment, but overall there were no significant differences between treatments (Fig. 4). Stomach enrichment varied widely across individuals, with bite rates positively correlated to labelling success. This trend suggested stomachs were not fully emptied prior to the experiment, and residual prey diluted the isotopic signal. Gut retention times were also likely longer than expected (>6 hours, compared to 1.5–2 hours reported by Cox (1986) and 2.75-5 hours in previous test trials). Subsequently, no enrichment was detected in faeces or tissues. Neither corals nor algae exposed to fish waste in the expulsion phase showed enrichment, indicating negligible nutrient release and uptake within the timeframe.

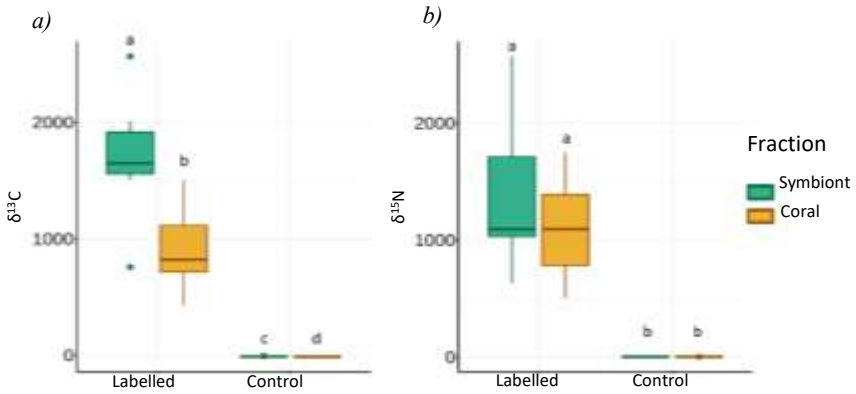

Figure 3. Enrichment levels (3*a*: $\delta^{13}C$ and 3*b*: $\delta^{15}N$) measured from coral fragments after 3h incubation in the pulse phase. Letters within plots denote significant differences ($p < 0.05$).

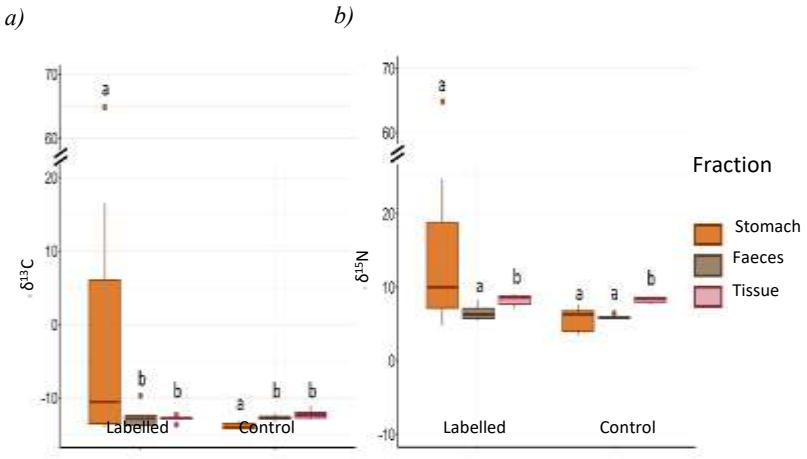

Figure 4. Enrichment levels (4*a*: $\delta^{13}C$ and 4*b*: $\delta^{15}N$) measured in fish after 3 h feeding on incubated corals followed by 3h of expulsion. Letters within plots denote significant differences ($p < 0.05$).

Concluding Remarks

This study was the first, to our knowledge, to employ isotopic labelling to trace nutrients through a corallivore-mediated trophic pathway. While we observed significant uptake of inorganic nutrients by the coral holobiont, subsequent transfers to fish and benthic recipients were minimal or undetectable within the experimental timeframe. These findings highlight methodological challenges, and we therefore provide recommendations for improvements:

Future approaches should consider longer fasting and feeding periods, larger sample sizes to account for behavioural variation, and higher nutrient concentrations during coral incubation to strengthen isotopic signals. These adjustments, however, carry trade-offs and should be accompanied by field-based observations that offer context for nutrient transfer and retention in natural conditions. Continuing to develop these methods remains critically important for resolving the role of reef fish in supporting benthic productivity and mediating nutrient cycling, particularly under ongoing environmental change.

The ICRS Graduate Research Fellowship was instrumental to this project by supporting the research stay at HIRS. The completed work has since been presented at two conferences and is now being prepared as a peer-reviewed manuscript, with the aim of advancing methodologies for studying reef fish nutrient dynamics.

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Environmental Memory Drives Holobiont Resilience Across a Reef Mosaic

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Introduction

Coral reefs are increasingly exposed to multiple dimensions of global change, including ocean warming, altered carbonate chemistry, deoxygenation, and more frequent extreme events, all of which are contributing to widespread bleaching and mortality on reefs worldwide (Hoegh-Guldberg et al. 2019; Pezner et al. 2023; Spady et al. 2026). At the same time, reef habitats differ substantially in their local environmental regimes, and this fine-scale variability is increasingly recognized as an important determinant of coral stress responses (Oliver and Palumbi 2011; Ziegler et al. 2017). In particular, the magnitude and frequency of temperature fluctuations can influence coral thermal tolerance, with colonies from more variable environments often exhibiting greater resistance to heat stress than conspecifics from more temperature-stable locations (Oliver and Palumbi 2011; Palumbi et al. 2014; Brown et al. 2024). Therefore, it appears that repeated exposure to sublethal variability may shape coral performance through physiological acclimatization and environmental memory that influence responses to later stress events (Hackerott et al. 2021; Brown and Barott 2022; Brown et al. 2024).

In this study, Heron Reef in the southern Great Barrier Reef was used as a natural laboratory to investigate how contrasting environmental regimes structure coral holobiont traits across space. We focused on *Pocillopora damicornis*, a species that occurs across a variety of sites. Across the reef mosaic, daily mean temperature was similar among sites, but diel temperature variability varied spatially, ranging from 1.12–3.39°C day^{-1}. By integrating a full year of high-frequency environmental measurements with data on coral physiology, Symbiodiniaceae composition, and bacterial community structure across reef sites, this project evaluates whether these differences in local variability are associated with consistent differences in coral condition and microbial partnerships, and whether these patterns provide insight into mechanisms underlying coral resilience.

Methods / Study Area

This work was conducted across six sites at Heron Reef, representing the major geomorphological habitats present there: Harry's Bommie (HB), Fourth Point (FP), Deep Lagoon (DL), Shallow Lagoon (SL), Reef Crest (RC), and Reef Flat (RF). These sites span less than 5 km, but differ strongly in environmental variability. Using one year of high-frequency environmental records, we compared temperature, light, dissolved oxygen, pCO_2, salinity, turbidity, and fluorescence among sites. We then collected 10 *P. damicornis* colonies per site and quantified a suite of host and symbiont traits, including biomass, host protein, skeletal density, photoprotective pigments, symbiont density, chlorophyll-*a*, and photochemical yield. To characterize the coral holobiont more broadly, we also sequenced bacterial 16S rRNA communities and Symbiodiniaceae ITS2 profiles.

Summary of Results

Diel temperature variation, rather than mean annual temperature, most closely tracked the observed biological patterns across the reef mosaic. Differences in mean daily temperature were non-significant among sites, but the magnitude of daily temperature fluctuations differed significantly. Colonies from the intermediately variable site, the Shallow Lagoon (SL), consistently showed the highest levels of biomass, host protein, chlorophyll-*a*, and photoprotective pigments, indicating a phenotype characterized by strong tissue investment and physiological buffering. In contrast, corals from the least variable habitats (HB, FP, DL) had muted physiological profiles, while colonies from the most variable habitats (RC, RF) retained relatively high thermal tolerance but showed lower average physiological investment than did the SL corals. Together, these results suggest a non-linear response to thermal history, in which moderate variability appears beneficial, whereas more extreme variability may impose energetic costs.

The ITS2 sequencing was especially interesting because it showed that all sampled colonies at all sites were dominated by the same Symbiodiniaceae

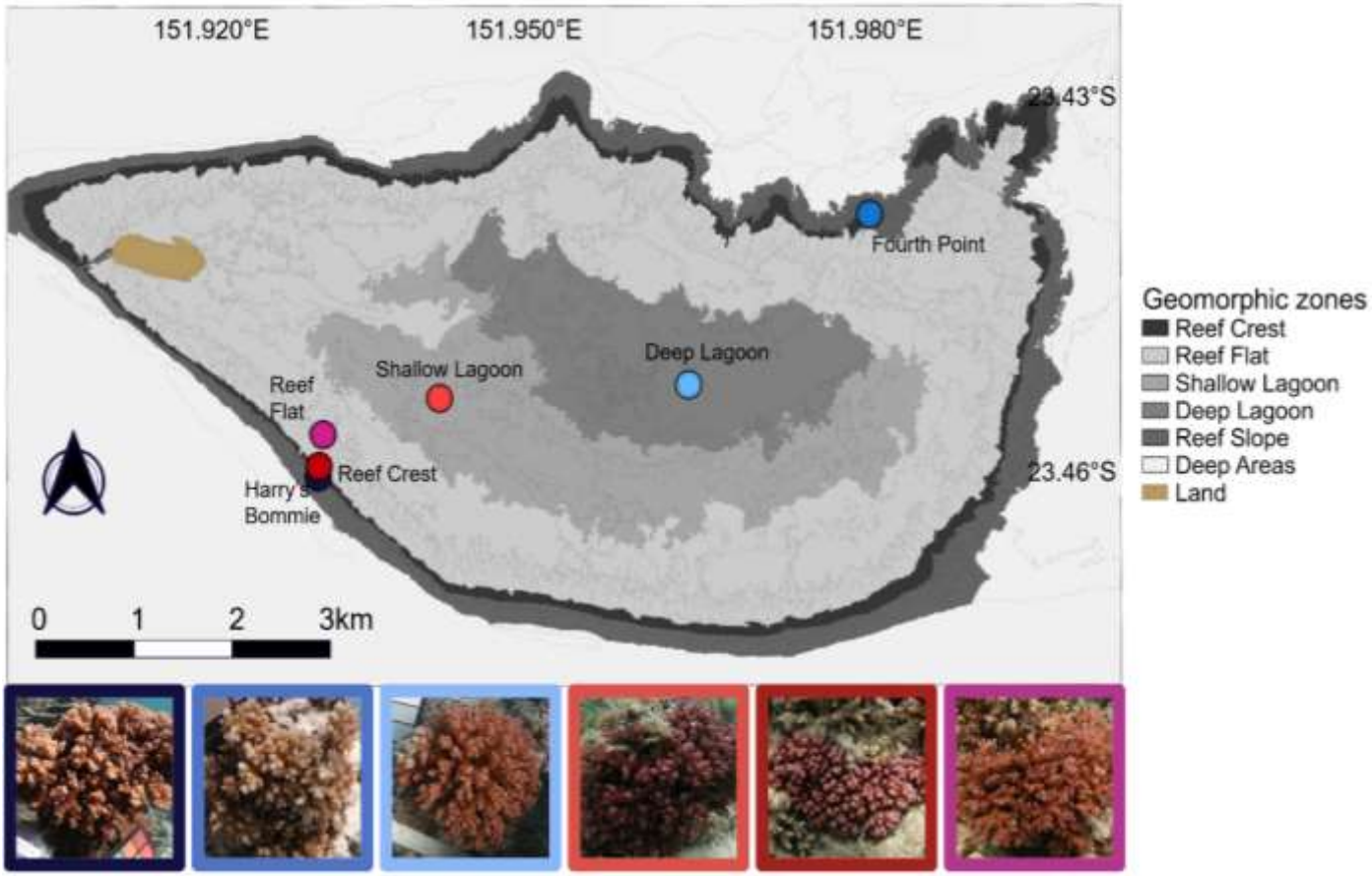

Figure 1. Sampling locations and geomorphological zones of Heron Island, southern Great Barrier Reef. The map shows the six study sites, listed from least (navy) to most (magenta) thermally variable: Harry's Bommie, Fourth Point, Deep Lagoon, Shallow Lagoon, Reef Crest, and Reef Flat. Map shading represents geomorphological zones redrawn from published Heron Reef geomorphology data (Phinn et al., 2012). Representative images of *Pocillopora damicornis* colonies from each site are shown along the bottom, illustrating variation in colony morphology and pigmentation across habitats.

partner, *Cladocopium latusorum*. Most colonies shared a highly similar ITS2 sequence signature and the same dominant type profile, with among-site differences driven mainly by low-abundance secondary variants, rather than by wholesale symbiont replacement. This matters because symbiont identity is often a major source of variation in physiology and thermal tolerance in corals. By confirming a remarkably consistent host-symbiont partnership across Heron Reef, the ITS2 data narrow the explanation for site-linked phenotypes to local environmental history, host condition, and finer-scale variation within the holobiont, rather than to simple symbiont turnover (Hume et al. 2019; Marhoefer et al. 2021; Brown et al. 2022).

The symbiont composition result was also important because it strengthens the interpretation of the physiological data. Corals from SL, for example, had greater biomass, symbiont densities, and photoprotective pigments, yet they did not host a different dominant Symbiodiniaceae species from the colonies at the other sites. In other words, the physiological differences observed across this reef mosaic are not explained by a shift to a different algal partner, but instead point to acclimatization and environmental memory acting within a largely stable *Pocillopora damicornis* - *Cladocopium latusorum* association. This finding is critical for understanding how fine-scale reef environments can shape coral performance even when the core symbiosis remains conserved (Palumbi et al. 2014; Brown et al. 2024).

Bacterial community patterns were more subtle, but still informative. All colonies hosted a broadly similar core microbiome dominated by *Endozoicomonadaceae*, yet corals from more thermally variable habitats tended to support more even and compositionally dynamic microbial assemblages. These findings suggest that both coral physiology and microbiome structure are shaped by local environmental history, even across very small spatial scales.

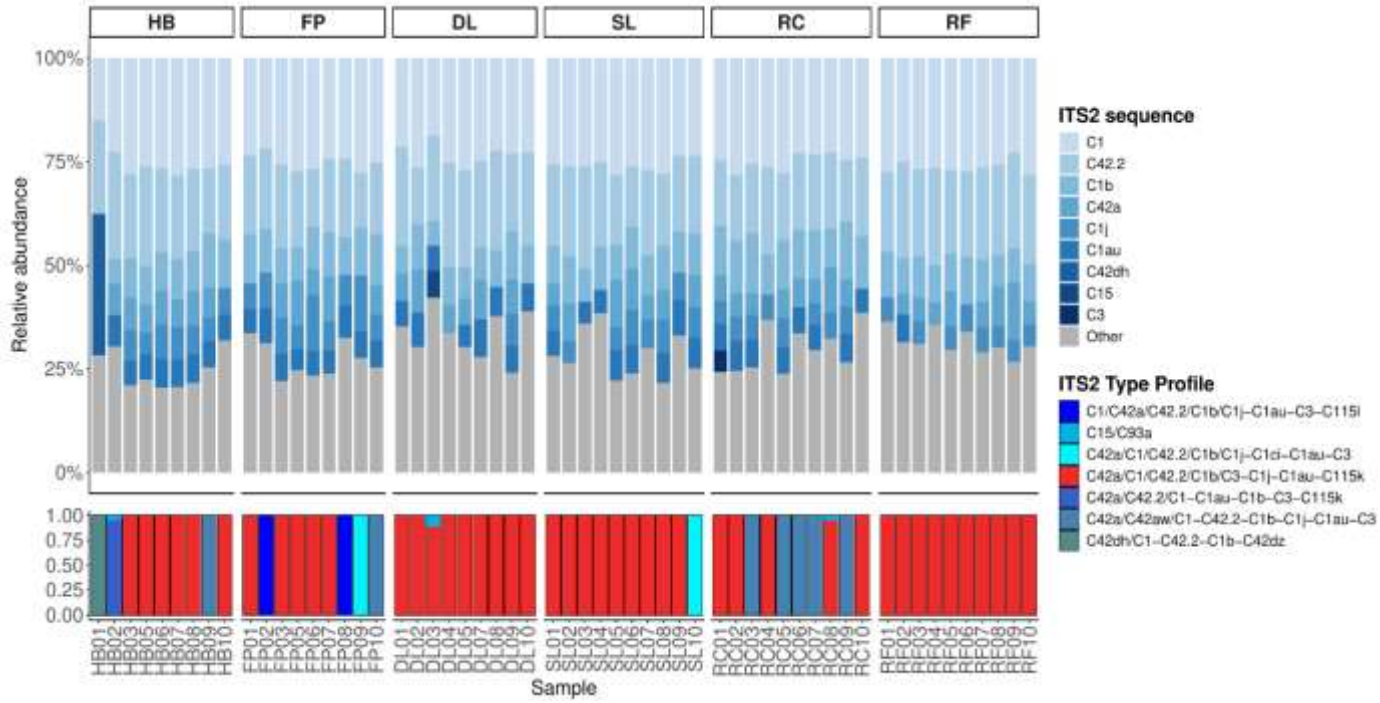

Figure 2. Symbiodiniaceae community composition of *Pocillopora damicornis* across six reef sites at Heron Island. Upper stacked bars show the relative abundance of ITS2 sequences in each colony, with sequences present at less than 5% relative abundance within a sample grouped as "Other" (gray). Stacked bars below show the corresponding ITS2 type profiles for the same colonies. All colonies were dominated by *Cladocopium latusorum*-associated ITS2 sequence variants and profiles, most commonly C42a/C1/C42.2/C1b/C3-C1j-C1au-C115k.

Discussion / Concluding Remarks

This project advances our understanding of how corals are able to persist in naturally variable environments by demonstrating that colonies are not simply partitioned between "good" and "bad" habitats. Instead, Heron Reef contains a continuum of environmental regimes that favor distinct holobiont phenotypes. The results are most consistent with the idea that intermediate levels of variability can prime corals in ways that enhance their baseline condition and preparedness, whereas very stable or very extreme conditions may be less inclined to favor adaptable phenotypes. Just as importantly, the ITS2 data demonstrate that these differences cannot be attributed to major changes in symbiont identity. *Pocillopora damicornis* at all six sites remained associated with the same dominant *C. latusorum*, suggesting that environmental history shaped coral phenotype without requiring symbiont-species turnover.

The ICRS Graduate Fellowship was instrumental in completing the Symbiodiniaceae sequencing that allowed this interpretation. With these data in hand, the major components of the project are now completed, including the physiological analyses, 16S and ITS2 sequencing, and multivariate integration of the microbial and physiological datasets. Future work will extend these comparisons to additional coral genera and explore whether microbially-derived metabolites contribute directly to thermal resilience.

About Marcelina P. Martynek

Marcelina is a graduate student in the Barott Lab at the University of Pennsylvania, Philadelphia, where she researches the effects of heat stress and ocean acidification on coral reefs.

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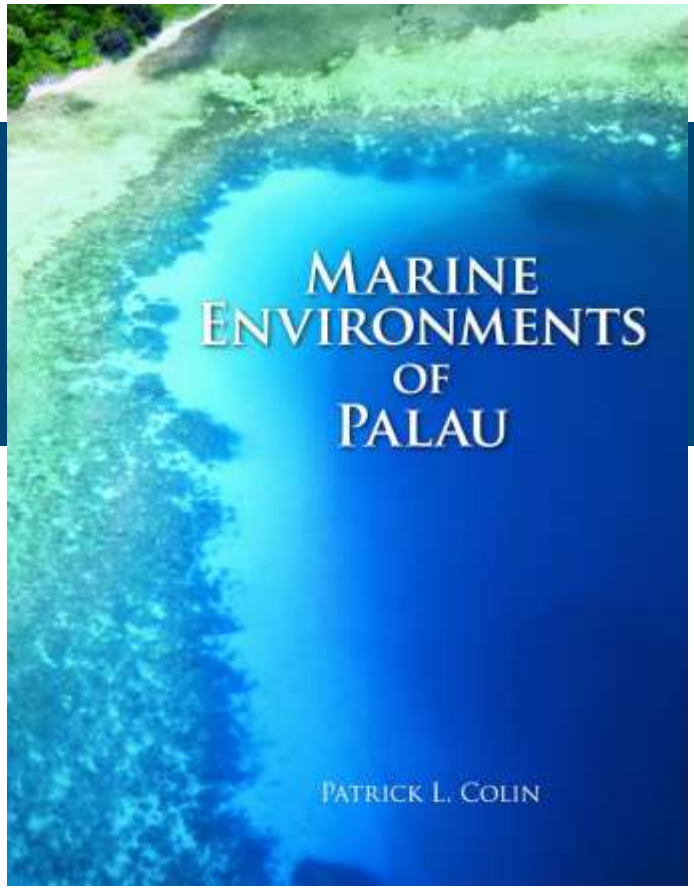
Just a memory? Picture of a flourishing coral reef – the reef slope at Chumbe Island, Tanzania. Photograph by Charlie Veron, from the revised Corals of the World website (see page 24).

REEF RECRUITS

Marine Environments of Palau

Indo-Pacific Press and Mutual Publishing. 414 pp.
2009
ISBN-10 0615274846



This book was published in 2009, but is worth reviewing again because, for those unfamiliar with it – this book is FANTASTIC!! Further, it is available for free as a pdf (see end). Palau has an amazing range of different marine habitats, including fringing reefs, barrier reefs, atolls, patch reefs, channels, lagoons, rock islands, marine lakes, and many others. This book is full of fascinating information and richly illustrated by the author's photographs from the air and underwater. There are several full-color photos on nearly every page. It is an amazing compilation of information from decades of research and observation by Dr. Colin. This book is fantastic for Palau, but much of the information applies to coral reefs all over the world. It is easy to read, yet addresses many things of interest to coral reef scientists. I regret that I had not read it until recently.

Among the more unusual features in Palau are its Rock Islands and the marine lakes. The Rock Islands are fossil reefs that have been uplifted above sea level by the rise of the substratum below them. Once the islands are out of the water, the slightly acidic rainwater starts to dissolve the limestone, causing it to form a pitted "Swiss cheese" structure, which geologists call "karst." Thus, rainwater does not run off the surface, it drains through the holes. There is vegetation growing on the Rock Islands even though it is a harsh habitat. When leaves drop and die, they rot, releasing acids, which both speeds dissolution of the limestone and increases acidity of the surrounding seawater.

Aerial view on an extremely calm day looking west across the central complex of the Rock Islands (Fig. 4.9).

Tketau Lake on Mecherchar Island, the largest and deepest marine lake in Palau (Fig. 9.76).

The Rock Islands are rounded and often occur in irregular chains, so that the water around them is partially constrained. There are tidal currents in some places, and others form nearly enclosed bays with little tidal flow. Between the islands, however, are both deeper basins and shallow shelves that support abundant corals. There is even a unique habitat, where wave action has eroded a deep notch typically extending a few meters into the islands at sea level. The water there is nearly as acidic as predicted for the world oceans in the future, yet the corals there appear to be tolerant of these conditions – an observation that has prompted a series of papers.

The marine lakes are isolated pockets of seawater between or within the Rock Islands, with no surface connection to the open ocean. Instead, they have connections to the surrounding waters through holes in the karst rock that forms the islands. These hidden connections to ocean waters vary in size and length among the numerous lakes. Where the holes are small and long, only a few species have managed to get into the lakes. Where the holes are wide and short, species diversity is higher. The most famous of these lakes is "Jellyfish Lake," which is dominated by jellyfish that contain zooxanthellae and migrate upward during the day and down at night. It has been suggested that Palau might have as many marine lakes as the rest of the world combined!

I hope I have these details right. Either way I urge readers to check out this book for its wealth of fascinating ecological and natural history stories. This book provides an excellent example of what might be done in other places, although replicating such work elsewhere would take a team of researchers. The author, Pat Colin, operates his own marine lab, complete with docks, boats, scuba gear, and guest quarters. In addition, the Palau government maintains a well-equipped marine lab that includes a public aquarium and plenty of experimental aquaria with running seawater, and is located close to the Rock Islands.

A section of the western barrier reef of Palau, looking south (Fig 2.2).

This book has been out of print for 5 years. There are just a few hard copies available on Amazon from time to time. But pdf copies are available free for download from the Coral Reef Research Foundation website at https://coralreefpalau.org/marine-environments-of-palau/

Douglas Fenner
Coral Reef Consulting, American Samoa

REEF DEPARTURES

Tributes to recently departed members and reef scientists

Roger Hudson Bradbury 1946–2025

Last year, the coral reef research community lost another of our exceptional elders, with the passing of Roger Bradbury. Roger grew up in Murwillumbah and graduated from Southport State High School, on Australia's Gold Coast in the 1960s. This was a time when the Gold Coast had a population of 50,000 or less and was known for its pristine beaches and long board surfing, recently borrowed from the Hawaiian Duke Kahanamoku, the 'Endless Summer', the Beach Boys and 'Bombora' by the Atlantics. Roger was hooked on the ocean from an early age.

Roger headed to Brisbane, from the bush to the nearest 'big smoke', 100km to the north, to study at the University of Queensland (UQ), completing his doctorate in 1975 on 'A local synecology of a marine system: studies on a demersal fish assemblage, Moreton Bay, Queensland'. This thesis was a foreshadow of Roger's long-term interest in unconventional analytic methods and systems thinking. Roger became increasingly interested in the complexity of ecosystems more generally, and especially the highly biodiverse tropical realms, with tropical coral reefs in the Indo Pacific being the pinnacle of ecological diversity and complexity of life on earth.

Roger's University days in Brisbane cemented his friendships with Alan Jones, Ann Cameron and Robert Endean; and also Bill Williams, a UK-born world leader in the mathematics of pattern analysis – a precursor of the neural nets and artificial intelligence of today. In the pursuit of truth, Endean and Cameron were unafraid to challenge the politically powerful people in both science and government. At UQ they encouraged innovation and the freedom of science questioning assumptions. A case in point was their 1970s warning to governments, both State and Federal, that the devastating 'plagues' of the coral-eating 'Crown-of-Thorns' starfish, *Acanthaster planci / spp.,* were not a natural phenomenon as suggested

by politicians, but likely caused by human impacts on the coral reef ecosystems.

Another case in point: Roger, with 36 postgrads, wrote an open letter more than 50 years ago titled, 'A Statement of Disenchantment' to the Australian Marine Sciences Association (AMSA) Symposium on Pollution in the Marine Environment'; they stated:

"The marine environment has been deteriorating for a long time and marine scientists were in a position years ago to inform the public that the crisis was approaching. ... Biology can and must provide a basis for an objective assessment of man as a species, but unless we seek for an immediate re-examination of the basic philosophies around which the institutions we foster and represent are built then we will have failed in our duty as scientists and we will have hastened the collapse of the biosphere."

In the more than five decades since that prescient open letter from UQ postgrads, Roger and many others have succeeded in informing decision-makers and society more generally. Roger continued his incisive commentary until his passing, including in recent issues of Reef Encounter. In his 2022 review of *'Coral Reefs of Australia: Perspectives from beyond the water's edge'* Roger noted that the dominant public

narrative of governments, NGOs and most scientists, remains positive:

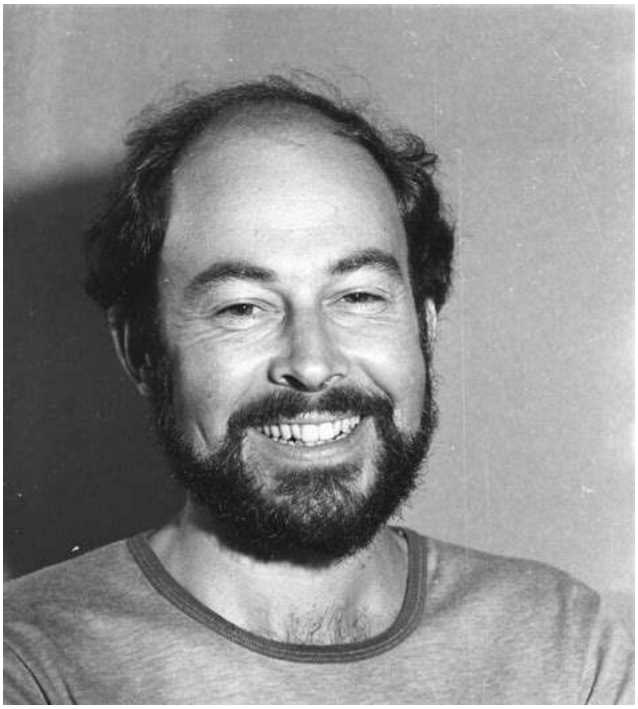
"The good news is that it is not too late to reverse much of the harm and turn from decline to recovery."

Bradbury considered this *"... a cyclically reinforcing Panglossian story – each stakeholder reinforcing the other ... But this is scientifically wrong. The Anthropocene forcings that are bringing an end to the world's coral reefs are locked in and are beyond the power of any government to alter. ... coral reefs are just roadkill on the Anthropocene highway."*

Clearly a fatalistic view, formed over a lifetime of thoughtful research. It fair to say that Roger was not alone. This view is widely held among ocean elders.

In the 1980s at the Australian Institute of Marine Science (AIMS) Roger was a Senior Scientist and later Director of the Institute. With colleagues he developed a reef survey tool adapted from rainforests that classified corals and other benthos as 'life-forms'. This enabled non-specialists to successfully collect valuable data. It was later adopted across the ASEAN nations as a key part of their nascent reef monitoring programs. He also encouraged research programs on the impacts and causes of the Crown-of-thorns. These further revealed that the plague-like outbreaks (now termed irruptions) of the starfish were not a natural phenomenon, but it was a native species driven to devastating outbreaks by various human impacts, direct and indirect. The main suspects included agricultural pollution enhancing starfish larval survivorship and reduction in predators across various starfish life-stages.

Roger encouraged younger scientists, such as Peter Moran and Randy Olson, to explore these ideas, and in his laboratory, where there was a healthy rebellious spirit, collegiality and intellectual curiosity prevailed. Indeed, the AIMS 'Module 3 coffee club' and occasional balcony 'long-lunches' were legendary at the time for the wide- and free-ranging discussions. Roger encouraged debate between colleagues at AIMS, James Cook University, and national and international centres of excellence.



A younger Roger, with characteristic knowing smile.

In one instance, Roger's curiosity did cause a drama with a happy ending. He had spent a week at sea collecting data on whether coral reef structures at different scales could best be described as having fractal dimension properties as described by Benoit Mandelbrot. "Perhaps hard to see the immediate practical application but who knows?" said Roger.

His boss at the time thought otherwise and Roger's penance was to convene a short program to measure the abundance of coral on the Great Barrier Reef – funded by a government employment program. The Great Barrier Reef is 2,000 km long with an area the size of the United Kingdom or Italy. Not a trivial task, but the young graduates employed to dive the length and breadth of the Reef were energetic and enthused. Many of those then-recent graduates have gone on to successful careers in marine science. The data were compiled and reported for 1985, and not long afterwards the Institute established what is now called the AIMS Long-Term Monitoring Program which continues today – 40 years later. An invaluable national asset helping science to evaluate the status of the Great Barrier Reef in the face of what we now know to be the real and worsening impacts of global warming caused by

burning fossil carbon fuels (the 'greenhouse effect') on atmospheric and ocean temperatures.

Roger left AIMS in 1990, returning to Canberra to lead the National Resource Information Centre in the Bureau of Resource Sciences. The role was to create national scale information systems for natural resources. The Soil Inventory was an early product. The work continues now with the Australian Bureau of Agricultural and Resource Economics and Sciences.

This seems a large jump from the Great Barrier Reef to a map of soil types across the Australian continent, but there is another facet to Roger's career that is less visible in the historical records. Early in his career, before working at AIMS, Roger worked for the Office of National Assessments – an independent statutory body directly accountable to the Prime Minister of Australia as an agency of the Department of the Prime Minister and Cabinet. ONA provided all-source assessments on international political, strategic and economic developments.

The work of the ONA and its successors necessarily attracts a wide range of expertise and while never discussed publicly, it is likely that Roger's expertise in complex systems analysis, and his inquiring lateral and contrarian thinking would be valuable to those analysing complex problems of national and international significance.

More recently Roger joined the Australian National University's National Security College. ANU describes the College as working in Australia's national interest to develop whole-of-government and whole-of-nation security capabilities, improve skills of Australian security professionals and to facilitate debate and policy contestability on national security, broadly defined.

To give an example of Roger's other world, see the introduction in his 2017 revision of his paper[1] at a Defence conference titled "Intelligence, complexity and the space between'.

The first paragraph of this paper is as follows:

> *I want to examine the idea of intelligence, the idea of complexity and the space between. That is, I want to use a trick from complexity science — thinking of problems as landscapes — to get at the issue of why intelligence and complexity are not closer in the space of ideas. And I want to ask what might be done about it. Obviously both complexity and intelligence are multi-dimensioned ideas, so our landscapes must also be multi-dimensional. To those of you that are not comfortable with imagining multi-dimensional manifolds in hyperspaces, I say, 'Don't worry, neither am I'. I think I shall be able to use the metaphor of landscape in a way that does not challenge any of us.*

The world of intelligence analysis is not readily transparent to the public, for national security reasons, but there are published papers that give an inkling to understand those who work on these issues. For our purpose, this briefly provides an understanding of Roger Bradbury's breadth of expertise, ability to think laterally and to bridge multiple disciplines.

A note published by the Australian National University provides a short description of Roger which could hardly be bettered. *"Roger made a significant contribution at the National Security College, the Crawford School and elsewhere across ANU, and is remembered with warmth and respect by former students and colleagues alike. His roles included serving as NSC Academic Director from 2014-2016 and pioneering our work on cyber security, technology and complex systems science. He was vividly independent in his thinking, research and teaching – his collection of Hawaiian shirts said it all. He drew on an earlier career in the Australian intelligence community and the scientific research sector – including his original training as a zoologist – to teach and inspire new generations of students and policy practitioners."*

Roger Bradbury cast a bright light on the world for many people. His family, Kate, Alice and Gillian, his friends and colleagues[2] will miss him. Roger passed away on 27 March 2025 in Canberra, Australia.

Russell Reichelt (with Lyndon DeVantier and Alice Bradbury)

[1] An edited version of his presentation to the pan-TTCP Symposium on Complex Adaptive Systems for Defence, sponsored by The Technical Cooperation Program and the Defence Science and Technology Organisation, Adelaide, 17-21 July 2006, entitled "*Intelligence, complexity and the space between"* is available from: https://www.researchgate.net/publication/320486727_Intelligence_complexity_and_the_space_between [accessed June 26 2025].

[2] Ed's comment: I counted myself among Rog's good friends, hugely appreciating his sharp analytical mind and wicked sense of humour. These were very evident in his articles for Reef Encounter, the most recent being the review of a book on John Büsst: Bohemian artist and reef saviour, by Iain McCalman, submitted not long before his death (Reef Encounter March 2025: 75-76).

Roger Bradbury – from schoolboy to reef scientist to defence expert. Top right with Russ Reichelt.

Aileen Morse 1941-2024

Aileen Nelson Catherine Morse, a pioneer in coral reproductive biology, died in Santa Barbara, California, in December 2024.

Aileen specialized in molecular marine biology, initially relative to chemical compounds involved in the recruitment of molluscan larvae. She discovered that a GABA-mimetic oligopeptide cue from crustose coralline red algae (CCR) triggers site-specific settlement and metamorphosis of planktonic abalone larvae. Extending her research to corals, Aileen discovered a very different kind of molecular cue – a sulfated oligosaccharide, on the surface of CCR – that triggers the chemosensory-directed, substrate-specific settlement and metamorphosis of scleractinian coral larvae. In this case, in contrast to the abalone larvae, she found considerable species-specificity in the coral-CCR associations that influenced larval recruitment patterns on coral reefs. Her research showed that chemically cued larval settlement and metamorphosis determine recruitment in a wide range of hermatypic reef-building corals - both those that reproduce by spawning and those that

Aileen (fifth from right) with staff (including Al Edwards) and students at the University of the Philippines marine laboratory in Bolinao, in the province of Pangasinan, NW Luzon.

brood their larvae. Thus, this represents an ancient chemosensory mechanism that predates the rise of the Pan-American isthmus, and her work put to rest the previous dogma that settlement and metamorphosis of coral larvae was a spatially random lottery for available substrate.

Aileen worked tirelessly for two decades, with her students and colleagues, circling the globe each year to follow the seasonally-determined schedule of coral spawning. They captured gametes released in the annual mass spawnings of broadcasting coral species, and triggered release of the larvae from brooding coral species, to better understand coral recruitment patterns relative to reef restoration and conservation. She was active in research focused on enhancing post-transplant survivorship of corals, and she developed novel and effective means for sexual propagation of corals for reef restoration practices. Aileen was also a leader in our understanding of coral larval behaviors relative to settlement and metamorphosis, and was part of the team that developed "coral flypaper" – an artificial substrate that stabilizes the morphogenic cue of specific corals, and other invertebrates, for use in restoration, mariculture, and biotechnological applications.

Aileen Morse was born in 1941 in Glasgow, Scotland and grew up in Edinburgh, where she first trained as a medical radiographer at the Royal Infirmary. She was recruited by Huntington Memorial Hospital in Pasadena, California and subsequently brought her skills in cancer radiotherapy and diagnostics to Stanford's Medical Center and Boston's Joint Radiation Center. Realizing her passion for research, she switched her career to molecular biology, first at Harvard Medical School, and then at the University of California in Santa Barbara, where her research on brain proteins established the groundwork for her subsequent discoveries of marine chemosensory mechanisms. Aileen was cherished by her many colleagues and students for her warmth, creative insight, and sparkling personality. Her ashes were scattered in the waters of a cove in western Scotland where she had played as a child.

Marc Slattery (slattery@olemiss.edu)
with Deborah Gochfeld on behalf of Aileen's
colleagues, friends and family

Select publications:

Boch CA, Morse ANC (2012) Testing the effectiveness of direct propagation techniques for coral restoration of *Acropora* spp. Ecol Eng 40:11-17. https://doi.org/10.1016/j.ecoleng.2011.12.026

Morse ANC, Iwao K, Masasuke B, Shimoike K, Hayashibara T, Omari M (1996) An ancient chemosensory mechanism brings new life to coral reefs. Biol Bull 191:149-154. https://doi.org/10.2307/1542917

Morse ANC, Morse DE (1996) Flypapers for coral and other planktonic larvae. Biosci 46:254-262. https://doi.org/10.2307/1312832

Raimondi PT, Morse ANC (2000) The consequences of complex larval behavior in a coral. Ecology 81:3193-3211. https://doi.org/10.1890/0012-9658(2000)081[3193:TCOCLB]2.0.CO;2

Zvy Dubinsky 1934-2024

We had intended to publish a memorial for Zvy Dubinsky in an earlier edition, but due to production issues were unable to do so at the time. The following is extracted (with copyright permission) from an obituary published in the Limnology and Oceanography Bulletin in October 2024[1].

Professor Zvy Dubinsky passed away on 25 March 2024. Zvy was a long-time member of ASLO, a distinguished colleague, and friend of many. Zvy left behind a legacy of excellent and ground-breaking science, generations of students, and extensive networks of colleagues around the world, many of whom became close friends. Zvy was also a devoted husband to Maya, father, grandfather of four, and great-grandfather of four.

Born in Barcelona in 1934, Zvy emigrated as a child to Israel where he trained as a teacher and worked for several years in developing an advanced, modern biology curriculum for high schools. In his mid-30s, he returned to study for a M.Sc. in biology at Bar-Ilan University (BIU), Israel where he investigated “The influence of select environmental factors on the abundance and composition of algal populations from Lake Kinneret (Israel)” and then continued to complete his Ph.D. (under Tom Berman's supervision) on “Light as an ecological factor in Lake Kinneret phytoplankton dynamics.”

After a postdoctoral fellowship at Queens College, New York, USA, where he focused on algal lipid physiology, biochemistry, and the potential of algae in biofuel production, Zvy accepted a faculty position at the Department of Life Sciences at BIU where he developed a laboratory focusing on biophysical, physiological, and ecological aspects of aquatic photosynthesis. He markedly advanced the research in the fields of phytoplankton photo-acclimation and their interactions with the underwater light field, and helped develop the application of photo-acoustics to directly determine photosynthetic quantum yields of any benthic phototroph. For his extensive publication list and highly cited papers, see https://scholar.google.co.il/citations?hl=en&user=0zUQYWIAAAAJ.

Zvy was one of the pioneers working on coral ecology and photobiology, formulating the first integration of energy and nutrient fluxes in zooxanthellate corals. In the late 1970s, Zvy's research expeditions to the Sinai reefs became notoriously popular (Fig. 2). Zvy applied the concepts of photo-acclimation and energy

Zvy, Paul Falkowski, and colleagues after a day of experiments on the coral reef at Nabq, Sinai. (photographer unknown, from Zvy's private collection).

requirement in diverse environments, which took him from the heat of the deserts to the cold Antarctic waters where he worked with Prof. Max Von Tilzer (University of Konstantz, Past Director of the Alfred Wegner Institute for Polar Research, both Germany).

With a flourishing scientific career Zvy planned and worked on >100 research projects, including ~25 international research projects funded by a variety of competitive sources, including the prestigious FP7 ERC Advanced Career Grant under which he was the Project Principal Investigator for CoralWarm (www.coralwarm.eu) which explored the impacts of anthropogenic eutrophication on coral reefs. His research also diverged to more applied projects, and he established the "Algal Biotechnology Center (BIU)" initiating research on biodiesel and natural products from microalgae.

Zvy's international scientific collaboration was literally global. His projects took him across the world to Australia, Hawaii, Antarctica, Japan, Eritrea, Seychelles, and other locations. But he also believed in building bridges closer to home and co-piloted (with Max von Tilzer) a joint Israeli–German–Arab project on the Red Sea (after the Peace Accords were signed between Egypt, Jordan, and Israel). Max explains: "The idea behind the project was to contribute to the peace process in the Middle East, in addition to supporting science. At the time of the project, this looked rather promising. In addition to German and Israeli scientists, researchers from Jordan, Egypt, and Palestine participated. One of the Palestinian participants was Mutas Qutob who had studied at Bar-Ilan University and subsequently became Professor at the Palestinian Al Quds University in Jerusalem."

Zvy's prolific work resulted in ~270 scientific publications and edited books, invitations to lecture around the world, and prestigious acknowledgment of his work via numerous international editorial and advisory positions to both industry and government, translating research into policy.

Zvy was also a dedicated and talented teacher. He mentored ~90 graduate students (including myself - I. Berman-Frank) and postdoctoral fellows, established a new program in ecology at BIU based on hands-on desert and coral reef studies in the field, taught a wide variety of courses from plant physiology and ecology to marine photosynthesis and ecophysiology, bioenergetics, and "Man and the Biosphere." This last course became one of the most popular courses taught at BIU, annually attracting >100 students from all faculties. Zvy also headed the M.B.A. program in Management of Natural Resources, Energy and Water at the Netanya Academic College (Israel), and a M.Sc. program in Marine Science at Ruppin College/Faculty of Marine Sciences (Israel).

Zvy organized many international symposia, workshops and seminars. One of the most notable was the co-founding of the Group of Aquatic Primary Productivity (GAP) workshops to which he contributed from 1980 to 2008. GAP workshops brought together freshwater and marine scientists to plan and work together, running experiments with state-of-the-science equipment and methodologies, analyzing data, and publishing the results in peer-reviewed journals.

Zvy was also a talented photographer with the flair and ability to record nature and people through the lens of the camera. This led to several exhibitions, including joint exhibitions with Max von Tilzer, with the last one titled "Ripples and Patterns" showing in Konstanz, Jerusalem, and at the German Embassy in Tel Aviv. Zvy's legacy will live on in the hearts of those he touched and in the countless contributions he made to the field of marine biology.

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[1] Berman-Frank I, Falkowski P, von Tilzer M, Levy O (2024) Zvy Dubinksy (1934-2024). Limnol Oceanog Bull 33:174-176. https://doi.org/10.1002/lob.10664

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ICRS membership is open to anyone interested in any aspect of the science of coral reefs. While the Society's membership consists principally of researchers, managers and students involved with coral reefs and associated ecosystems, and other people with genuine interests in or concern for reefs, of any type, are welcome. The benefits of membership include:

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- Receipt of the Society's newsletter/magazine *Reef Encounter* (by email or on-line)
- Eligibility for the graduate fellowships, students travel grants and communications fellowships offered by the Society
- Eligibility for the multiple honors and awards given by the Society, including mid- and early-career and conservation awards
- Access to the Society's on-line membership services, including the on-line Membership Directory
- Reduced registration fees for the International Coral Reef Symposium and other meetings sponsored by the Society.

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Reef Encounter welcomes in particular, (1) general overview articles (3-5 pages) on particular reef science topics in which the author(s) has a special interest, (2) short communications / scientific letters (1-2 pages) reporting recent observations, and (3) general interest articles describing personal views and experiences. It also carries Announcements, Conference Reports, Book and Product Reviews, and Obituaries.

Authors are encouraged to include colour pictures or other illustrations (normally 2-4 per article). There are no specifications regarding the format of articles for submission to the editors, but we particularly ask that references should be cited and listed using the style of the ICRS academic journal CORAL REEFS, see: http://www.springer.com/life+sciences/ecology/journal/338. Articles from non-ICRS members are welcome, but those from members are generally given priority. Items should be submitted by email to the senior editor (rupert.ormond.mci@gmail.com) or a relevant member of the editorial panel (see page 2).

Indigenous delegates at the COP 30 meeting in Belém, Brazil.
See article page 32 (photo Mariana Rocha de Souza)

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