REEF ENCOUNTER

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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.

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ABOUT THE COVER | ICRS 2022 Opening Ceremony. Photo by Rupert Ormond.

OFFICERS' REPORTS

PRESIDENT'S MESSAGE

Andréa Grottoli, ICRS President (2019 - 2022)

Dear ICRS Members:

It is with great pride that I end my four-year term as ICRS President and pass the baton to Dr. Christian Voolstra. The past four years have been amazing, thanks to the dedication of the ICRS Officers and Councilors, and the unflagging engagement and support of the ICRS members.

Meeting all the Goals of the Plan of Action

Shortly after I took office in January of 2019, we established a new mission statement, crafted a new vision statement to help guide our purpose, and **developed a five part ICRS Plan of Action to help chart a course for the Society.** The goals of the plan were to **1) proactively promote science-based decision making and coral reef protection, 2) reduce our carbon footprint, 3) formalize partnerships with other science-based coral reef societies and organizations to coordinate action and amplify our collective voice**, 4) **encourage ICRS members and supporters to take the** ICRS Pledge for Coral Reefs**, and 5) support fellowships in science communication.** I am happy to report that the Society accomplished all goals in the Plan of Action by engaging at multiple levels.

ICRS is now at the table in top negotiations and drafting of commitment documents at the United Nations, Committee of the Parties (CoP), and the International Coral Reef Initiative (ICRI). Thanks to the hard work of the ICRS Conservation Committee, ICRS is now an official participant at CoP meetings. We also have representatives on major committees within ICRI tackling issues on biodiversity, restoration, and resilience-based management. ICRS is also on the scientific advisory board and the governing committee for the Coral Reef Accelerator and Development Program (CORDAP) and has members involved in the Global Fund for Coral Reefs (GFCR) initiative. Most importantly, ICRS published the science-to-policy paper "Rebuilding Coral Reefs: A Decadal Grand Challenge" and promoted it through press releases and two science-to-policy discussion forums. This document formed the cornerstone of the ICRS position at all the above-mentioned events and committees.

ICRS hosted its first carbon neutral in-person symposium in Bremen, Germany in 2022 and its first fully virtual symposium in 2021. While covid was disruptive to the planned 2020 symposium, it forced us to accelerate our plans for a carbon neutral meeting and to be innovative in the virtual conference space. We also were able to make registration for the 2022 symposium completely free for all ICRS members from low, low-middle, and middle-income countries. Thanks to the tireless efforts of the 14th and 15th Symposium Organizing Committee, both symposia were huge successes.

ICRS also welcomed three new Chapters to the ICRS family. All five chapters work together with ICRS to create a common message among coral reef organizations, which helps us to amplify our collective voice and create a forum for communication between organizations. ICRS also provides financial support to its Chapters for local meetings and workshops, which facilitates sharing of research and management findings at the regional scale. ICRS is looking to grow chapter connections with other organizations throughout the world.

ICRS' efforts to reach a broader audience were accomplished with the Pledge for Coral Reefs and the launching of the Science Communication Fellowships. The pledge provides a resource for individuals who want to do their part to help coral reefs. Through both large and small individual choices and actions, we can all make a difference. The science communication fellowship program has supported five fellows who are helping to make scientific discoveries accessible to all.

Going Beyond the Plan of Action

We then went beyond the Plan of Action and 1) **developed a financial plan** that maps out a path for keeping the Society financially stable while increasing our ability to fulfil our mission, 2) brokered a **new deal with Springer** for the journal *Coral Reefs*, giving the Society **royalties for the first time,** the ability to submit **multi-lingual abstracts,** and the ability to provide open-access viewing through *ShareIt*, 3) **partnered with the Coral Restoration Foundation for financial management services** (the CRF is providing these services as an in-kind donation to ICRS), 4) developed five areas of development for financial donations, 5) **created a fund to pay for the registration at the ICRS symposia for all ICRS members from low, low-middle, and middle-income countries**, 6) ran our **first fund-raising campaign** that was bolstered by **matching funds from a generous donation by R. Scott Winters**, and 7) increased support for fellowships and awards by 56%. Our financial plan includes continued expanding support for student and early career fellowships, grants, and awards, lowering the costs of registration and participation at the ICRS Symposia; supporting ICRS Officers and Council member participation in high level meetings like CoP; and making conservative financial investments to ensure long-term financial stability.

So Many People to Thank

This amazing amount of work would not have been possible without the incredible dedication and commitment of the ICRS Officers and Council Members (**Figure 1**). I would like to especially thank the following individuals who have done some heavy lifting for the Society during my four years as President:

Outgoing Vice President Joanie Kleypas for her unwavering support, dedication to the development of the ICRS Code of Conduct, the development and chairing of the Equity, Diversity, and Inclusion Committee, representing ICRS on the CORDAP scientific advisory committee, and being the website guru.

Outgoing Communications Secretary Mike Sweet for his re-invigoration of ICRS' presence in social media, chairing of the communications committee, careful archiving of ICRS minutes and documents, and for being a constant source of new and innovative ideas.

Past Treasurer Erinn Muller for her ability to get our taxes and name change documentation sorted out, setting up the first investment account, and for coercing her husband to make the ICRS awards.

Past Recording Secretary Liz Drenkard for handling the entire website migration to the new platform and debugging for a year, as well as setting up new pages and functionality to the website.

Current Treasurer Anderson Mayfield for his tireless hours of work in transitioning our financial services from our old service provider to the Coral Restoration Foundation, for managing all aspects of the transition in our member platform MemberClicks, submitting our taxes, dealing with the bank, and for managing all the behind-the-scenes financial details associated with moving to a new financial services model.

Current Recording Secretary Ania Banaszak for diligently recording, organizing, and compiling all ICRS documents and minutes, representing ICRS on the ICRI restoration ad-hoc committee, representing ICRS on the CORDAP scientific advisory committee, and being a backup for the webpage and MemberClicks.

The awards committee, currently chaired by Carly Randall and previously chaired by Lisa Rodrigues, for their tireless work in compiling, organizing, and reviewing hundreds of applications.

Figure 1. ICRS Officers and Council Members from 2019 – 2022 from left to right. **Officers**: Andréa Grottoli President, Joanie Kleypas Vice President and Chair of the EDI Committee, Michael Sweet Communications Secretary and Chair of the Communications Committee and CoP26 representative, Ania Banaszak Recording Secretary, Anderson Mayfield Treasurer and Financial Committee Chair, Morgan Pratchett Editor-In-Chief for *Coral Reefs*, Erinn Muller past Treasurer, Elizabeth Drenkard past Recording Secretary. **Council Members and Committee Chairs:** Luis Calderon-Aguilera Education Committee Chair, Carly Randall Awards Committee Chair, Raquel Peixoto Conservation Committee co-Chair and CoP 26 and 27 representative, Simon Harding Conservation Committee co-Chair and CoP 26 representative, Rupert Ormond Reef Encounters Coordinating Editor and CoP26 representative, Caroline Rogers Reef Encounters Deputy Editor. **Past Council Members and Committee Chairs:** Sue Wells Past Conservation Committee Chair and CoP26 representative, James Crabbe past Education Committee Chair, Christian Wild past Council Member and Symposium Organizing Committee Chair, Lisa Rodrigues past Awards Committee Chair and Council Member. **Chapter Chairs:** Tom Moore Coral Restoration Consortium Chapter co-Chair, R. Scott Winters Coral Restoration Consortium Chapter co-Chair, Gert Worheide European Chapter Chair, John Burt Mid-East Chapter Chair, Guillermo Horta-Puga Mexican Coral Reef Society Chapter Chair, Jenny Mallon Student and Early Career Chapter co-Chair and CoP26 representative, Morgan Short Student and Early Career Chapter co-Chair. **Past Council Members:** Carly Kenkel past Council Member, Hollie Putnam past Council Member, Traci Ainsworth Graduate Fellows Committee Chair, Council Member, and Vice President Elect, Caroline Palmer past Council Member. **Current Council Members:** Nicola Brown, Margaret Miller, Vikash Munbodhe, Sarah Davies, Kennedy Osuka, Rangeet Bhagooli, Christian Voolstra President Elect, Atsushi Watanabe, Nikki Traylor-Knowles, Ilsa Kuffner past Awards Committee Chair.

Members of the CoP26 ICRS delegation Simon Harding, Raquel Peixoto, Michael Sweet, Rupert Ormond, Jenny Mallon, Sue Wells, Michael Berumen, Jens Zinke, Nadia Jogee, and David Obura and members of the CoP27 ICRS delegation Raquel Peixoto and Yassar Geneid for representing ICRS at this international stage with grace and professionalism.

Reef Encounters coordinating and deputy editors **Rupert Ormond** and **Caroline Rogers**.

The 14th and 15th ICRS Symposium Organizing Committee, chaired by Christian Wild, for their amazing commitment and tireless work over a six-year period to organize and run a canceled meeting in 2020, and virtual meeting in 2021, and an in-person meeting in 2022.

The 16th ICRS Symposium Organizing Committee, chaired by Simon Davey and Stacey Jupiter who have already started working on the next symposium to take place in New Zealand in 2026.

2022 Darwin Medalist Nancy Knowlton for leading the charge on the ICRS paper *Rebuilding Coral Reefs: A Decadal Grand Challenge*, and to **Sebastian Ferse and Christian Wild** for developing and facilitating two science-to-policy events based on the paper.

Chapter Chairs and the groups they represent for their diverse perspectives, rich contributions to the Society, good work being done within their organizations, and active participation in the development of ICRS' platform. A special thank you to the Coral Restoration Consortium Chapter and the Mexican Coral Reef Society Chapter for hosting regional conferences that provided more local opportunities for members to share their ideas and research findings, and to the European Chapter that is involved in a European Coral Reef Symposium for 2024.

Committee Chairs and their members for their leadership in tackling the various agenda items and goals of the Society.

The Coral Restoration Foundation and Scott Winters for their commitment to ICRS and in-kind donation of support of our financial services. This partnership opens the possibility for creative financial management and development opportunities.

The Student and Early Career Chapter for their enthusiasm, creativity, and energy. Of note is the amazing work for the Plan of Action flyer, the CoP26 Flyer, and engagement in the EDI initiatives of the Society.

All Officers and Council Members for your energy, commitment to the Society and coral reefs, eagerness to make things better and make a difference, willingness to volunteer your precious time for the good of the Society, our mission, and our vision.

All ICRS members for your continued support, feedback, energy, and passion for the Society and commitment to coral reefs.

It has been a great honor to serve as ICRS President for the past four years. I feel so proud of all we have done and excited for the future of the Society. The Society has become a more dynamic, forward-thinking, and equitable organization over my tenure. I look forward to the new accomplishments, engagement, and positive influence the Society will have on studying, protecting, and restoring coral reefs over the coming decades. I wish all the best to the new and continuing Officers and Council Members, and to the new ICRS President Christian Voolstra.

Happy New Year!

Sincerely,

Dr. Andréa Grottoli, PhD | Professor, Ohio State University

VICE PRESIDENT'S REPORT

Joanie Kleypas, ICRS Vice-President 2019-2022

The ICRS VP role is perhaps the least defined of all the Officer positions. What does a vice-president do in **any** organization, anyway? At the most basic level, the role is a backup and sidekick for the ICRS President. In reality, it is a safety net to take on those tasks that don't fit neatly into the other Officer roles.

The saying "if you want to get something done, give it to a busy person" has been well borne out by the other ICRS officers I've served with: Liz Drenkard, Erinn Muller, Morgan Pratchett, Michael Sweet, Ania

Banaszak, Anderson Mayfield, and especially the tireless Andrea Grottoli. With every one of these fine people, emails were always answered, tasks were completed on time, meetings were attended, creative ideas were powered up, and the term "Sure, I can do that" was the norm. Their generosity of time and ideas is astounding and under-appreciated. The truth in "It's been an honor to serve the Society" is that it's entirely underwritten by the camaraderie and sense of purpose of the Officers, as well as the many ICRS Councilors and Chapter Chairs, and many others who give their time, including the editors of *Reef Encounter*, who carry much of the committee work. But that's what it takes for strong ICRS leadership and that's what the Society needs to fulfill its mission

And what a reward to know that our Society is stronger than ever! Please read the list of accomplishments that Andrea presided over for the past four years. Under her amazing leadership, the ICRS has accomplishing multiple milestones that, for me, fall into three categories.

First is the work to shore up ICRS as a more professional society and one that truly embraces the diversity of its membership. This took strong planning and collective vision. The ICRS still has a long way to go in being more diverse and inclusive, but the first inroads by Caroline Palmer, Liz Drenkard, and Lisa Rodrigues toward ICRS's Equity, Diversity, and Inclusion policy, are now being traveled by many more in the Society.

Second is ICRS's stronger partnerships and role in international decision-making. This includes participation in meetings such as the COPs to ensure coral reef scientists have a voice heard by the delegates. The transition from "Why should I care about coral reefs?" to "What can we do to sustain coral reefs?" was a sharp turn witnessed by ICRS attendees at COP26. Yes, it builds on years of many scientists yelling their lungs out, but now our more recognized stature at the international level will provide the efficiency of a common voice.

And the third is watching younger scientists benefit from their Society, from attendance at the ICRS virtual and in-person meetings, to finding their own leadership roles. I have humbly learned a lot from the ICRS Student and Early Career Chapter. They have been bold and are not about to sing doomsday for coral reefs. Anyone attending the 2021 virtual and 2022 Bremen meetings (so expertly planned and executed by Christian Wild and his team!) could see that it was the students and early career scientists who finally turned the focus toward solutions for coral reefs. Observing that, for me, was worth every ICRS council meeting, document, web page, email, and deadline.

The reality of promoting institutional change means addressing all the nuts and bolts that hold it together. As VP, my tasks included hours of learning and debugging Word Press web pages, nervously uploading files to precisely match the launch of our policy document (including on an airplane before take-off), organizing meetings across every time zone imaginable (and then feeling horrible about the time zone discrimination against those on the "night side" of the world), and responding to way too many emails. That was the necessary grunt work. The cool work was being exposed to the amazing science being done by ICRS members and being reminded of how many truly wonderful people there are in our Society. We are all privileged and beleaguered to work on such an amazing ecosystem. Rolling up the sleeves, zipping up the wetsuit, downloading the software, writing up the documents – all of these are the necessary tasks embodied by our society members to ensure a future for reefs. Thanks to all of you for your work and your perseverance, and for your support of the ICRS community and your local colleagues, too.

Finally, here's to the able hands of the next ICRS leadership! On behalf of those of us at the ends of our terms, we thank you for stepping up and wish you the very best as you shape the next few years for ICRS. The fuel to keep you going is knowing that ***you will certainly have an impact***.

With best wishes to all for 2023,
Joanie

Society Elections

As a result of the recent elections the following members have been elected as ICRS Officers and Council members.

President

Christian Voolstra, University of Konstanz, Konstanz, Germany

Vice President

Tracy Ainsworth, University of New South Wales, Sydney, Australia

Communicating Secretary

Mark Eakin, Silver Spring, Maryland, USA

Council Members

Deepeeka Kaullysing, University of Mauritius, Moka, Mauritius
Tries Razak, Bogor Agricultural University, Bogor, Indonesia
James Reimer, University of Ryukyus, Nishihara, Okinawa Prefecture, Japan
Hector Reyes-Bonilla, Universidad Autonoma de Baja California Sur, La Paz, Mexico
Verena Schoepf, University of Amsterdam, Amsterdam, Netherlands

Their terms of office begin on 1 January 2023 and last for four years.

The Society would also like to take this opportunity to thank the outgoing Officers and Council members. Through their work and dedication ICRS has continued to flourish over the past four years.

President: Andrea Grottoli
Vice President: Joanie Kleypas
Communicating Secretary: Mike Sweet
Council Members:
Ranjeet Bhagooli
Margaret Miller
Atsushi Watanabe
Carly Randall
Christian Voolstra (ICRS President-elect)

Dr. Andréa Grottoli

Society Grants and Awards

Please submit **nominations and applications** for the following awards and fellowships offered by the Society to recognize the scientific, leadership, educational, practitioner, and policy achievements of its members.

All nominations and applications must be submitted by 15 February 2023.

Please see details of how to nominate or apply on the Society's website at:

https://coralreefs.org/awards-and-honors/nominations/

Eminence in Research Award: In recognition of a scientist for an outstanding body of research performed over an extended period of time (up to two per year)

Mid-Career Scientist Award: In recognition of excellence in research by a mid-career scientist performed over the preceding 10 years (one per year)

Early-Career Scientist Award: In recognition of a publication or series of publications by a scientist no more than six years post-PhD (one per year)

ICRS Fellow: In recognition of scientific, conservation, or management achievement, as well as service to ICRS, over a significant period of time

World Reef Award: In recognition of scientific or conservation achievement by an individual who is a member of an under-represented group of members in the field of reef science or management (one per year)

Coral Reef Conservation Award: In recognition of a regionally or globally significant contribution to the protection of coral reefs (typically one per year)

Ruth Gates Fellowship: In memory of Dr. Ruth Gates, this research grant is available to students and early-career scientist (no more than three years post-PhD; one per year)

Graduate Fellowships: a grant awarded to registered graduate research students to assist in the costs of undertaking fieldwork or visiting laboratories (typically six per year, half to students from developing countries)

Science Communication Fellowship: a grant awarded to an ICRS member at any career stage in any type of position (e.g. academic, NGO, government, private sector, other) to gain science communication skills through a workshop, course, internship, or equivalent experience

A REMINDER that the 5th Asia-Pacific Coral Reef Symposium (APCRS) will be held at the National University of Singapore, over 19th – 23rd June, 2023.

With the theme '*Coral reef science and management in a rapidly changing world*', the 5th APCRS will be a forum for reef scientists and managers to present, discuss and integrate the science and conservation of Asia-Pacific coral reef ecosystems. We hope the Asia Pacific scientific community can come together to create new paradigms to meet the key challenges facing the region's reefs.

On behalf of the Organising Committee, we have the following updates:

- Abstract Submission now CLOSED for evaluation! Stay tuned for the outcomes in late January 2023.
- Details of Registration Fees, Conference Grants, Conference Proceedings, and so on… are available on our website at: https://www.apcrs2023.org/.

If you have submitted your Abstract, the deadline for grant applications is 31st December 2022.

IMPORTANT DATES

1 January 2023: Early Registration Opens

31 January 2023: Presenters Notified of Abstract Evaluation

28 February 2023: Early Registration Closes

March 2023: Conference Session Schedule Announced

May 2023: Full Conference Programme Announced

19–23 June 2023: Asia-Pacific Coral Reef Symposium

Above, the National Marine Laboratory on St John's Island, which is located about 6 km south of the main island of Singapore.

Galleries in the Lee Kong Chian Natural History Museum, which was built in 2015 on the Kent Ridge Campus of the National University of Singapore.

Plenary Speakers include:

- Dr. David Baker, Associate Professor at the University of Hong Kong's (HKU) School of Biological Sciences and at the Swire Institute of Marine Science.
- Chaolun Allen Chen, Research Fellow and Professor at the Biodiversity Research Center of Academia Sinica, Taiwan.
- Rili Djohani, who is the Co-Founder and Executive Director of the Coral Triangle Center.
- Mark Erdmann, Vice President of the Asia Pacific Marine Programs for Conservation International.
- Beverly Goh, Senior Lecturer at Singapore's National Institute of Education, Nanyang Technological University.
- Dr. Youna Lyons, a marine policy analyst who is Visiting Associate Research Professor with the Centre for International Law at the National University of Singapore.
- Dr. Nalinee Thongtham, who is a former researcher and head of the Marine Ecology Unit of the Phuket Marine Biological Center, Department of Marine and Coastal Resources, Thailand.

The major themes and sessions will cover:

- Coral reef histories
- Diversity, ecology and evolution
- Ecosystem connectivity
- Marginal reef environments
- Responses to environmental change
- Threats and impacts
- Interventions for reef recovery
- Ecological engineering
- Emerging technologies
- Integrated management and solutions

The Organising Committee is working with Bulletin of Marine Science to provide an opportunity for authors of accepted abstracts to submit a full paper, which will be peer-reviewed (according to the journal's regular practice) and considered for publication in a Special Issue "Proceedings of the Asia-Pacific Coral Reef Symposium 2023".

Field trips will be available, including to the National Marine Laboratory on St John's Island (SJINML), and the Lee Kong Chian Natural History Museum (LKCNHM).

To keep abreast of conference news , please follow us on Facebook, Instagram and Twitter @apcrs2023 or visit our website at https://www.apcrs2023.org/.

IF YOU HAVE EVER WANTED TO VISIT SINGAPORE – JOIN US AT THE ASIA-PACIFIC CORAL REEF SYMPOSIUM!

PRELIMINARY ANNOUNCEMENT

2024 European Coral Reef Symposium

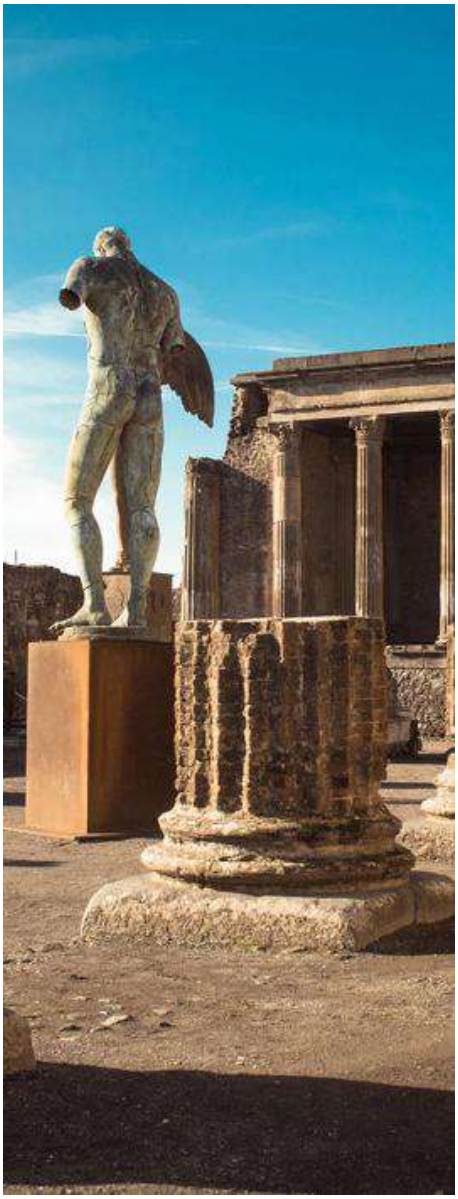
2 | 5 JULY
2024

NAPLES, Italy

The well-known Stazione Zoologica Anton Dohrn Napoli, founded in 1872

The European Chapter of ICRS is pleased to announce that it has selected a bid from an Italian consortium to host the next European Coral Reef Symposium (ECRS) in the city of Naples. The arrangements have yet to be finalised, but the dates are being announced so that members can note the dates and add them to their diary. The consortium is led by Prof. Massimo Ponti of the University of Bologna and Prof. Carlo Cerrano of the Polytechnic University of Marche.

Following the previous highly successful ECRS held in Oxford, UK in 2019, Naples will offer a contrasting European venue that likewise offers a wide range of historic and artistic attractions, as well as a suitable venue and quality accommodation options. The city is home to one of the very first Marine Biological Laboratories, the well-known Stazione Zoologica Anton Dohrn Napoli, founded in 1872. It is also the city we have to thank for the pizza, although this is by no means all its diverse cuisine has to offer.



The proposed venue is the Naples Citta Della Scienza, which includes the most significant conference centre in Southern Italy, with up-to-date technical facilities and a capacity of 2,000 seats across 13 rooms.

Conference facilities apart, Naples offers an excellent base from which to visit the UNESCO World Heritage Sites of Pompeii and Herculaneum (the Roman cities frozen in time as a result of the violent eruption of Mount Vesuvius in AD 79). Not much further away is the Amalfi Coast, a stretch of Mediterranean coastline celebrated for its landscape and natural diversity.

Further details of the Symposium will be made available within the next 6 months.

What are the ultimate causes of coral reef decline and what can we do about them?

Douglas Fenner

Lynker Technologies, NOAA Fisheries Service, Pacific Islands Regional Office, Honolulu
Coral Reef Consulting, PO Box 997390, Pago Pago, American Samoa
(douglasfennertassi@gmail.com)

Photo: Andrés Sánchez Quinto

It seems the world always has a long list of unsolved serious problems! As a U.S. citizen, I think the U.S. has its share. Our Society studies coral reefs and it has been obvious for quite some time that they are in deep trouble, and at risk of being largely destroyed in the near future. There are a lot of things that humans do that have caused damage to corals (or made the damage worse) in the past and which present grave threats to the future of coral reefs, not least global warming, acidification, overfishing, sediment & nutrient runoff, coral disease, and introduced species. These can be called "proximate causes," that is the things that directly (or almost directly) impact coral reefs. They are the things we usually try to do something about in order to save reefs. But there are also even bigger issues, the "ultimate causes" or "root causes," which drive the proximate causes. If we only work on proximate causes, we may be endlessly trying to put out numerous small fires while the ultimate causes keep causing more fires, resulting in an endless, losing battle. It's like a doctor trying to treat a disease. If all you treat are the symptoms, you may alleviate the discomfort, but that doesn't cure the disease; you need to treat the cause, not just the symptoms, to make any progress that isn't just temporary. To continue the analogy, we do even better if we prevent diseases rather than deal with them after we get them. We do this by attending to things like public health, clean water, sewage, healthy food, stopping smoking, moderating alcohol use, getting vaccinations, and taking enough exercise (though, as we shall see, improved human longevity may be part of our problem!). The saying is, "an ounce of prevention is worth a pound of cure." Very true about both health and dealing with environmental problems.

So, what are the ultimate causes of coral reef decline? They are surely the same as those of other human-caused environmental problems. Coral reef damage is just one of many kinds of damage that humans do to their environment. We're a pretty destructive species. It is coming back to bite us, and all predictions are that it will do so more and more unless we change our ways. "Because our practices are unsustainable, we strongly erode the natural capital that we have used to flourish, thus endangering our, and our descendants' future" (Groom 2006). We have destroyed entire ecosystems, such as the North American prairie, which was plowed and made into farmland to feed a growing population. We are now farming nearly all of the world's arable land (which is the great majority of ALL land). We're destroying forests, not just tropical forests like the Amazon, but other forests as well. We appropriate for human use almost all the carbon that is fixed by all the plants on earth. The global stock of domestic poultry now weighs more than the weight of all wild animals combined (are the chickens coming home to roost?) And we've been polluting our atmosphere with greenhouse gases that threaten existential damage to the natural world, including to coral reefs, and indeed to humans.

A popular concept is that of "carrying capacity." The world and its resources are finite, not infinite; there is a limit to the extent of resources. That would seem to imply a limit to how many people the earth can support sustainably. That limit depends in part on the level of our consumption[1]. If everyone on earth consumed like North Americans do, the planet could support many fewer people than it could if the consumption and living standards of all were more like those of poorer developing countries. Do we really want to live at the level of the latter so that we can have a much larger population? If everyone had the same living standard, how many people could the world support sustainably? Research on sustainable population levels finds that the answer depends on a great many variables, and is near impossible to measure. There are a variety of criticisms of the idea of a "sustainable population," and, according

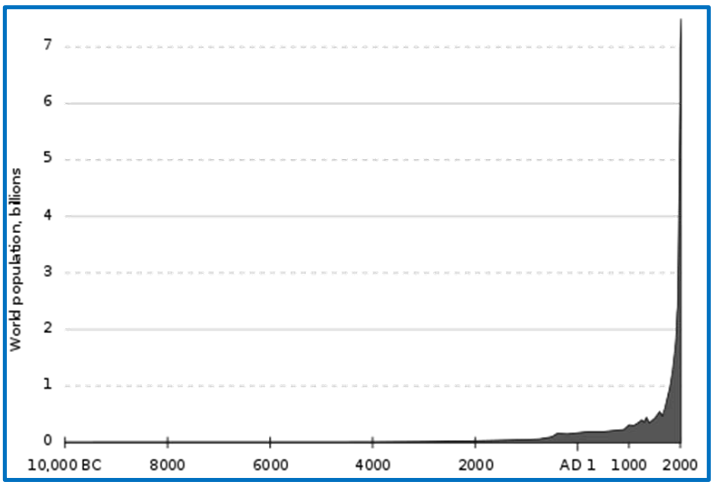


Figure 1. The form of the growth in total global human population since 10,000 BC (Wikepedia Creative Commons)

[1] As early as 1972 an ad hoc group termed The Club of Rome published the influential report, The Limits to Growth, which used computer modelling to argue that continued population growth trends would lead to global system collapse.

to Wikipedia ("Sustainable Population) "In popular discourse the concept has largely left the domain of academic consideration".

Nevertheless, one of the most obvious drivers of resource consumption is the size of the global population. The human population has over a long timespan been growing exponentially. In recent centuries, it has really exploded, as shown by the graph (Fig 1). Given the huge impact humans have on the environment and nature, one could view them as the scourge on the planet ("we have met the enemy, and they are us!"). Certainly, huge human populations make many problems worse; it is a multiplier of problems. For instance, greenhouse gas emissions. If the world population was decreased by half (and all countries had half the population), emissions would be reduced, perhaps to around half. Reducing the population would reduce almost all human impacts on the environment.

Why have human populations grown so fast? Partly it is our own success at producing more food, starting with the agricultural revolution that started about 10,000 years ago, greatly increasing after our discovery of how to manufacture fertilizer in 1900, and continuing to the present day. Most recently, the application of science and medicine has saved vast numbers of lives, for it takes only relatively small amounts of public health measures and modern medicines to cut human mortality rates dramatically. That has already happened over almost the entire earth. It reduces human suffering, which is of course a good thing. However, family planning and birth control have lagged *way* behind medicine and public health. These two effects together have resulted in a "perfect storm", producing a classic population explosion. That this has happened is in part a consequence of the fact that species of all kinds generally produce many more young than can normally survive, so that even if there is major mortality the species won't go extinct, and once conditions improve can recover. Before scientific medicine, human mortality could be very high and parents had to produce as many as 10-20 children for just a few to survive to adulthood. Now, almost all children survive. The result was the global population explosion.

People forget that Europe had a population explosion before the rest of the world (that's where all those people who went to the Americas and Australia came from). However, more recently some developed countries have had their birth rates go right down. Japan and Italy have had birth rates below replacement for quite a while. The U.S. long had a birth rate that was close to replacement, 2.1 children per mother, but it is now below replacement at 1.7[2]. China was for long the world's most populous country, but now has a birth rate of only 1.1, half of replacement, and was recently overtaken by India as the country with the largest population. In fact, surprisingly, almost all countries now have had their birth rates in sharp decline[3]. As a result, China is only a few years away from peak population, after which its population will start to decline. The annual world population growth rate peaked at 2.1% in 1968. It has since dropped to 1.1%, and is in the process of dropping even further, likely to 0.1% or even zero by 2100, after which it is expected to slowly become negative (Fig.2).

But total population size has enormous inertia. Past high birth rates coupled with reduced death rates mean many developing countries have a large proportion of their population that is under 40 and still having children. In some countries, 30-40 % of the population is under 20 years old. As a result,

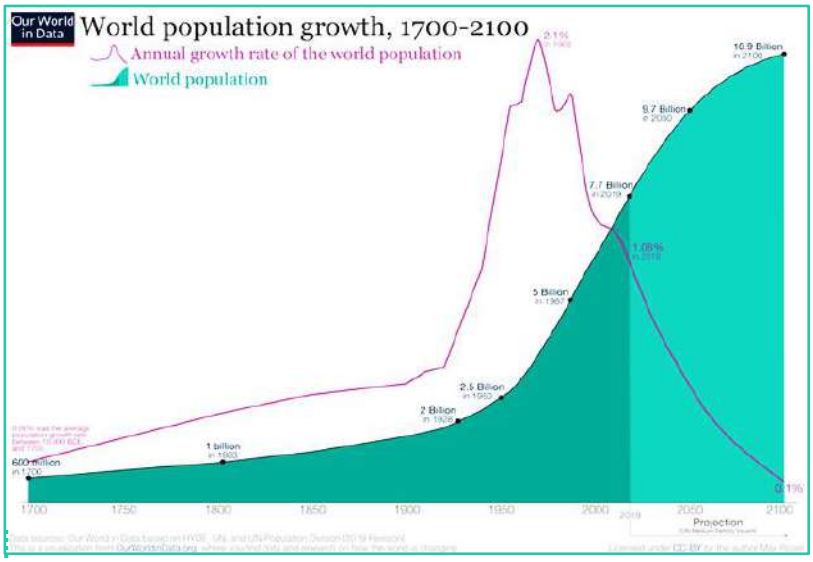


Figure 2. Changing global human population growth rate (Wikipedia Creative Commons)

[2] The U.S. population size is now growing only because of immigration.
[3] Take a look at www.youtube.com/watch?v=ncZW73QMBt8 or just do a search on YouTube for "declining population."

reductions in birth rates don't reduce the rate of population growth as fast as we might suppose. The UN projects that the world population is most likely to peak at about 10.2 billion sometime between 2075 and 2100, and only then gradually begin to decline (Adam 2022). That projection is based on assuming that present trends in birth rates continue. So, population growth rate (birth rate minus death rate) peaked in 1968, but total population will peak only somewhere between 2075 and 2100 (Fig.2). Thus it will take about 107-132 years from the peak of the growth rate to the peak of population. That shows just how slowly world population responds to changing growth rates. Reducing the birth rate rapidly and drastically also has consequences; it decreases the number of younger people in the workforce, who are supporting an increasing portion of the population of retirement age. Japan is already well into the process, and China is entering it now On the flip side, fewer children mean fewer schools and lower education costs.

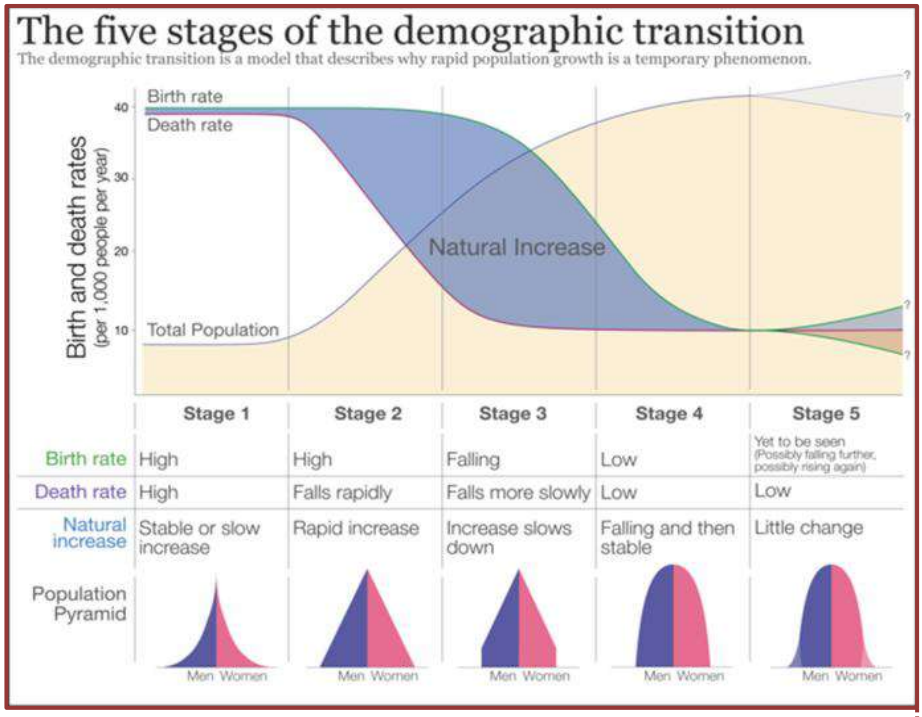


Figure 3. Changes in birth rate, death rate and total population during the demographic transition. The thickness of the dark blue area labelled "natural increase" indicates the rate of population increase (Wikipedia Creative Commons) (https://en.wikipidia.org/wiki/Demographic_transition)

Birth rates declined first in developed countries, in what is called the "demographic transition" (see Fig. 3). Originally both birth and death rates were high, yet populations stable. Then death rates decreased dramatically due to improved medicine and public health. Only more recently did birth rate also decline. Why? Likely because of several factors. One is that in an agricultural society, children also function as agricultural workers, so it is advantageous to have more of them. In developed countries, however, children are expensive. In the U.S. it costs several hundred thousand dollars to raise a child to age 15[4]. In China, the cost of children is frequently given as the main reason that parents now only want one child. But there are other factors. Increasingly, women want to work outside the home. That happened some time ago in Western Europe and the U.S., but is also happening in Japan, and probably China. If childcare is not readily available women are obliged to choose between larger families or work, and increasingly they choose work Moreover, women are increasingly more able to make their own decisions, and to have control over their own fertility. Economic development promotes all of these processes, further encouraging the reduction in the birth rate.

The data indicates that the decrease in birth rate that characterizes the demographic transition depends on the rate of economic development and occurs mainly in its mid to late stages. Thus, the speed with which birth rates decline depends on the speed of development, which in turn probably depends on macroeconomic factors. For example, from late in the last century development was very rapid in South Korea, Taiwan, and Singapore, and the birth rate in each of these countries declined quite quickly. However, the size of the population depends on both the birth rate and death rate, and it is the death rate which declines first during the demographic transition. For the population size to decrease, you have to wait for individuals to grow old and die (and that of course takes a lifetime!). That is why, even though the world's mean birth rate peaked in 1968, and has been declining ever since, the global

[4] See https://en.wikipedia.org/wiki/Cost_of_raising_a_child

population has yet to reach its peak, let alone begin to decline.

Thus, it appears that eventually the world population will take care of itself, although this will take a century or more. But for coral reefs, the projections are that they will be hit hard within just 20-30 years, unless we can reduce greenhouse gas emissions to zero within a decade. So, if we wait for the world's human population to fix itself, coral reefs will be mostly dead, long before that. Are there any alternatives? Well, to reduce the population fast, you basically have to greatly increase the mortality rate. Removing all medical care and public health (or a really virulent viral epidemic), or ceasing the manufacture of fertilizer might just do that. Or the killing of vast numbers of people, such as through an outbreak of nuclear conflict. Neither of those two options is desirable, ethical, moral, legal, or popular. Let us hope they never happen!

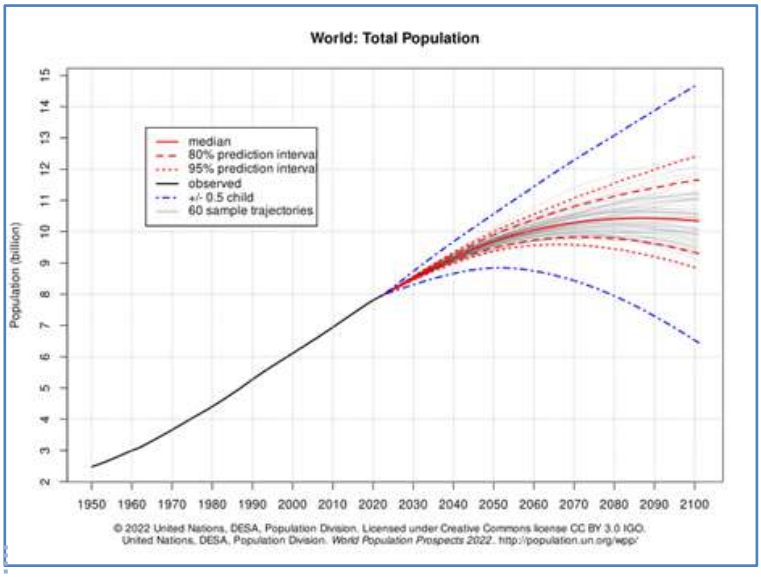


Figure 4. Modelled peak in global human population level. (Wikipedia Creative Commons)

Any other options? Well, one is for rich countries to provide free, voluntary family planning for everyone on the planet that wants it but can't afford it. It is eminently feasible, it could be done, and compared to the size of the world economy it would be a trivially small expense. Why don't we do it?? Americans think that they are a generous country and provide much more foreign aid than their country actually does; in fact the U.S. overseas aid budget is a smaller percentage of the economy than that of any other developed country. Further, when in the U.S. a new president is elected, sometimes the tiny amount of foreign aid allocated to family planning is eliminated, because certain religious groups strongly oppose it. But surely it must be in the best long-term interest of developed countries to fully fund voluntary family planning.

Of course, access to family planning is necessary for slowing population growth, but it is not sufficient. People have to want to have smaller families, or else they won't make use of it. Improvements in education and social equality appear to promote interest in having smaller families. Modeling small family size in TV and radio shows / "soap operas" is believed in countries, including Mexico, India, and Tanzania, to have encouraged viewers / listeners to aspire to smaller families. Such programs have proved quite inexpensive in relation to their effectiveness. Not only are they not coercive, but they don't lecture people about what they should do; instead they illustrate the options in culturally appropriate ways that are widely accepted and even very popular (Ryerson 2012).

Nevertheless, modelling indicates that even with a fertility-reduction to one-child per female by 2100, it would take until 2153 to reduce the world population to 2 billion people (Fig. 4) (Wikipedia "Sustainable Population"). So, reducing the world's population is not likely to be fast enough to solve the coral reef crisis. But it **IS** a critical tool for the world environment and biodiversity crisis. And whether the coral reefs survive or not, the world will continue to have an environmental, nature, and biodiversity crisis, one that if more is not done is likely to get worse, and the population is part of the problem. The best approach to the population problem seems to be a mix of family planning and educational soap operas - to lower the peak population and start the population decline sooner, and get it down sooner.

Is population the only ultimate threat to the natural environment, to nature, to biodiversity? No. As Groom (2006) has emphasized, "it is the combinations of human population levels and consumption pressures that are the root threat to biodiversity". This view has been further refined to distinguish three major threats: population level, consumption, and the third - technology (Ehrlich 2010). Each of these three compounds the effects of the other two. With no population, there would be no problem. Or with no consumption, there would be no problem. Or may be with only limited

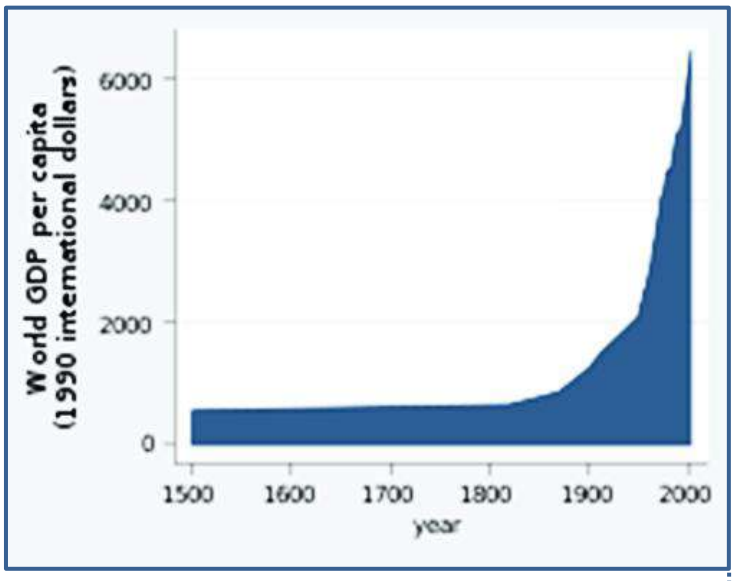


Figure 5. World economic growth. Note the similarity to the graph of the growth of population. This is not due to population, since it is GDP per capita, not the total GDP. (Wikipedia Creative Commons)

technology, there would be no problem. Take for example the problem of plastic waste and pollution. Before the invention of plastics by scientists there were no plastics in the environment, and there still wouldn't be if technology hadn't invented them. But likewise, if they had been invented, but nobody used them, there would still be little or none in the environment, whether there was a huge population or not. Equally, if there were plastics and people bought them, but only a few people, there would still be little or no plastic in the environment.

People in wealthy countries like to think the main population problem is the consequence of [...] population growth in developing countries. This may [...] be a way for people in wealthy countries to avoid acknowledging their own role.

People in wealthy countries like to think the main population problem is the consequence of recent exponential population growth in developing countries. This may, subconsciously, be a way for people in wealthy countries to avoid acknowledging their own role. But let us remind ourselves that a developed country, the US, has the third largest population on the planet, and still has a growing population. The European Union is similarly developed, and if it were a single country would have a population of 447 million, larger than the U.S. (330 million). But it is true that the countries now most likely to have the largest further population increases are all developing countries: Egypt, Ethiopia, Tanzania, Nigeria, the Democratic Republic of Congo, Pakistan, India, and the Philippines.

So, there is no question that population is a very real problem. It should be discussed and tackled more vigorously by environmental scientists. It has an easier and cheaper solution than tackling climate change. But this would still be only a slow solution: "It will take much longer to humanely reduce population size than to alter human consumption patterns" (Ehrlich 2012). There are much faster alternatives, at least in principle. "In the past two centuries, population growth and expanding per capita consumption have contributed roughly equally to humanity's assault on its life support systems. Reducing the assault and transitioning to a sustainable society will require action on *both* factors" (Ehrlich & Ehrlich 2012). Estimates vary widely, depending on different assumptions underlying them, with 8 billion people being a typical estimate. But the conclusion is that "it is the combination of population increase in the developing world and unsustainable consumption levels in the developed world that poses a stark challenge to sustainability"[5].

There is evidence that in at least some situations, consumption is a greater problem than population. "For instance, the Las Vegas, Nevada metro area population increased by 750,000 between 2002 and 2021, yet its water consumption decreased by 26 billion gallons in the same period. Also, the U.S. is estimated to waste between 161 and 335 billion tons of food a year, food which requires 140 million acres and 5.9 trillion gallons of water to produce (Thompson 2022). "Kenya, which is suffering through a devastating drought, has 55 million people, about 95 times more than the population of the U.S. state of Wyoming, but Wyoming emits 3.7 times the carbon dioxide emitted by Kenya. Africa as a whole has 16.7% of the world's population but historically has emitted only 3% of the global carbon pollution, while the United States with only 4.5% of the planet's population, has since 1959 released 21.5% of global carbon dioxide emissions (Borenstein 2022) (see Fig. 6).

[5] Wikipedia "Sustainable Population"

These discrepancies arise because carbon emissions are usually proportional to the size of the economy. Not all environmental impacts work that way, and some are likely driven more by population size. The point is NOT that consumption is the only thing that drives environmental destruction, but rather that it is another factor that exacerbates the effects of population size. More significantly, it is a factor that, potentially, could be moderated much more quickly. For it is hard to deny that the American life-style is hugely wasteful. People practically kill themselves in the economic rat race so that they can buy loads of stuff that they don't use, and with which they then fill their garages, or need to rent "mini-storage" facilities! Notably wealthy countries eat more meat, which takes much greater amounts of land and grain to produce, than if the land could instead be used to feed humans directly. Do rich countries have to do that??? No, of course not. And the strong move among younger people in many developed countries towards vegetarian or flexitarian diets is to be welcomed, and indeed promoted.

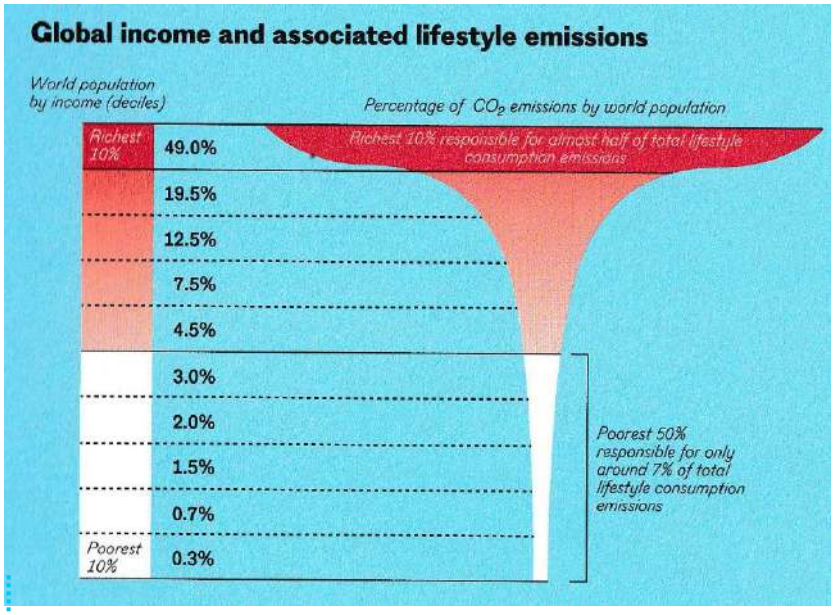


Figure 6. Variation in carbon dioxide emissions with income. (from: The Climate Book, created by Greta Thunberg, Penguin Random House, UK p.4

Surely it is possible to consume less, waste less, and still live comfortably. The idea of abandoning the objective of endless growth of wealthy economies has been called "degrowth", which it is argued "can enable rapid decarbonization and stop ecological breakdown while improving social outcomes" (Hickel et al, 2022). Could consumer culture be changed? In theory, it could be changed very quickly, but changing the ways of a whole society is not easy, especially if the society doesn't want to change, being shaped by inherited human nature. Further it can be assumed that industry and the financial sector would fight such a move, just as they have fought to protect other activities (such as smoking) that have killed millions.

It is probably useful to distinguish economic growth in the low-income countries, or among the poor in all countries, from that of the wealthiest countries and regions, and the wealthiest individuals within countries. The former, most of us would accept, have a right to develop further, which the latter should not if we are to save the planet, and ourselves. Unfortunately, it appears that in many people great wealth does not decrease the desire for more wealth. But this doesn't mean we shouldn't try to reduce consumption by the richest countries, or waste by the middle class, or the economic disparities between all, surely, we should try and try hard. Moreover, working less and freeing up quality time, can improve the quality of our lives.

Could consumer culture be changed? In theory, it could be changed very quickly, but changing the ways of a whole society is not easy, especially if the society doesn't want to change [...]

Well, how about technology?? Admittedly, at first, technology solved many of humanities pressing problems; it produced so much more food that it greatly reduced starvation[6]. The invention of the "Haber Process" for making ammonia fertilizer from methane was a huge contributor to increasing food production and thus to population growth from 1910 to the present; it has been called the "detonator of the population explosion." In fact,

[6] I am reminded however of the maxim that "most problems started as solutions to other problems" (ed.)

food production continues to grow faster than population, while technology has produced most of the things that make life better. But can it also get us out of these environmental fixes. Almost all plans to remedy climate change depend on technological developments, for example in renewable energy production, efficient batteries, and electric vehicles. And no-one is saying that we have to have a lower standard of living, because lowering the standard of living is not necessary. Some things are simple like insulating more houses and improving car fuel economy. Others are more difficult (like energy storage and transforming the world economy). But it is doable, and it can potentially be done much faster than reducing global population size.

Stopping the use of HFCs (hydrofluorocarbons) in air conditioners and refrigerators, and reducing methane leaks are relatively easy and effective, low-hanging fruit. HFC's are about 250 times stronger greenhouse gases than is CO_2, and methane is about 85 times stronger, plus they have short lives in the atmosphere, so if their emissions are reduced, the effect is much quicker than for CO_2. Stopping their emissions could prevent about a half degree of heating, which is of huge significance, especially for coral reefs! Further renewable energy is now cheaper than fossil fuels, so that huge reductions in carbon footprint should be possible to achieve. But it will take time, and there is huge opposition; as we have seen at COP27, countries are neither pledging enough, nor living up to their pledges. The fossil fuel industry is fighting every step of the way, and there are huge numbers of climate deniers. But everything that needs to be done to avoid climate change is good to do for other reasons as well. For example, reducing air pollution from burning coal, since burning coal releases mercury which is estimated to have killed 20,000 people a year in the U.S. alone! Nevertheless, these changes are not going nearly fast enough. We haven't even managed to slow the addition of greenhouse gases to the atmosphere as yet. It is a race against time, and there is no guarantee we will win. But it's all technologically feasible, and it is not only in our best interests that we solve these problems but absolutely critical that we do so.

So, if the ultimate causes of the environmental crisis, and the coral reef crisis in particular, may be identified as human population growth, resource consumption, and technological development, what are the solutions? I argue it is "all of the above." Reduce birth rates by free voluntary family planning and linked public awareness campaigns, such as radio and TV "soap operas" that model behavior in culturally appropriate ways. Get people in rich wasteful countries to consume and waste less. Find and implement all the technological solutions we can. As difficult and expensive as some of the technological solutions may be, they are likely to be effective faster and impinge on our standard of living less, rather than focusing entirely on short-term remedies or only on global population control. We need to convince people to do these things[7]. Governments need the support of their citizens to act, and citizens must push to get their governments to act. Let's get to work!! ▸

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REEF RECRUITS
Graduate Fellowship Reports

Tracing the impacts of poor water quality: a highly prevalent coral disease at a high-latitude lagoon

Charlotte E Page[1], B Leggat[2], S Egan[1], TD Ainsworth[1]

[1]UNSW, Centre for Marine Science and Innovation, School of Biological, Earth and Environmental Sciences (BEES), Kensington, NSW, 2033, Australia

[2]University of Newcastle, School of Environmental and Life Sciences, University Dr, Callaghan, NSW, 2308, Australia

Introduction

The pressures coral reefs face continue to increase across global and local scales. In addition to events like marine heatwaves (Leggat et al. 2019), other manifestations of climate change include warmer than average temperatures in both winter and summer (Heron et al. 2016) and changes in rainfall associated with El Nino Southern Oscillation cycles (Yun et al. 2021). Increasing rainfall events outside of normal seasonal cycles link a changing climate with local stressors such as run-off from land to the sea, that reduces ocean water quality. A recent study identified pollution as impacting 63.1 % of the world's coral reefs, and therefore as a top-ranked threat to reef systems (Andrello et al. 2022). Poor water quality can increase the risk of disease in hard coral taxa. Sewerage has been identified as the source of potential pathogenic strains directly causing disease in corals (Sutherland et al. 2011), and nutrient enrichment can increase severity of disease (Bruno et al. 2003). However, effects of pollutants on coral colonies depends on factors like the location and type of pollution source, timing of rainfall with tidal cycles and flow conditions at a site. Water flow over reefs can lead to mixing, rapidly diluting elevated pollution levels, or conversely it can deliver pollutants to unimpacted areas (Floehr et al. 2013). Through altering boundary layers between coral tissue and the surrounding water column, flow conditions can also alter uptake of nutrients from the water column and rates of other physiological processes (Page et al. 2021).

Over the last two years, in South-East Queensland and Northern New South Wales, Australia, La Nina was associated with extreme flooding. Increased rainfall associated with La Nina has also impacted other coral reefs in the Pacific, including at Norfolk Island, a remote high-latitude island approximately 1400 km from the East Coast of Australia (29° 01'58.18" S, 167° 57'15.81" E). In November 2020 a novel tissue loss disease was observed affecting the primary reef building taxa (*Montipora* spp.) in the coastal lagoon at Norfolk Island. This observation followed several stress events, including widespread coral bleaching in March 2020 and pollution from terrestrial sources caused by high rainfall in the following winter period (Ainsworth et al. 2021). To effectively manage local stressors like water pollution we need to better understand how exposure to pollution and oceanography interact, potentially mediating or increasing pollution impacts. In this project we provide a description of the disease impacting *Montipora* before quantifying disease prevalence through the Austral summer of 2020-2021. We then present the results of an investigation in December 2020 and April 2021 into the terrestrial inputs of pollution at coral reef sites at Norfolk Island using stable isotope analysis of macroalgal tissue. Macroalgal isotopic composition is a time-integrated measure of nutrients and $\delta^{15}N$ and is a commonly used tool to trace terrestrial input into coastal systems when nitrogen sources are isotopically distinct from each other (Risk et al. 2009). We further contextualise disease and pollutant levels with measurement of flow conditions within the lagoon.

Methods

This work was conducted in the lagoonal reef system on the south-side of Norfolk Island. Within the lagoon are two bays, Emily Bay and Slaughter Bay (Fig. 1). Following methods by Work and Aeby (2006), disease signs were categorised through observations of lesions on the colony. Monitoring of tagged lesions on distinct colonies was conducted in December 2020 to determine lesion progression. To quantify disease prevalence (i.e. the proportion of community infected) ecological surveys were conducted at the initial disease observation,

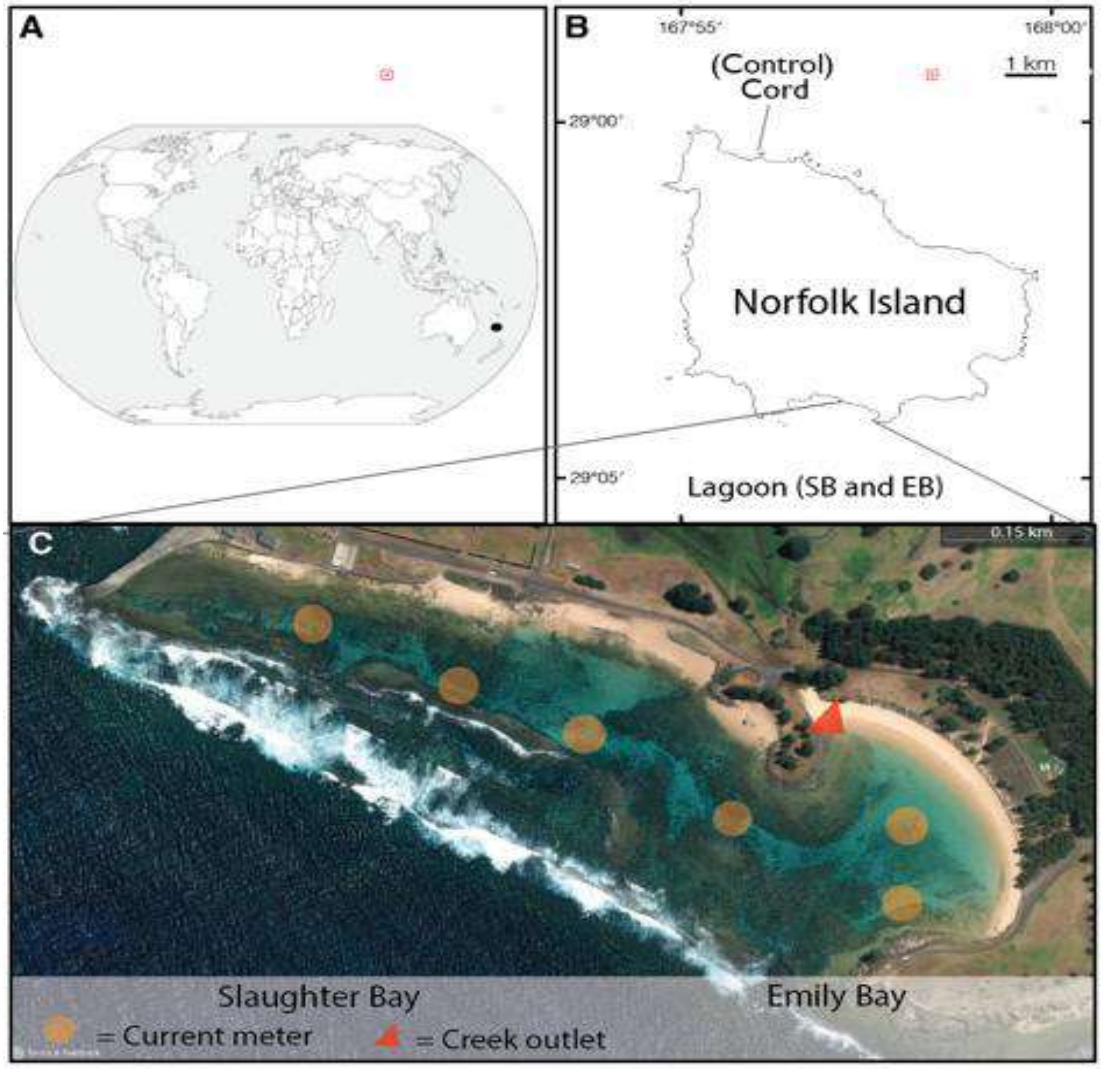

Figure 1. A. World map showing the location of Norfolk Island (black dot). B. A map of Norfolk Island showing location of the lagoonal reef system and the control site used for macroalgal Stable Isotope analysis, referred to as the Coord on the North Site of the Island. C. A satellite map of the lagoonal reef system showing Slaughter Bay, Emily Bay and the location of deployed current meters (yellow dots) in addition to a creek outlet (red triangle) into Emily Bay.

December 2020, and at the end of the summer period, April 2021. All colonies of Montipora over 10 cm in diameter and within 1 m to either side of a 10 m transect were monitored for signs of disease at each time point. Six replicate semi-fixed transects were placed across Emily and Slaughter Bays. Disease levels were considered consistent with outbreak levels when they were above endemic levels recorded on reefs i.e. < 1% in the Indo-Pacific (Haapkylä et al. 2007).

We sampled a brown alga Dictyota sp. in the lagoon for stable isotope analysis in December 2020 and April 2021 in the lagoon, and a control site exposed to oceanic sources of nutrients (the Coord). Sampling regimes within the lagoon allowed for analysis of spatial patterns of isotopic signatures using spatial interpolation methods. To investigate flow conditions within the lagoon we deployed seven Marotte HS drag-tilt current meters (http://www.marinegeophysics.com.au/current-meter/). Two meters were placed in Emily Bay and four in Slaughter Bay, attached to concrete blocks placed on sandy substrate adjacent to coral patches (Fig. 1).

Preliminary Results and Discussion

In this project we recorded the extent and potential drivers of a coral disease outbreak that impacted a foundational hard coral taxa at Norfolk Island, South Pacific. Signs of disease were observed in all taxa identified as Montipora spp. and manifested similarly in all growth forms and colour morphs (Fig. 2). These included foliose colonies with plating and column structures and encrusting colonies growing on substrate (Fig. 2). Description of disease signs and measurement of lesion activity within the Norfolk Island lagoon led to us describing it as a novel , tissue loss disease with unknown aetiology, referred to as Montiporid White Syndrome (Bourne et al. 2015). The disease presented with multifocal patterns and discrete patchiness of tissue loss areas across the affected colonies. Disease signs began with initial paling of tissue, followed by three discrete phases of disease progression. We measured transitions between these disease phases

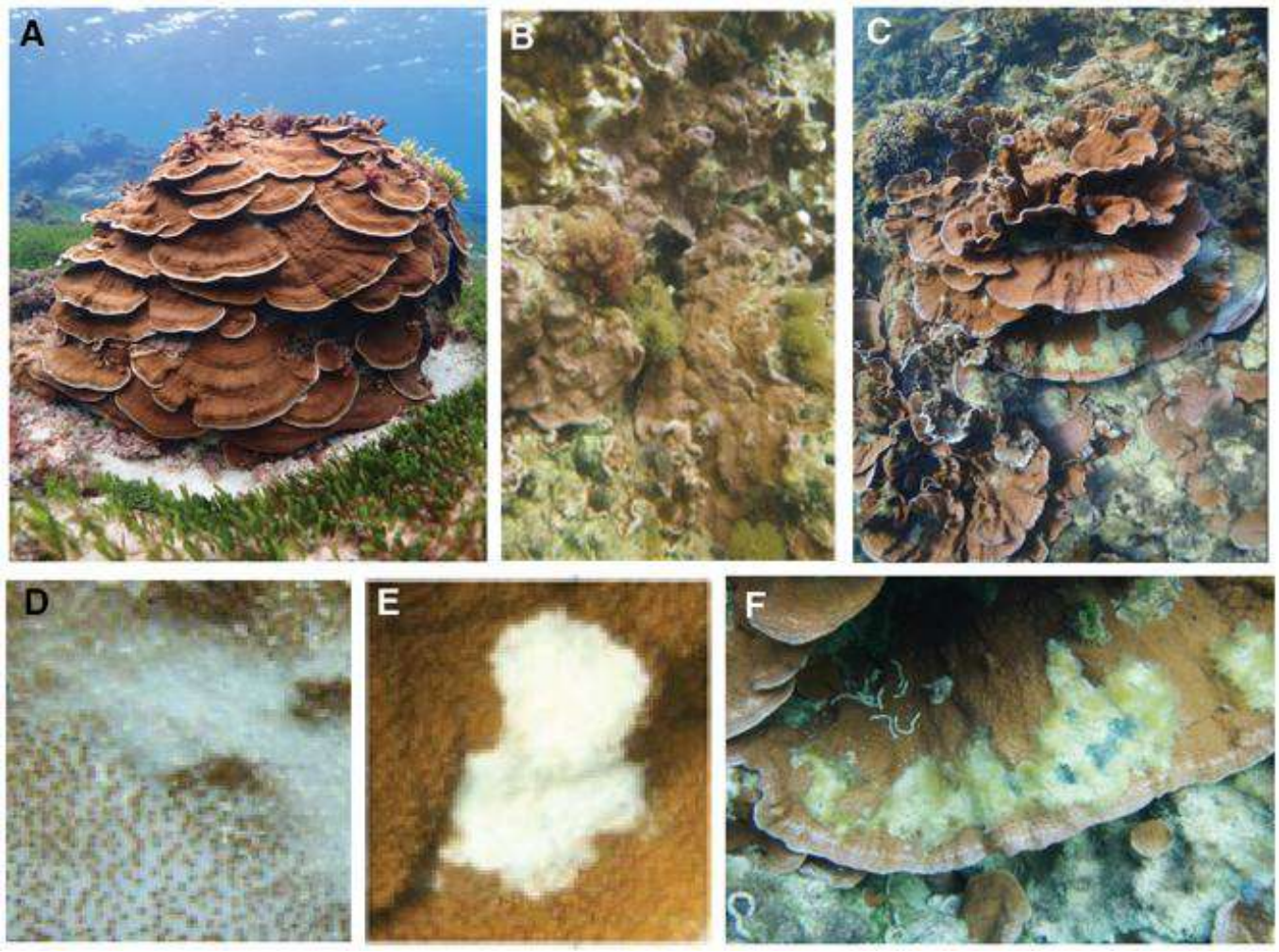

Figure 2. Examples of a (A) healthy foliose *Montipora* with pillar and plating structures and (B) an encrusting *Montipora* colony. (C) A medium *Montipora* colony with multifocal lesions. White Syndrome signs include (D) paling of tissue (E) loss of tissue revealing white skeleton and (F) initial colonisation of skeleton by microbial biofilm.

on coral colonies. The final stage of disease presented as lesions with signs consistent with skeleton colonisation and overgrowth. Bleaching of coral tissues prior to tissue loss is a common feature of many white syndromes and subsequent colonisation by biota has been recorded following loss of tissue in other reef locations (McClanahan et al. 2004). Moreover, the four distinct disease phases identified in the present study are similar to those seen in corals affected by Atramentous Necrosis, a disease first described in the Central Great Barrier Reef (Jones et al. 2004). Future work will use histopathological methods to investigate presence of potential disease-causing agents.

In December 2020 and April 2021 we observed high disease prevalence in the surveyed community, higher than normal endemic levels (~ 1%) and comparable to recent outbreaks of SCTLD in the Caribbean, where up to 70 % of the coral community have been recorded as showing signs of disease (Table 1) (Muller et al. 2020). Whilst we did not measure a change in disease prevalence over the summer period, we did find in December 2020 significantly higher disease prevalence in Emily Bay than in Slaughter Bay. This pattern suggests a possible link between disease and exposure of communities to poor water quality during creek overflow events in the preceding winter period.

Exposure is likely higher in Emily Bay due to proximity to creek outlets (Ainsworth et al. 2021). In the present study we were unable to track colony fate therefore it is unclear whether colonies recorded as diseased in April 2021 represent newly infected colonies compared to those recorded in December 2020.

Analysis of naturally occurring Stable Isotope ratios of Nitrogen content in macroalgal tissues indicate different levels of exposure to terrestrial pollution in the lagoon compared to the control site. We found that ratios of isotope 15N at the control site (the Coord) suggest it is predominantly exposed to

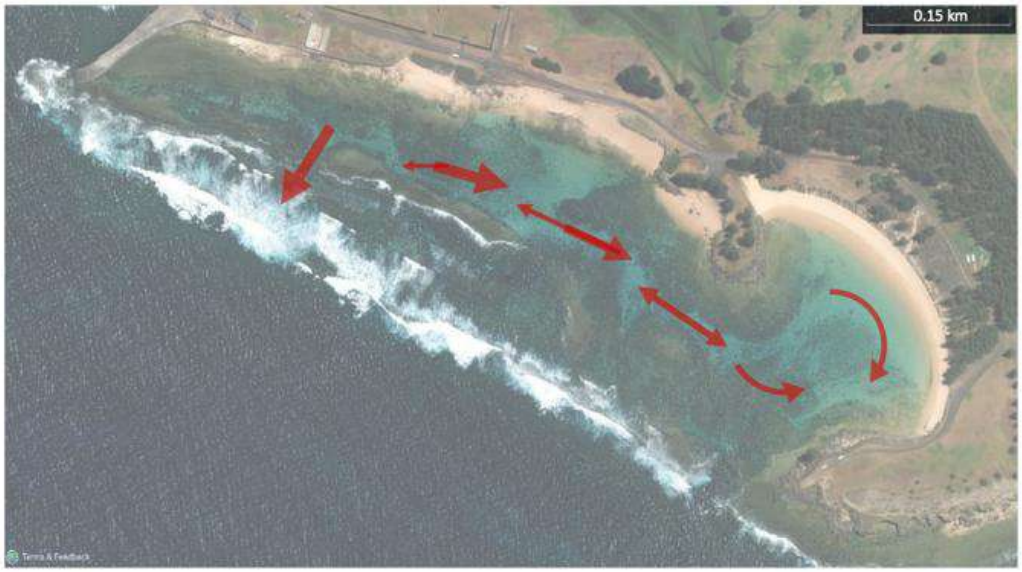

Figure 3. Predominant flow direction measured by current meters in Norfolk Island Lagoon. Width of the arrow represents approximate relative speed.

Table 1. Approximate disease prevalence levels recorded in Emily and Slaughter Bays in December 2020 and April 2021.

Time point	Site	Disease prevalence levels
December 2020	Emily Bay	>50 % (comparable to SCTLD, Muller et al., 2020)
	Slaughter Bay	<50 %
April 2021	Emily Bay	>50 %
	April 2021	Emily Bay

oceanic sources. In December 2020 δ15N content in macroalgal tissue was similar across all sites, whilst in April 2021 macroalgal tissue content indicated depletion of δ15N in Emily Bay compared to the Coord site, consistent with sources of N from terrestrial sources. Additionally, spatial investigation of stable isotope composition within the lagoon was reflective of the creek outflow into Emily Bay. Studies consistently find evi dence for an inverse relationship between stable isotope values and distance from source, where δ15N values move closer to background environmental levels further away from the shore (Adam et al. 2021). We suggest that in addition to direct point-source exposure, flow conditions present within the lagoon could have led to higher disease-risk in Emily Bay, since within the lagoon water primarily moves in an easterly direction, with a major outflow occurring at the western end of Slaughter Bay (Fig. 3).

In characterising disease-levels of Montiporid White Syndrome at Norfolk Island lagoon we highlight spatial patterns in disease-risk associated with pollution exposure and flow conditions. Future work will look to further investigate terrestrial impacts and exposure levels at reef sites around Norfolk Island through analysis of N content of macroalgal tissue. We will also assess the sub-lethal impacts of the Montiporid White Syndrome on coral colonies, including any impacts on reproductive output.

About Charlotte E Page

Charlotte Page is a PhD candidate at UNSW Sidney and is interested in understanding mechanisms that effect the maintenance of the coral-algal symbiosis in an increasingly warm ocean.

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Twitter: CharEvePage

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Metabolomic features linked to bleaching phenotypes in Porites astreoides under chronic thermal stress

Kevin Wong

Department of Biology, University of Rhode Island, Kingston, RI, USA; kevin_wong1@uri.edu

Introduction

Increased seawater temperature above the annual maximum disrupts the symbiotic relationship between corals and their algal symbionts, Symbiodiniaceae (LaJeunesse et al. 2018), leading to severe energy reduction and increased potential coral mortality, commonly referred to as "coral bleaching" (Glynn 1996). However, there are differential bleaching responses across coral species (e.g. Grottoli et al. 2014), populations (e.g. Barshis et al. 2013), and individuals (e.g. Matsuda et al. 2020). Variation in thermal resilience of corals can be driven by acclimatization, which is elicited through repeat exposures (Brown et al. 2000, Ainsworth et al. 2016) or higher thermal variability (Barshis et al. 2013). However, conspecifics (i.e. individuals of the same species) in close proximity have also exhibited different bleaching phenotypes and responses to *in situ* thermal stress (Matsuda et al. 2020).

Coral bleaching is an energetically costly consequence of stress that commonly leads to mortality; however, survival after bleaching is possible if the level of stress returns below the physiological thresholds, or if alternative routes of energy acquisition are available, such as catabolism of stored reserves and heterotrophic feeding (Grottoli et al. 2006). These alternative outcomes - (1) bleaching then mortality, or (2) maintaining a symbiotic "bleached" state, involve different cellular mechanisms that have not been directly compared. Metabolomics (i.e. the study of metabolites) is widely used to identify rapid changes in cellular physiology and can describe energy allocation throughout an organism. Metabolomics is becoming increasingly useful for understanding metabolic states in marine non-model organisms such as corals (Williams et al. 2021). Given the ecological consequences of coral mortality, it is critical that we understand the physiological and molecular mechanisms that lead to mortality under stress, and provide insight on why some corals are more resilient than others.

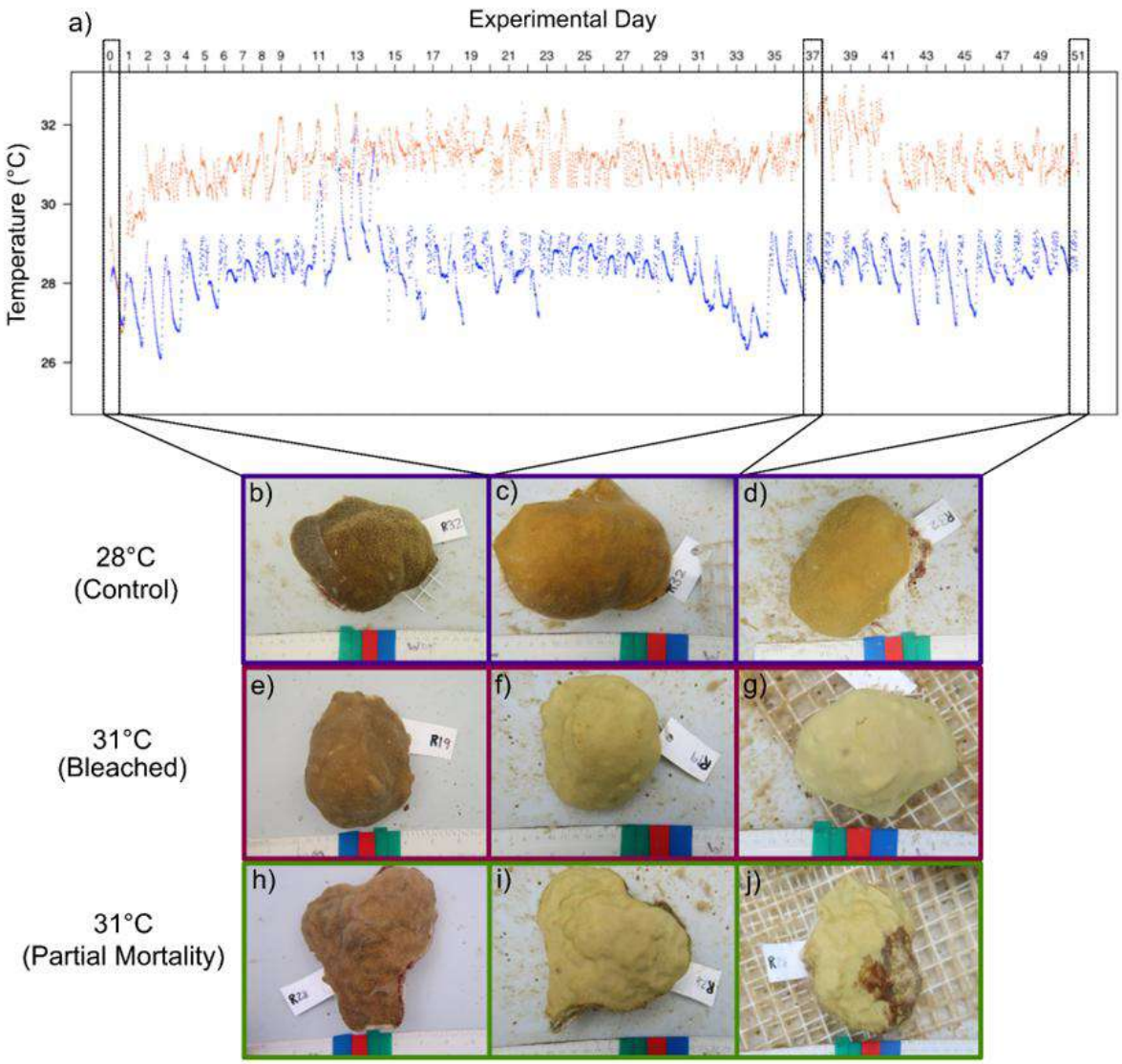

Figure 1. (a) Experimental temperatures of the treatment tanks over the 52-day experimental period. Photographs of the Control *P. astreoides* colonies in the ambient treatment (28˚C) at (b) Day 0, (c) Day 37, and (d) Day 52 sampling timepoints. Photographs of the Bleached colonies in the heated treatment (31˚C) at (e) Day 0, (f) Day 37, and (g) Day 52 sampling timepoints. Photographs of the Partial-Mortality colonies in the heated treatment (31˚C) at (h) Day 0, (i) Day 37, and (j) Day 52 sampling timepoints.

In this study, we aim to understand the metabolomic features that underlie the occurrence of differential bleaching phenotypes ("mortality" vs "bleached") in response to chronic thermal stress in the common reef-building coral, *Porites astreoides*. This is a resilient Caribbean coral that can tolerate a wide range of environmental conditions, but is nevertheless susceptible to bleaching (Kenkel et al. 2013). By investigating bleaching and mortality at a cellular level in such a coral, we can determine the mechanisms allowing it to survive under prolonged thermal stress. Thus, the primary goal of the present study was to identify the metabolites present under thermal stress in bleaching and partial-mortality phenotypes.

Activities Undertaken

Experimental Design. Forty adult *P. astreoides* colonies (~10 cm in diameter) were collected from Hog Reef (32°27'26"N, 64°50'05"W) in Bermuda and transported to the Bermuda Institute of Ocean Sciences (BIOS). The colonies were held at 28°C for five days in an outdoor mesocosm facility. The colonies were then randomly assigned between treatments, four to a tank. In one set of tanks (heated treatment) the temperature was increased by 0.5°C/day until a daily average of 31°C was achieved. In the other set of tanks the temperature was maintained at 28°C. The corals were then maintained subject to the same temperatures (28°C or 31°C) for a further 46 days, resulting in a total 51-day experimental period (Fig. 1a).

During the experiment the colonies were sampled three times: Day 0 (immediately before any temperature ramp), Day 37, and Day 51 (Fig. 1). At each sampling, point, the colonies were photographed to record mortality, photosynthesis and respiration rates were measured (as in Wong et al. 2021; Fig. 2), and live tissue biopsies were snap frozen in liquid nitrogen and stored at -80°C for later physiological (endosymbiont density, chlorophyll a, total protein, and total carbohydrate) and metabolomic (LC-MS) analyses. After the end of the experimental period, 15 colonies were categorized into three phenotype groups: Control corals with no bleaching (from the 28°C treatment; n=5), Bleached corals (from the 31°C treatment) with bleaching but no tissue loss (n=5), and Partial-Mortality corals (from the 31°C treatment) with bleaching and visible tissue loss (n=5; Fig. 1b-j).

Data Analysis. Photosynthesis (symbiont), respiration (holobiont), photosynthesis to respiration ratio (P:R), endosymbiont density, chlorophyll a, and total protein (coral and symbiont) were measured and analyzed following the methods described in Wong et al. (2021). Total carbohydrate content (coral and symbiont) was measured and analyzed following Bove et al. (2019). All metrics were either standardized to surface area as determined by ImageJ (cm^{-2}) or endosymbiont cell density ($cell^{-1}$). A principal component analysis (PCA) was performed to determine the percent variation explained by all physiological variables, and a biplot generated to illustrate the significant loadings driving the direction and magnitude of variation.

Figure 2. PhD candidate, Kevin Wong, measuring photosynthetic and respiration rates of *P. astreoides* colonies.

Untargeted metabolomics identification was performed at Rutgers University using methods similar to those described by Williams et al. (2021). Identified metabolites were normalized to input tissue weight, zero inflated by 1000, and log transformed. An unsupervised approach (PCA) and PERMANOVA were used to visualize and distinguish groups over time (Fig. 3a). A supervised PLS-DA was performed between the Control group and each phenotype (Bleached or Partial-Mortality) to extract metabolite variables of important projections (VIPs). Significantly accumulated or depleted metabolites were identified if VIPs were >1 and were validated by t-tests with corrections for false discovery rate (FDR). These metabolites were then categorized into those unique to the Bleached phenotype, unique to the Partial-Mortality phenotype, and those shared between groups (Fig. 3b-g).

Results and Discussion

Physiology. There was a significant effect of both Time ($p<0.01$) and Group ($p<0.01$), and an interaction of Time and Group ($p<0.05$) on *P. astreoides* physiology. Colonies at 31°C experienced significant declines in endosymbiont cell density, chlorophyll a per cm^{-2}, gross photosynthetic rate, and P:R in comparison to the control group. In contrast, endosymbiont total protein per cell and total carbohydrate per cell increased through the experiment in both the Bleached and Partial-Mortality groups compared to the Control group.

Metabolomics. Similarly, there was a significant effect of Time ($p<0.001$) and Group ($p<0.001$; Fig. 3a) on metabolites. On Day 52, there were 8 differentially accumulated and 2 differentially depleted metabolites in the Bleached group compared to the control (Fig. 3b), and 29 differentially accumulated and 5 differentially depleted metabolites in the Partial-Mortality Group (Fig. 3b). The Bleached group had 2 unique metabolites that were differentially accumulated compared to the Control group: homocitrulline and itaconic acid. The production of itaconic acid is known to inhibit the growth of marine pathogens, such as *Vibrio* spp. (Van Nguyen et al. 2019), which may play an important role in preventing tissue loss under

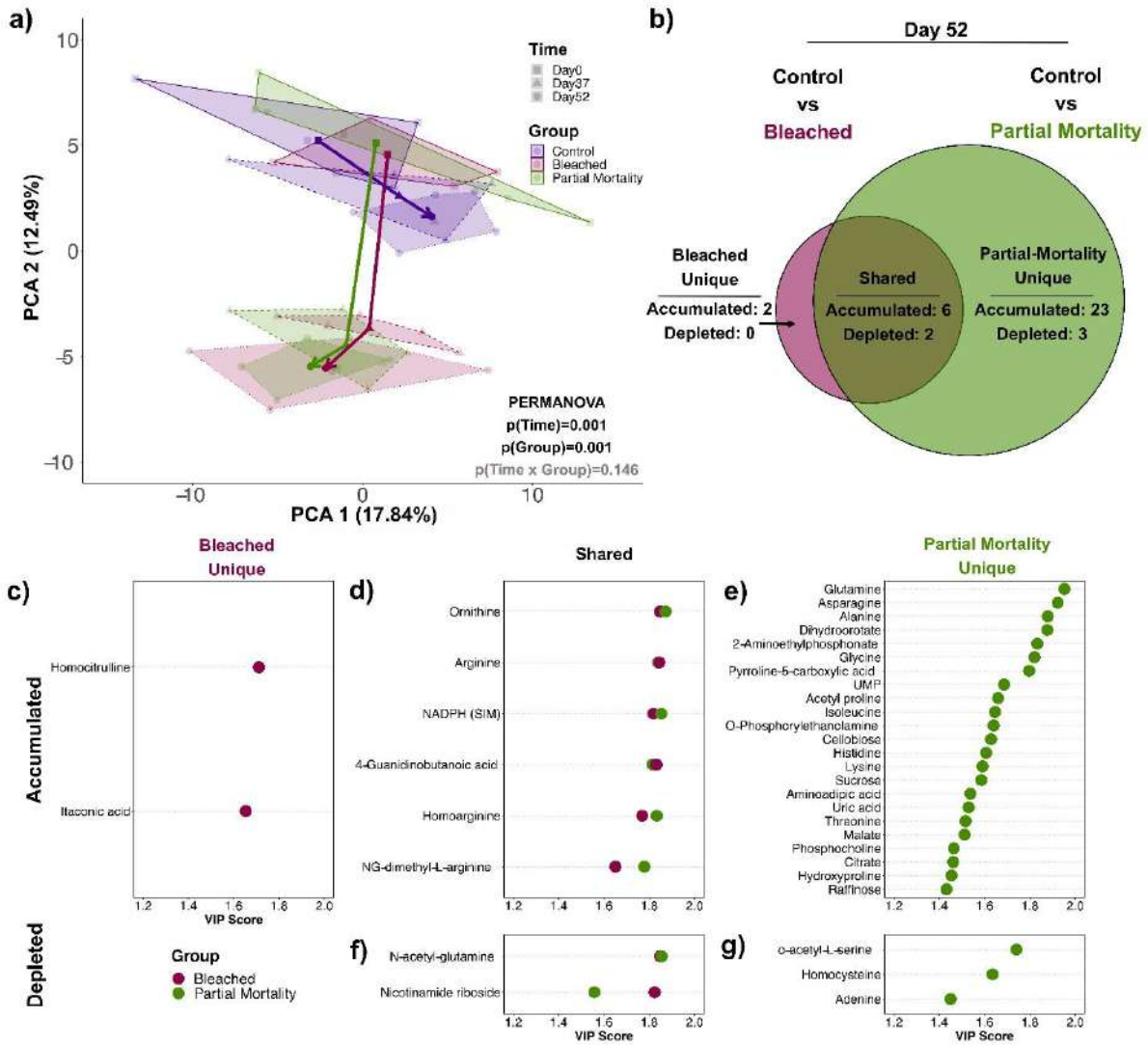

Figure 3. (a) PCA of all identified metabolites. Polygons outline the ordination groups with purple shades corresponding to the Control group, red shades corresponding to the Bleached group, and green shades corresponding to the Partial-Mortality group. Square data points represent Day 0 sampling, triangular data points represent Day 37 sampling, and circular data points represent Day 52 sampling. (b) Venn diagram showing the significantly different accumulated and depleted metabolites between the Control and Bleached group (red), and Control and Partial-Mortality group (green). (c-g) Metabolite names for each part of the Venn Diagram with VIP scores >1 and validated by t-tests with corrections for false discovery rate (FDR). (c) Accumulated metabolites that are unique to the Bleached group. (d) Accumulated and (f) depleted metabolites that are shared between the Bleached and Partial-Mortality groups. (e) Accumulated and (g) depleted metabolites that are unique to the Partial-Mortality group.

thermal stress and dysbiosis. The Partial-Mortality group had accumulated metabolites relating to nitrogen assimilation (i.e. glutamine), which is important for maintaining the coral-algal symbiosis (Su et al.2018).

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About Kevin Wong

Kevin Wong is a Postdoctoral Researcher at the University of Miami in the Cnidarian Immunity Laboratory. His research aims to understand how marine organisms will respond to future climate change stressors.

Stay connected

Twitter: kevhwong

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The applications of multispectral orthomosaics to the evaluation and monitoring of juvenile corals

Rodrigo Adrián Rodríguez Vázquez

Spatial Research Program in Coastal and Marine Environments (PIESACOM) at UMDI-Sisal, Facultad de Ciencias, Universidad Nacional Autónoma de México (UNAM); rod1519@ciencias.unam.mx

Figure 1. Left: Satellite image showing locations of georeferenced survey sites. Right: Divers positioning 1m^2 quadrats on the reef during the rainy season survey.

Background

Coral reef ecosystems are facing significant degradation due to the synergy of local (e.g., eutrophication, sedimentation, pollution) and global (ocean acidification, global warming, sea level rise) stressors (Hoegh-Guldberg & Bruno 2010), leading to loss of coral cover, decrease of reef complexity and habitat quality, and phase shifts from coral to macroalgal dominated systems. In this context, the development of more efficient monitoring methods that can be applied to support the decision-making processes in conservation and management of coral reef ecosystems is more urgent than ever (Halpern et al. 2008), particularly regarding assessment of juvenile corals (< 4 cm). Traditionally, reef surveys have required highly trained divers to perform underwater in situ surveys. While direct visual surveys provide accurate observations, they can only cover a limited area of the reef under typical logistical constraints. They required extensive field times, are affected by the performer's expertise, and do not

Figure 2. Left: the author collecting traditional data on juvenile corals during the dry season survey. Right: the MicaSense Red Edge-M short-range multispectral sensor adapted for underwater use.

generate a lasting record of the habitat structure for re-analysis (Chennu et al. 2017). The advantages of image-based surveys are that they increase the area covered per unit effort, are not destructive, provide quantitative spatial and temporal measures from the communities generate a lasting record of the habitat, and are constantly improving (Aronson & Swanson 1997, Guo et al. 2016, Lirman et al. 2007). Emerging technologies and novel applications will complement, as well as streamline, the capture of direct and digital observations. Specifically, a high potential imaging technology to streamline the capture of underwater relevant spatial data is multispectral imaging which has already shown its relevant use in other environments. This project has been developed on the east coast of Yucatan's Peninsula at Akumal's reef, Quintana Roo, Mexico, a typical fringing reef, with three different seasons: dry from March to May, rainy from June to September, and north-winds from October to February.

Activities

With the support provided by the ICRS, we were able to carry out two field trips to Akumal's reef, to record the spatiotemporal changes in juvenile corals during the 2021 dry (April 19th-23rd; 11 scuba dives) and rainy (September 28th to October 2nd; 8 scuba dives) seasons. For this, a stratified sampling design was surveyed during both seasons in three reef sectors - Northern, Centre, Southern - and two reef zones, - reef front, reef slope- , in each of which three 10m long transects with three equidistantly placed 1m^2 quadrats were placed (Fig. 1).

During fieldwork, the number of juvenile corals was estimated in each quadrat. Subsequently, to test the new methodology, a MicaSense Red Edge-M short-range multispectral sensor (5 bands) adapted to an underwater housing with artificial illumination (Keldan 8x) was used to collect multispectral data from each quadrat (Fig. 2). In the lab, multispectral data were processed in the Agisoft Metashape software (academic license purchased with the ICRS Graduate Fellowship) to develop multispectral orthomosaics (Fig. 3).

Summary of Results

During the two seasons (dry and rainy 2021), a total of 108 1m^2 quadrants were analysed for juvenile corals through traditional (visual) methods, however, the multispectral data were only collected during the dry season due to the failure of the MicaSense Red Edge-M sensor at the beginning of the rainy season survey (Table 1).

Table 1. Rainy and dry season survey information

Method	Number of 1m^2 Quadrats	Dry Season Survey	Rainy Season Survey
Traditional (Visual)	108	Yes	Yes
Multispectral	54	Yes	No

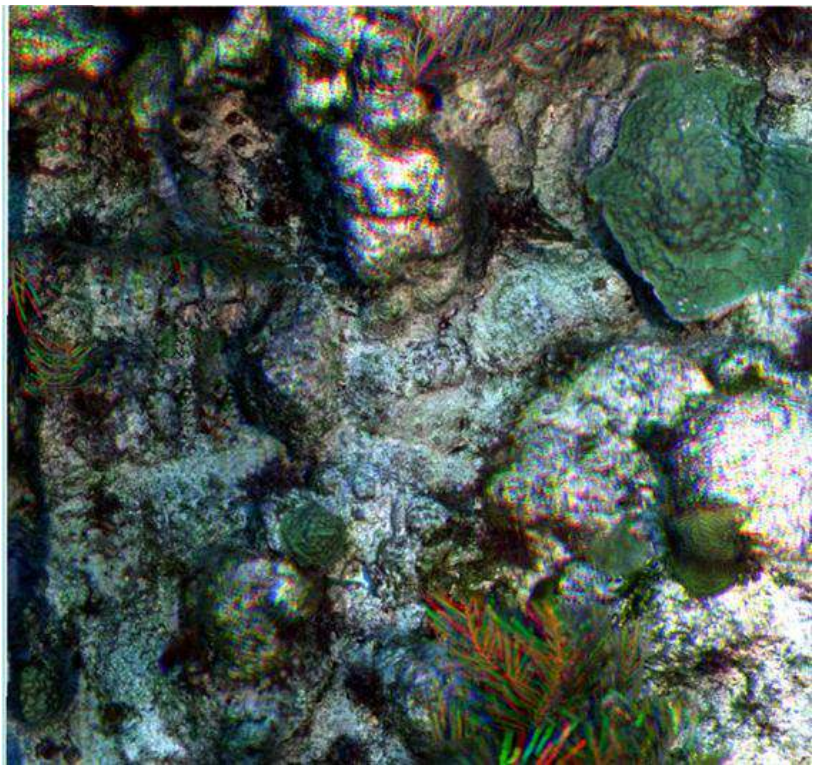

Figure 3. Showing a 1m^2 multispectral orthomosaic collected during the dry season survey at the southern sector of the reef front. RGB visualisation.

About Rodrigo Adrián Rodríguez Vázquez

Rodrigo Vázquez is a PhD candidate from UNAM. He currently specializes in the use of Remote Sensing and Geographic Information Systems (GIS) for the assessment and monitoring of coastal and marine ecosystems.

Concluding Remarks

Due to the mobility limitations imposed by SARS-COV2, the progress of my Ph.D. research was significantly affected; however, now that restrictions have been lifted, I will catch up on my project activities, and the next research step is to test different supervised classification algorithms (Maximum Likelihood, Mahalanobis, Neural Networks, Support Vector Machine, Random Forest) on the multispectral orthomosaics to select the most accurate classification product for surveying juvenile corals. Then, these classified orthomosaics will be used to test, by univariate and multivariate statistical analyses, the existence (and magnitude) of differences between traditional and multispectral methods.

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REEF EDGE

Discrepancies between Coral Reef Watch Bleaching Alerts and in situ temperatiure records on Coral Reefs on the Abrolhos Bank, Brazil

Natiely Priscila Paiva Monteiro[1], Renato David Ghisolfi[2]

[1] Federal University of Espírito Santo, Vitória, ES, Brazil, (email: natielyp31@gmail.com)

[2]Oceanography and Ecology Department, Federal University of Espírito Santo, Vitória, ES, Brazil (email: renato.ghisolfi@ufes.br)

Introduction

The Abrolhos Bank is located off the east Brazilian coast, within the South-west Atlantic Ocean region. It forms a 200km seawards extension of shallow seabed from what is otherwise only a narrow continental shelf. The bank sustains the richest and most extensive reefs in the South Atlantic, and provides habitat for many corals, some of which are endemic, such as *Mussismilia brasiliensis, Mussismilia hispida, Mussismilia harttii, Favia gravida, Favia leptophylla, Millepora braziliensis*, and *Millepora nitida* (Leão et al. 2003). Like other coral reef areas across the world, the Abrolhos Bank has, from the 1980s, endured a series of bleaching events due to warming sea surface temperatures. However, there is also evidence that some Abrolhos Bank reefs may have been less impacted by thermal stress than other reefs in the region. Heat stress is of course the main environmental stressor causing coral bleaching (Lought et al. 2018), the death of the coral resulting from the expulsion of the zooxanthellae living in symbiosis within the coral (Jokiel & Coles 1977, Glynn 1983, Gates et al. 1992). Nevertheless, while temperature itself is the main stressor, it may also lead to additional physical (e.g. reduced dissolved oxygen content), chemical (e.g. changed concentrations of substances in the water) or biological (e.g. altered behavior of other aquatic biota) effects.

Results

To investigate this possible anomaly further, estimated sea-surface temperatures (SSTs) were extracted from NOAA's Coral Reef Watch (CRW) satellite-derived ocean temperature database, and compared with those obtained *in situ* at selected points on the Abrolhos Bank (Fig. 1). The data were plotted separately for the different data collection points; those on the part of the bank nearer the coast were on the shallow coastal reefs at Sebastião Gomes and Pedra de Leste (see Fig. 1). Despite these reefs being close to each other, the *in situ* temperature records revealed that whereas the *in situ* temperatures at Sebastião Gomes (Fig. 2) could be slightly cooler than those suggested by the CRW data, Pedra de Leste was usually subject to distinctly higher thermal stress than indicated by CRW data (Fig. 3). Notably at Sebastião Gomes, from May 2017 to July 2017, *in situ* temperatures were colder, and from October 2017 to January 2018 warmer, than levels predicted by CRW (Fig. 2). The results also demonstrate that the bank is thermally inhomogeneous, especially in the austral summer, when cold deep ocean water moves up onto the bank. The mechanisms driving this phenomenon are under further investigation.

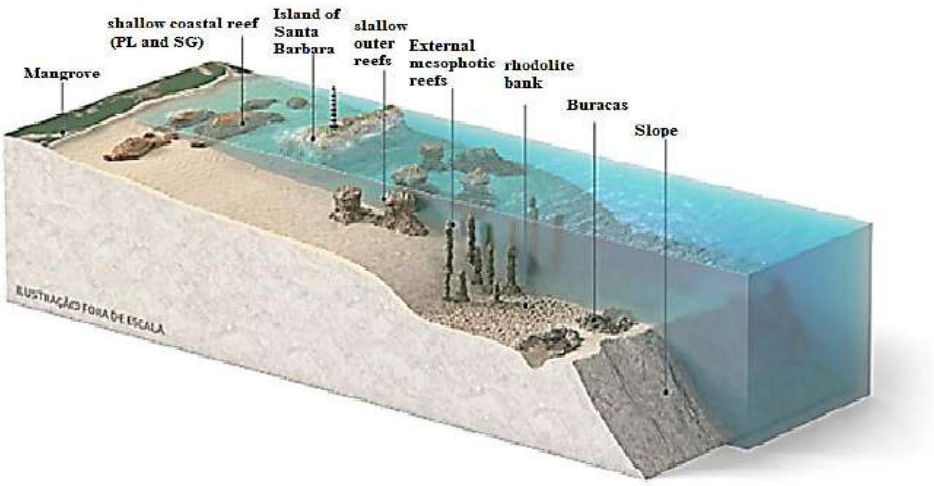

Figure 1. Schematic representation of megahabitat distribution on the Abrolhos platform, indicating the locations of the shallow coastal reefs (SG = Sebastião Gomes, PL = Pedra de Leste), of Santa Bárbara Island (part of the Abrolhos Archipelago), the outer coral reefs, the deeper outer mesophotic reef zone, the rhodolith (red algal) banka, and the buracas (sink-hole like features). Infographic: Rede Abrolhos.

Discussion

Some authors suggested that discrepancies between CRW and *in situ* temperature data may be due to the occurrence of suspended particulate matter input to the coastal ocean via river discharge. In contrast, Ghisolfi et al. (2015) highlighted evidence that during the austral summer the presence of colder water in the lower part of the water column can act as a thermal buffer against high sea surface temperatures. However, it must also be borne in mind that satellite-dervived data integrates SST on a larger scale than recorded by single *in situ* recording devices. The present observations can be explained if the extent of intrusion of warmer or cooler water onto the reef varies between locations. We conclude that while CRW bleaching alerts are invaluable in monitoring over very large areas, especially if *in situ* information is lacking, it must be remembered in mind that there may be significant local variation in actual SSTs.

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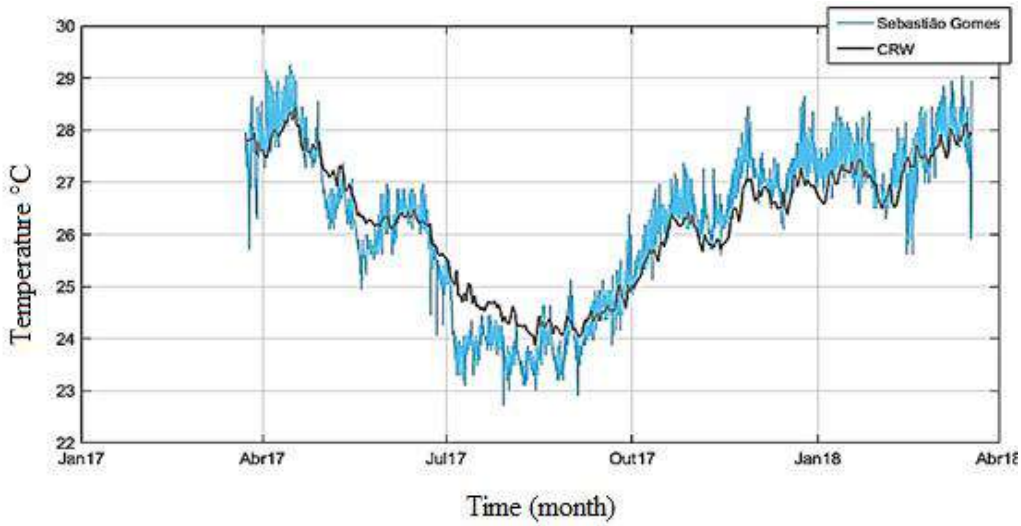

Figure 2. Temporal distribution of the TSM (CRW – in gray) and the temperature measured in situ on the reef for Sebastião Gomes (in blue). The period shown corresponds to that in which the measurements are concomitant.

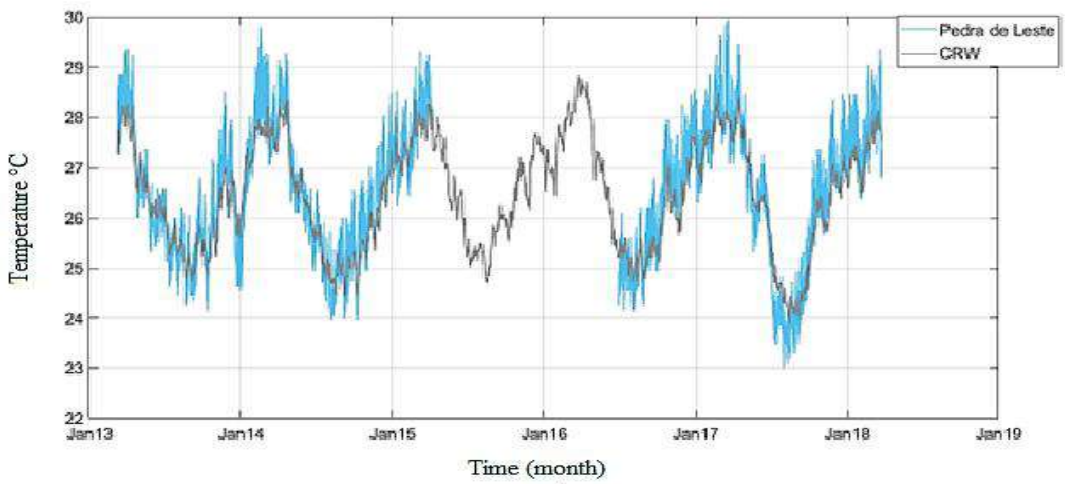

Figure 3. Variation in temperature as estimated by Coral Reef Watch data (CRW – in gray) and recorded directly *in situ* (in blue) on the reef at Pedra de Leste. Unfortunately, *In situ* data were not recorded for the central part of the period shown.

Shell Crushers: Durophagous Fishes Turn Molluscs into Island Sediment

Jake Nilsen[1*], Joshua Bonesso[2,6,7], Dylan Benson[1], Shannon Dee[1], Nicola K. Browne[1], Kyle Morgan[3], Mick O'Leary[2,7], Michael Cuttler[4,5,7], Jennifer McIlwain[1]

[1]School of Molecular and Life Science, Curtin University, Bentley Campus, Perth, WA, Australia; [2]School of Earth Sciences, University of Western Australia, Perth, WA, Australia; [3]Asian School of the Environment, Nanyang Technological University, Singapore; [4]Oceans Graduate School and UWA Oceans Institute, UWA, Perth, WA, Australia; [5]Wave Energy Research Centre, UWA, Albany, WA, Australia; [6]ARC Centre of Excellence for Coral Reef Studies, University of Western Australia, Perth 6009, Australia; [7]UWA Oceans Institute, University of Western Australia, Perth 6009, Australia.

*Corresponding author, email: jake.nilsen@curtin.edu.au

Coral reef islands are some of the landforms most at risk from climate change, due to their low elevation (<5 m) and reliance on biologically produced carbonate sediment from nearby reefs. A study of over 1,200 islands found that between 6-12% of reef islands globally could be submerged under a 3 m sea level rise (Bellard et al. 2013), resulting in significant loss in landmass and potential displacement of human populations. Further, island inundation and increased wash-over events will have profound impacts on island ecology and regional biodiversity (Courchamp et al. 2014). Reef islands with a continual sediment supply are less vulnerable to these threats due to an increased ability to morphologically adjust to changing conditions (Liang et al. 2016). Hence, a greater understanding of processes that underpin reef island development and stability, will improve our ability to effectively manage these systems.

Recent work by Tuck et al (2019, 2021) demonstrated the ability of reef islands to accrete vertically under rising seas when there is adequate sediment supply from adjacent reefs. This interconnection between reef ecology and has been well documented in the Maldives, where parrotfish play a central role in carbonate sand production (Morgan and Kench 2016). These fish actively erode the reef framework as they predate upon algae and/or cyanobacteria living within coral tissue (Nicholson and Clements 2020), producing large volumes of carbonate sand transported onto the island by currents (Perry et al. 2015). The ecological processes, however, that drive sediment supply to low-lying reef-fronted carbonate landforms differ between reef settings and environmental conditions. For example, many reef sediments are dominated by fragments of *Halimeda* (e.g. Timor Sea, North-western Australia; Heyward et al. 1997), foraminifera (e.g. Green Island, North-eastern Australia; Yamano et al. 2000) or molluscs (e.g. Lagoonal waters of New Caledonia; Chevillon 1996), highlighting the role of other organisms in carbonate sediment production, supply, and island building.

To improve our current understanding of the links between carbonate sediment production and reef island building, we must quantify the ecological processes that generate sediment within a wider range of reef systems, including under-studied reef types where corals may not dominate landform sediments. Historically, inshore turbid reefs have largely been over-looked scientifically due to the assumption they are degraded (Browne et al. 2013, Zwifler et al. 2021). Yet due to rising seas, changing climate patterns, and ongoing coastal development, these reefs are likely to increase in prevalence (Ogston and Field 2010). Hence, understanding how these reefs are supporting associated reef islands and coastlines is critical for their effective management.

In addressing this knowledge gap, we investigated the potential role of invertivore fishes (i.e. genera *Choerodon*, *Lethrinus*, and *Diagramma*) as producers of carbonate sediment in the semi-turbid waters of the Exmouth Gulf, northwest Australia. Previous work revealed sediments in the region have a high proportion of molluscs (>30%), although the origin and pathways in which they are derived were initially unclear. Combining methods from the disciplines of marine ecology and palaeontology, we confirm that invertivores (Fig 1)

Figure 1. A blackspot tuskfish (*Choerodon schoenleinii*) foraging on the reef substrate. Note the large protruding teeth that are used for removing and crushing invertebrates.

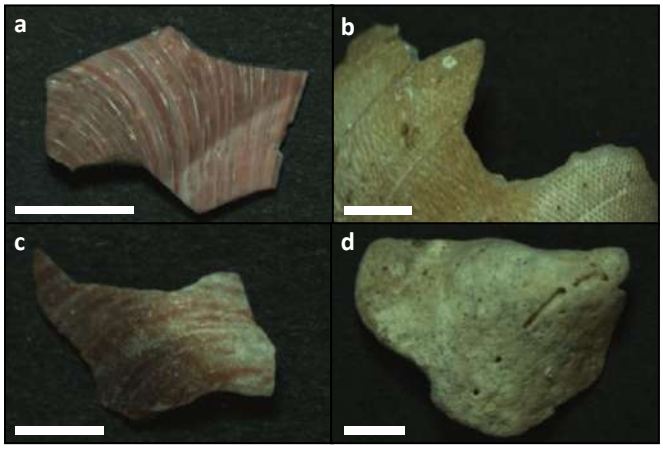

Figure 2. Examples of mollusc fragments used for origin analysis from a) an individual *C. schoenleinii*; b) and c) two of the sheltered sites; and d) an exposed site. Note the sharp edges of a and c (indicative of predation); and round and sharp edges of b and all round edges of d (indicative of taphonomy). Scale bar represents 1 mm.

are a dominant feeding guild at Eva Island and generate transportable sized sediments via durophagy (i.e. shell-crushing) – a pathway that has rarely been studied, especially in the context of reef island development. Underwater stereo-video transects found invertivore biomass (4496 g ± 2395 g/1000 m^2) to be twice as great than the next feeding guild (2200 ± 1389 g/1000 m^2), the herbivores (i.e. parrotfishes). More than 95% of items found within the guts of invertivores were carbonate in nature (e.g. molluscs, echinoderms), and further taphonomic assessment of the benthic sediments found that more than 30% of molluscs grains were predatory in origin based on their angularity and edge characteristics (Fig 2). These findings highlight the importance of invertivores in the production of transportable-sized carbonate sediments within turbid reef settings, where parrotfish are in low abundance.

Acknowledgements

This study was supported by a DECRA Fellowship DE180100391 awarded to Nicola Browne of Curtin University, Perth, as part of the island resilience project (2018–2020). The authors would like to thank Benjamin Saunders for providing stereo-DOV equipment and for assisting with video analyses, Rowan Kleindienst and Sophia Clark-Ioannou for their technical support, and Adi Zvifler for assisting with field operations.

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Ecosystem Approach to Sudan's Red Sea Fisheries

Shipping containers impacting remote pristine southern coral reefs

Even Moland[1], Khadija Y. I. Abaker[2], Motasim A. M. Omer[3], Elfatih B. A. Eltaib[2], Motaz A.A. Abdelrahman[4], Portia Joy Nillos Kleiven[1], Kirsty L. Nash[5]

[1] Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway. [2] Faculty of Marine Science and Fisheries, Red Sea State University, P.O. Box 24, Port Sudan, Red Sea State, Sudan. [3] Red Sea Fisheries Research Station, P.O. Box 730, Port Sudan, Red Sea State, Sudan. [4] Marine Fisheries Administration, Baladia Street, Port Sudan, Red Sea State, Sudan. [5] Centre for Marine Socioecology, University of Tasmania, Hobart, Australia.

From 5th to 25th November, participants from the Institute of Marine Research, Norway, and from three organisations in Sudan's Red Sea State, surveyed coral reef sites along Sudan's Red Sea coast from Osseif in the north to Talla Talla Kabir in the south, on board the MV *Don Questo*. The work was undertaken as part of a project entitled "Building institutional capacities for an ecosystem approach to management of the marine fishery in the Red Sea State", a project managed by the UN Industrial Development Organisation (UNIDO) and supported financially by the Norwegian Embassy in Khartoum. The executive agency in Norway is the Institute of Marine Research, and the counterpart organisations in Sudan are: i) the Marine Fisheries Administration, Red Sea State, Sudan, ii) the Faculty of Marine Sciences and Fisheries, Red Sea State University, Port Sudan, Sudan, and iii) the Red Sea Fisheries Research Station, Port Sudan.

The objectives of the survey were two-fold: firstly, monitoring of biophysical conditions. This primarily focused on obtaining fishery independent data on fish species occurrence, abundance, and size distribution – by means of visual sampling techniques (BRUVs, and UVC with diver operated video). The survey revisited stations sampled in previous surveys (2015, 2016 and 2017). Benthic cover was monitored using both the diver operated video and point intercept transects to compare findings from the two methods. These ecological data were supported by oceanographic data collected from throughout the water column at each site visited. Secondly, all participants from partner institutions received additional training in visual sampling techniques and the use of scuba diving as a scientific tool in coral reef research and monitoring.

Left: Mustafa M. Mustafa and K.Y.I Abaker examining a mound containing old mammal bones, most likely of dugong, on the islet of Talla Talla Kabir; photo credit Even Moland. Right: Kirsty Nash recording benthic cover data at Shaab Rumi – the reef made famous by Jaques-Yves Cousteau as the site of the Conshelf II project and film 'Le monde sans soleil'; photo credit Mustafa Khalafalla.

Left: a shipping container in the lagoon at Dhanab Al Qirsh, photo credit Francisco Paz. Right: medical products on the beach at Harorayeet Island, photo credit Kirsty Nash.

Coral reefs visited were generally in good condition, although we also visited sites that appeared to have undergone considerable changes over the five years that have passed since our previous survey. Our data will be analysed to investigate such apparent changes.

At one of the Islands in the Talla Talla Kabir group we discovered two mounds of animal remains. One appeared to be entirely made up of turtle shells and bones, while the other contained mammal bones – probably from dugong (*Dugong dugon*). The bones were brittle and bleached, and the local survey participants did not have knowledge or information regarding the age of the mounds, or their origin. However, the site has clearly been used for processing of turtle and dugong, and the islands possibly served as a base for turtle and dugong hunting expeditions at some distant point in the past.

Heading further among the deserted islands off the southern coast of Sudan, we had expected to see little above water apart from seabirds and a few nesting ospreys. Unfortunately, this was far from our experience; on the 5th of October – one month prior to the start of our survey, the TSS Pearl, a containership on its regular route from Jeddah, Saudi Arabia to Aden in Yemen caught fire and sank. Thankfully all the crew were rescued, but afterwards many of the containers were observed floating in the area. While most of the 1853 containers the ship was carrying may have sunk with the ship, the accident clearly dispersed many of them within the southern Red Sea. To give an idea of the scale of the issue, over 1600 containers were estimated to be lost at sea, globally, in 2021[1].

The outcome of the accident was all too evident as we travelled south. The first sign of debris were packs of shoes floating in the water. Then on arriving at Dhanab Al Qirsh, a reef 335km northwest of where the TSS *Pearl* sunk, we saw our first container, stuck in the lagoon, its sides cut open, presumably by opportunistic seafarers trying to salvage the contents. All that was left were empty cans of powdered milk and a smell of rotten dairy. Further west, we visited Harorayeet Island, and the extent of the impact on the marine environment became more apparent. Here we found the windward side of the island strewn with medical supplies – masks, needles, surgical gowns and more. Our attempt at cleaning up the rubbish didn't even put a dent in the problem, besides which we were unable to remove any of the oil that was clinging to areas of rocky pavement in the lagoon. Further south, at Talla Talla Kebir, there was a similarly depressing picture with multiple containers and diapers, gloves and plastic packaging scattered on the reef both above and below water.

Members of the expedition collected as much rubbish as possible over the course of our stay in the southern reefs and participants from the Marine Fisheries Administration recorded data on the type of rubbish we found. There is a clear need for an intensive clean-up effort in the region affected, and we are currently reaching out to organisations to try and gain funding to kickstart this effort.

[1] World Shipping Council. 2022. Containers Lost at Sea 202 Update.

COP27

Yasser Geneid
Institute of Oceanography and Fisheries (Suez, Egypt)

The 27th Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) took place in the Egyptian resort city of Sharm El Sheikh over two weeks, from 6th – 18th November. Given the global threat to coral reefs from climate change, the Society played a significant role in promoting the 1.5°C target limit to global warming at COP15 in Paris, and most recently sent a six-member delegation to the critically important COP26 in Glasgow. However, although progress was made in Glasgow on securing greater commitments to greatly reduce many nations' carbon emissions, these were by no means sufficient to ensure that global warming is limited to 1.5°C. Hence it was agreed to that negotiations should continue through the year and be finalized at this next COP in Sharm El Sheikh.

To ensure that coral reefs were not forgotten at this event, the Society arranged to have a further delegation attend. This consisted of four members led by Raquel Peixoto (Brazil), co-chair of ICRS's Conservation Committee. The other members were Yasser Geneid, Luiz Rocha and Mariana Rocha de Souza.

The location of the COP in Sharm El-Sheikh, at the entrance to the Gulf of Aqaba (the narrow north-eastern extension of the Red Sea) was perhaps significant since it was here that some of the most heat resistant corals (the so-called super-corals of the Gulf of Aqaba) have been found. However, despite the enthusiastic attitude of so many delegations and extensive discussions of how to deal with the huge problem of global climate change, and of ways of mitigating its effects on organisms, including on corals, the truth is that very little progress was made on the key issue of further increasing countries' commitments to cutting their carbon emissions, despite the COP being extended for an additional two days.

Throughout, the Society's representatives wherever possible emphasized the extreme importance of coral reefs in relation to both biodiversity and human well-being, and promoted ideas for attempts to enhance their resilience against heat stress and disease through the application of nature-based solutions. For as Peter Thomson, the UN Secretary-General's Special Envoy for the Oceans, stated in his speech in the Saudi pavilion: "There is no earth without oceans, and there are no oceans without coral reefs".

The COP did feature one notable achievement, driven on by the news that perhaps as much as one-third of Pakistan was then under water as a result of completely unprecedented rain-storms. This was agreement on a "Loss and Damage Fund" to be used to compensate less developed countries for the impacts being caused by the increasing frequency of severe droughts, storms, heatwaves and climate instability. Must try harder is the verdict on COP27. We can only hope that countries national commitments are visited yet again at COP 28, due to take place in another year's time in Abu Dhabi, United Arab Emirates, where as much as anywhere coral reefs have been suffering repeated mass mortality due to extreme summer water temperatures.

Clockwise from top left: i) Raquel and Yasser at the forum on nature-based solutions for mitigation of the effects of climate change on marine ecosystems, ii) Mariana with the Egyptian Minister of the Environment Dr. Yasmin Fouad, iii) Yasser and Mariana at a RINGO (Research and Independent Non-Governmental Organisations) event, iv) Mariana with the President elect of Brazil, Lula da Silva, v) Yasser and Raquel supporting Africa, vi) The indigenous group in the Brazilian pavilion proved especially popular. Images i), iii) and v) courtesy Yasser Geneid, images ii), iv) and vi) courtesy Mariana Rocha de Souza.

15th ICRS (in-person)
July 2022, Bremen, Germany

Conference impressions and reports by a cross section of attendees.

The Organiser's Perspective – The job (almost) done!

Prof. Dr. Christian Wild, Faculty of Biology & Chemistry (FB2), Universität Bremen UFT, Leobener Str. 6, D-28359 Bremen, Germany

After more than six years of work for the ICRS in Bremen, Germany, the project is almost complete. All that remains is the final accounting.

It has been a wild journey over the last years with lots of financial and logistical challenges, plan changes, adjustments, and sleepless nights.

But in the end, we could offer two exciting events: The 14th ICRS 2021 Virtual and the 15th ICRS 2022 in Bremen! In retrospect, the decision to organize two instead of one ICRS was probably our best

The local organisation team for the 15th ICRS in Bremen during the opening ceremony on July 4th 2022. From left to right Christain Wild, Inae Kim-Frommherz, Selma Mezger, Svea Vollstedt, and Heinz Krimmer.

decision, although it required much more time investment. We are grateful to ICRS president Dr. Andrea Grottoli, who carried along this decision with us. The dual strategy gave us not only more funding options, but also provided (particularly early career) researchers with more and earlier opportunities to present their work. With the dual strategy, we could also repeat our important and clear messages reflected in the expert paper Rebuilding Coral Reefs: A Decadal Grand Challenge so that these messages became more visible and lasting. This was reflected by two high-level Science-to-Policy Dialogues in 2021 and 2022. Moreover, we had the chance to extend the accompanying exhibitions in the museums, add several public events, and thus reach more people of the public.

I am very proud that both ICRS events organized by University of Bremen were sustainable in an ecological, social, and economical way.

Thank you to all participants providing the constructive feedback displayed in the current issue of Reef Encounter. I fully agree that the disturbance of the well-deserved laudation for Dr. Nancy Knowlton during the opening ceremony should not have happened and apologize for this unwanted incident.

There are several good improvement suggestions to be considered for the preparation of the upcoming 16th ICRS in New Zealand. It is great that our coral reef research community is actively and consistently involved in shaping and giving the world's largest coral reef conference a leadership role in equity, inclusion, diversity, and sustainability.

Overall, I am very happy that many participants liked the first European Venue for ICRS and enjoyed the cozy city of Bremen. It was great to see how well our experiments with virtual and hybrid formats worked.

Nevertheless, among the many highlights of both the 14th and the 15th ICRS, my personal favorite was the end of the closing ceremony of the 15th ICRS, when I handed over all duties and responsibilities to Dr. Simon Davy, who even seemed to enjoy this special moment😉.

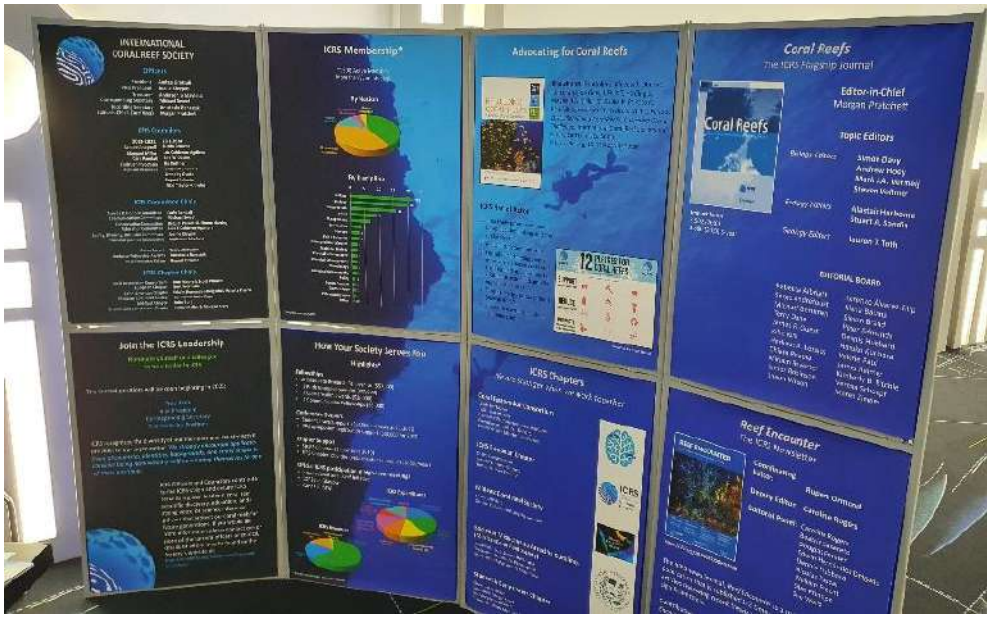
All the best to you Simon, and to your team, for the preparation of the 16th ICRS in Auckland, New Zealand!

Christian Wild and Simon Davy. The conference baton just transferred from Germany to New Zealand at the end of the closing ceremony on July 8th 2022.

ICRS 2022 BREMEN

Clockwise from top: Reception at the Townhall to welcome the conference to Bremen; Award of the Society's Darwin Medal to Nancy Knowlton (right) by ICRS President Andréa Grottoli; Nancy Knowlton giving her Darwin medal Plenary address; Award of the Climate Neutral Certificate to the Conference (left Oliver Heitmann, right Christian Wild); handing of his Honorary ICRS Membership to HE Prince Albert II of Monaco, by Andréa Grottoli. Photos by Thomas Hellmann, except top photo by Rupert Ormond.

Top: Recipients of 2022 Society Honors, awarded at the conference. Bottom: recipients of the conference student best presentation awards. In each case with conference organiser Christian Wild (far left) and ICRS President Andréa Grottoli (far right). Photos by Thomas Hellmann.



Clockwise from top left: The statue of the Bremen City Musicians, a famous landmark in the city, referring to an old folktale; the excellent student helpers from Bremen University who helped make the conference run so smoothly; gathering of ICRS Council and Fellows in the ICRS room; the main display summarising the Society's activities, also in the ICRS room; Past and future conference organisers - Christian Wild (left) and Simon Davy (right) with conference opening display performers; Pete Mumby with friends at the end of conference party. Photos by Rupert Ormond, except top right and bottom left by Thomas Hellmann.

Attendees at ICRS 2022 came from across the world. This is a Latino group photograph. ▸

Struggling Corals in a Disturbed Ocean

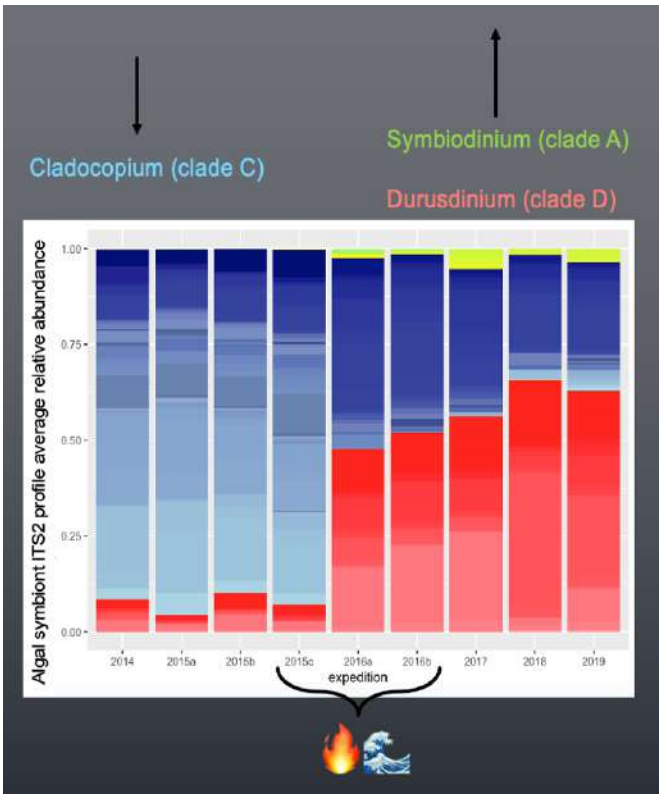
Rebecca Campbell Gibbel DVM (MS Graduate Student)
(RebeccaCampbellGibbel@gmail.com)

The ICRS 2022 conference was a triumph of organization, aided by additional years of preparation time and a very efficient and motivated German support team. The planners' mission of educating, feeding, and entertaining all the participants seemed flawlessly executed. It was quite a challenge for me to choose which presentations to attend from the impressive breadth of conference offerings and it was wonderful to be able to meet in person again.

I joined a conference-sponsored tour of the Center for Marine and Environmental Sciences (MARUM) lab at the University of Bremen, which specializes in deep sea exploration. MARUM houses Bremen's International Ocean Discovery Program's core repository, one of three academic sites in the world that safeguards drilled sediment samples from the ocean floor. A sediment core on display captures the geologic K/T boundary layer from 65 million years ago. This seabed core from the Yucatán records the "fireball layer" of cataclysmic global environmental changes thought to have been produced by a massive asteroid strike. In the layers before this abrupt transition, the sediment contains microfossils from the rich Cretaceous period of complex plants and dinosaurs. After the impact, the Tertiary period sediment records 100,000 years of a scorched earth nearly devoid of life. It was sobering to see this tangible evidence of an utterly devastated environment.

Sediment core including the K/T boundary at the Bremen International Ocean Discovery Program's seabed core repository.

The ICRS' program had an appropriately large focus on climate change's effects on the ocean and its inhabitants, since this is the largest menace that today's coral reefs have ever faced. Although diseases and thermal bleaching may be the proximate cause of much coral mortality, no amount of research will mitigate them if the underlying ultimate cause of climate change is not addressed. As all of the conference attendees are well aware, human activities are the fireball of the



Annual community distribution of *Durusdinium* and *Symbiodinium* before and after environmental stressors

Anthropocene, causing untenably rapid environmental degradation.

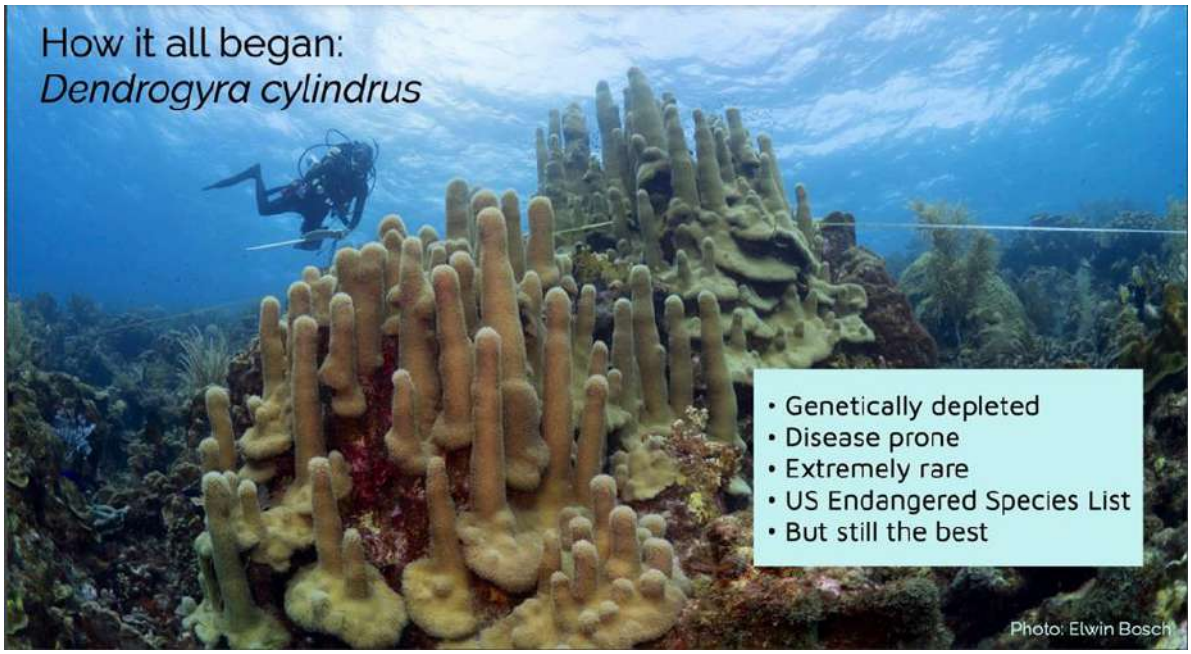
I sought out presentations about coral disease and attended the workshop and lectures exploring the complexities of coral-Symbiodiniaceae associations. I found a number that seemed particularly notable. Daisy Buzzoni gave a dynamic talk describing how chronic local disturbances of human origin, such as sewage pollution and overfishing, as well as acute global heat stress events, drive Symbiodiniaceae-coral relationships in the Pacific. She and her colleagues studied >1000 coral colonies surrounding Kiritimati Island, spanning a major heat wave in 2015-2016. The corals' Symbiodiniaceae were sampled at different times across a gradient of sites with varying levels of chronic human disturbance. Buzzoni described how stressors can shape Symbiodiniaceae diversity by causing a differential loss of susceptible symbionts and corals, and by breaking down the original coral-symbiont partner specificities. Overall, the Kiritimati coral community changed from *Cladocopium* to the more heat tolerant *Durusdinium* over the course of the acute heat wave, as well as in the chronic disturbance locations, although there were some exceptions by coral genus. The corals that switched to *Durusdinium* and *Symbiodinium* dominance maintained those new relationships for the three years of study following the heat wave. Some corals, both heat sensitive *Montipora* and heat tolerant *Porites*, maintained their original symbiont fidelity through the heat wave years. However, heat sensitive *Platygrya* colonies that changed to *Durusdinium* in chronic stress environments, did not survive better in the heat wave, making it difficult to predict survival solely based on Symbiodiniaceae associations in "an increasingly disturbed ocean". Buzzoni concluded by discussing the putative metabolic disadvantages of a "hangover" or long-term maintenance of stress-tolerant symbionts like *Durusdinium*, which have been shown to reduce the nutritional subsidy of photosynthates transferred to the coral host.

In separate presentations, Katherine Eaton and Sonora Meiling both discussed topical treatments for virulent coral diseases. Eaton et al.'s work found that the undisclosed antiviral and antimicrobial ingredients in a newly developed product named "Coral Cure" arrested black band disease (BBD) in wild *Pseudodiploria* corals in St. Croix, US Virgin Islands. BBD is a polymicrobial disease, with the characteristic black band consisting of a mat of cyanobacteria, sulfate-reducing bacteria, and sulfide-oxidizing bacteria. Previous attempts at treating BBD lesions have included removing the bacterial mat using suction and applying topical pastes such as chlorinated epoxy, but treating the lesion line typically results in one third of treated colonies developing new lesions within several months. Eaton et al.'s study tested 13 different combinations of treatments, including "Coral Cure" impregnated into ropes affixed to the BBD lesion line. Although the sample sizes were small, **two different formulations of "Coral Cure" saturated ropes halted lesion progression, with no sign of reinfection within 3-5 months in 100% of the corals treated.** This encouraging report is likely to open new avenues of study, once the chemical composition of the compound is shared.

Meiling et al.'s work studied reef-level outcomes of treating another, more virulent coral disease with established therapies, but after a statistical review of the results, they came to a less optimistic conclusion. Stony coral tissue loss disease (SCTLD) was first observed in 2014, and is currently decimating Caribbean reefs, so major efforts are underway to attempt to control it. Topical amoxicillin paste is very effective at controlling individual lytic coral lesions, although labor-intensive, repeated treatments are often necessary. Since many treated corals develop additional destructive lesions, colony mortality remains high, even with this antibiotic application. Meiling presented results of a study in the US Virgin Islands, comparing plots of untreated corals with similar sites that had SCTLD-affected corals treated with bi-weekly application of 1:8 amoxicillin to Base2B compound, with some amputation and removals. After one year, there was no statistical difference in disease prevalence (total number affected) or coral community composition (number of species) between treated and untreated plots, although perhaps a longer study time would be informative. Meiling's presentation called for a new consideration of how topical amoxicillin paste is used in the fight against this coral disease. Rather than viewing amoxicillin as the main strategy in the war against SCTLD, it may be better employed as a tool to use more selectively to save specific iconic or reproductively mature coral colonies. Clearly, more research is needed to identify alternate treatment approaches.

Virgin Islands diver Logan Williams applying amoxicillin paste to SCTLD-affected coral colony.

I am sad that I live in a world where corals need assisted reproduction, but I'm glad that Kristen Marhaver is here to help. Her research provides hope that even corals with unpredictable reproduction may be utilized in breeding programs to help restore degraded reefs. Earlier coral reproduction work focused on hermaphroditic corals with mass "broadcast" spawning, which is closely synchronized with the moon, making spawning events easy to see and predict. Marhaver discussed advances in decoding spawning predictions for Caribbean corals with more subtle breeding strategies. Corals like *Dendrogyra cylindrus* and *Dichocoenia stokesii* have male or



Dendrogyra coral in Curaçao being monitored in preparation for spawning.

female (gonochoric) colonies, although Marhaver noted that some can switch and cleverly pursue a flexible strategy of bidirectional sequential hermaphroditism. In Curaçao, Marhaver et al. observed incredible feats of coral spawning synchronization. Not only do separate male and female *Dendrogyra* colonies briefly spawn on the same night, but the males release sperm approximately 30 min before the females release eggs, improving the chances that the far less abundant eggs will encounter drifting sperm. *D. stokesii* and *Meandrina meandrites* are even more complicated gonochoric species, spawning on multiple nights within a month, apparently decoupled from the lunar cycle. With further spawning observations, Marhaver's lab is improving their predictions of when to collect gametes for fertilization or storage. Ending on a hopeful note, Marhaver reported that her lab tested 18 different sperm cryopreservation methods with gonochoric species to "enable gene banking and the long-term preservation of genetic diversity" and identified two cryoprotectants that successfully enabled recovery of gamete motility following thawing.

Although I enjoyed the 15th ICRS, I would like to offer some constructive criticism.

- In this year on the cusp of the pandemic, an option for enjoying lunch and coffee breaks outdoors would have been very welcome, and the organizers could have encouraged mask wearing by providing a box of masks in each room. Poster sessions in the entry atrium with doors open would have been helpful too. These measures might have reduced the number of COVID infections from the conference.
- Names could be printed on both sides of the badges, since somehow the wrong side of people's badges always seemed to be displayed, in defiance of binomial odds.
- The meet-with-a-mentor program was a good idea, but since it is difficult to meaningfully mingle in a crowded dining room or coffee break area, it would be useful to expand the program to include meetings offered every day with both early and late career scientists. Even brief coffee break meetings, if held with just a few people in one of the smaller rooms, would be a fantastic addition.

University of the Virgin Islands conference attendees. Left: the whole group. Right: Kathryn Cobleigh and Brad Arrington enjoying the local German beer.

A long-awaited ICRS 2022

Alice (Chapman) Kojima, PhD Candidate, Department of Geosciences, University of Arizona (alicechapman@arizona.edu)

After attending the virtual 14th ICRS in 2021 and answering questions about my recorded talk at 1 am local time, I was eager to be present (and fully awake) at the in-person 15th ICRS in 2022. I was particularly excited to travel to Germany for the first time and take advantage of the well-reputed public transport. I was also nervous to be travelling internationally for the first time since COVID-19 began, and a level of uneasiness stayed with me the whole time, especially because neither vaccinations nor negative COVID tests were required to attend the conference. While masks were still mandatory on public transportation in Germany, they were not required indoors at the conference venue and many attendees chose not to wear one. Even for those who did wear a mask, they had to make a decision come lunchtime to eat the lunch served daily in a large hall packed with other mask-less attendees, or to eat outside (where tables were not set up for that purpose). I suspect that there were students in attendance who were not comfortable eating indoors, but saw it as the only option for networking or hanging out with their lab group. Perhaps next time, there could be a designated outdoor eating area with amenities making it more conducive for participants to eat outside. The lunches themselves were delicious; they were meatless and avoided disposable materials, which aligned with the conference's goal to be as sustainable and climate-friendly as possible. While this effort was definitely appreciated, there could have been more information available regarding the ingredients of various dishes for those with gluten intolerance and allergies. Nevertheless, this was the first conference I have attended that served a hearty, climate-conscious lunch and snacks throughout the day, so I was thrilled.

One of the memorable moments of ICRS 2022 for me was on the first day, when ICRS president Dr. Andrea Grottoli introduced this year's Darwin Medal awardee, Dr. Nancy Knowlton. During her introduction, Dr. Grottoli was interrupted to allow H.S.H. Prince Albert II of Monaco, who had just arrived, to speak. Without any explanation or apology for this interruption, this set a strange tone for the day. It was also cringe-worthy that a man interrupted the first female president of ICRS as she introduced the first female Darwin Medalist. However, despite this strange start, Dr. Knowlton was reintroduced and proceeded to give a powerful plenary talk, highlighting the need for a big picture approach to rebuilding coral reefs: local conditions matter and fixing the climate problem will not help if we don't have a habitable environment for corals. Dr. Knowlton also mentioned that "social change is constrained by the speed of trust", reminding us that

Dr. Nancy Knowlton, Darwin Medal winner, giving her plenary presentation, complete with attentive polyp!

special efforts need to be made to bridge the gap between scientists and the public before we can see policies change.

The inspiring plenaries did not stop with Dr. Knowlton. ICRS 2022 had a dynamic line-up of speakers. Two memorable plenaries took place on the second day, with Dr. Natalie Ban in the morning, and Dr. Raquel Peixoto in the afternoon. Dr. Ban emphasized that humans are an integral part of marine systems, and that the conservation of these systems is embedded in the way of life of indigenous peoples. She discussed the importance of scientists developing relationships with indigenous peoples that are based on trust, which may lead to invitations to co-create knowledge and solutions. "Helicopter science" can be very harmful and is a form of neocolonialism, especially when scientists force their own solutions on communities without considering all the components that are woven together to create the whole system. We can all learn to integrate this holistic approach into the way we go about our research. At its very core, conservation should not be considered a separate field or approach, but should be integrated with scientific research from the beginning. Dr. Peixoto's plenary highlighted her work using Beneficial Microorganisms for Corals (BMCs), essentially probiotics for corals, as a way of improving coral health and resilience. While this was not my first time hearing about Dr. Peixoto's revolutionary work in microbiome stewardship, her talk still made my jaw drop. She discussed the small-scale experiments performed at her institution's Coral Probiotics Village (KAUST), and the positive outcomes they observed after applying a probiotic solution to corals via syringe. Dr. Peixoto and her team are at the forefront of developing a standardized framework for implementing such adaptive intervention methods on a global scale, to ensure that in the face of thermal stress, reef-building corals will be less likely to bleach, and if they do, that they will recover.

While the sessions I attended were mainly in the "Reef environments and climate of the past" theme, there were a couple of talks in other sessions that I found fascinating. First was Dr. Tim Lamont's talk on "The changing song of the sea: reef soundscapes as symptoms and drivers of ecosystems". I was blown away by the concept of a reef soundscape, especially since as a snorkeler and scuba diver, I only hear my own breathing and water rushing by my ears. These soundscapes reflect the health of the reef, and Lamont and co-authors have documented changes to these soundscapes (they have become quieter!) as a result of climate change-related impacts such as bleaching. Quieter reefs signal to fish that the reef is not as hospitable as it once was, thereby jeopardizing chances of recruitment and recovery. What further blew me away was that if the sounds of a healthy reef are played on a loudspeaker, fish will actually be attracted to and settle on those reefs, thus restoring the reef to its healthy and melodious state.

I took full advantage of the workshops offered at ICRS 2022 and found all four that I attended to be engaging. To highlight a couple, I attended "Reimagining future coral reefs from clues of the past", which brought together paleoclimatologists, paleontologists, paleoecologists, evolutionary biologists, and geobiologists to discuss what we know about the stress response of corals in the near and distant past that can be applied to our current and future climate. This type of cross-disciplinary

Three generations of coral reef climate researchers: Dr. Julia Cole (University of Michigan), Dr. Diane Thompson (University of Arizona), and Alice (Chapman) Kojima (University of Arizona).

discussion does not happen often enough, and I was grateful that the organizers of the workshop took advantage of the mix of disciplines that ICRS 2022 brought together. Some outcomes of this workshop were that 1) we can use coral phylogenetic diversity to help identify key coral species that are worth studying in the fossil record, 2) past turbid, or "muddy", reef environments may be good analogs for comparison with current and future reef changes, and 3) when comparing rates of change between the fossil record and today's reefs, we must reconcile differences in resolution. In the workshop, "How do you accelerate coral reef science and conservation through better data management workflows?" led by NOAA's National Center for Environmental Information, we discussed best practices for handling the foundation of all of our research: our data. It was refreshing to speak in detail about something so important, yet often misused and miscommunicated. Some topics included how to be intentional about organizing your data by developing a comprehensive data management plan, reduce ambiguity in the way that we record data, and eliminate human error. I found the workshops at ICRS 2022 to not only be a nice break from back-to-back presentations, but also a great way to engage with attendees I might not otherwise have met, and in a purpose-driven way.

Overall, I thought that ICRS 2022 was a big success and I'm glad that I decided to attend. Some personal highlights included 1) attending the conference with my PhD advisor, Dr. Diane Thompson, and seeing her talk on remediation and restoration efforts in the Biosphere 2 mesocosm, 2) meeting her PhD advisor, Dr. Julia Cole, and taking a lovely photo of our three "generations", and 3) visiting the Bremen Town Musicians statue and rubbing the donkey's front legs for good luck the morning of my talk! Finally, I am grateful to have left without contracting COVID, since I know that many folks were not as lucky. I sincerely hope that the COVID landscape will have improved significantly by 2026, so that we can enjoy a worry-free 16th ICRS in New Zealand!

An Early-Career Perspective

Emma Pontes, Ph.D. Candidate, Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami (epontes@earth.miami.edu)

Arriving in the small town of Bremen, Germany, I wondered why an international coral conference such as ICRS would be held in a location so far from the tropics. Others must have been asking the same question because Dr. Claudia Schilling, the Senator for Research in Bremen, promptly addressed it in the opening ceremony. Dr. Schilling clarified that Bremen is a hotspot for active coral research at the University of Bremen and Max Planck Institute, citing that 30% of coral research conducted in Germany occurs in Bremen.

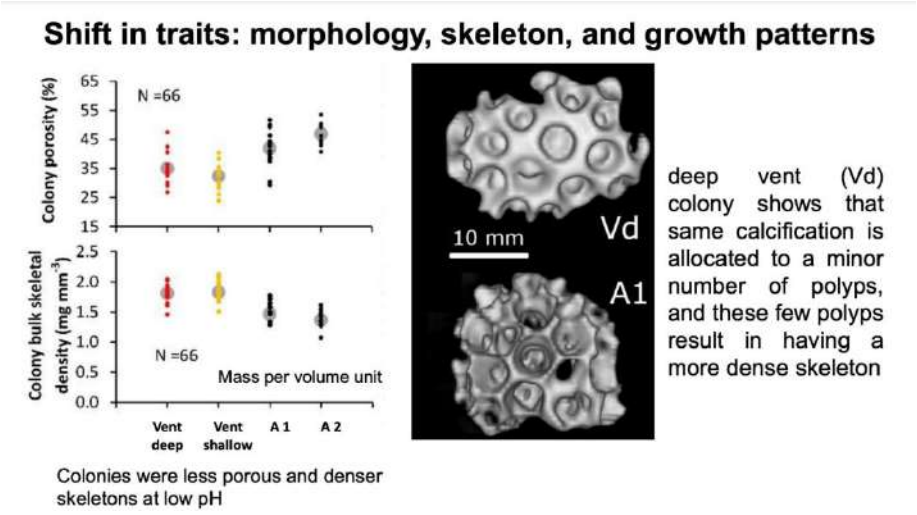
My favorite portion of the opening ceremony was witnessing Dr. Nancy Knowlton become the first female recipient of the Darwin Award. Applause erupted from the audience when Dr. Knowlton enthusiastically said that she "sure as hell won't be the last" female recipient of this award. In her plenary talk, Dr. Knowlton shared how she transitioned from being recognized as one-half of 'Drs. Doom and Gloom' (alongside her husband Dr. Jeremy Jackson), to focus on optimism and solution-oriented communication surrounding the status of coral reefs worldwide. As a coral biologist, it's easy to report just the negative impacts that coral reefs face, and there is no shortage of such impacts. However, Dr. Knowlton argued that negativity gets in the way of action, especially when communicating with policymakers who prefer to hear about problems that have solutions. Dr. Knowlton concluded her talk with a few valuable lessons she'd learned: trust your intuition, take advantage of the unexpected, learn to tell your story, and don't neglect the positive!

The opening ceremony included a spectacular performance by a local performing arts group that embodied coral reefs using intricate costumes, stunning light displays, and soothing sounds. Their magical act during the opening ceremony left me in awe! With the opening ceremony complete and the tone of #OceanOptimism set by Dr. Knowlton, I felt ready to tackle a busy week of coral discussions. As a first-time attendee and presenter at ICRS, I admit that the number of presentations was a bit overwhelming, especially with multiple talks occurring simultaneously. I had some difficult decisions to make!

One of my favorite talks was given by Dr. Cesar Pacherres who discussed how cilia-induced mixing within the diffusive boundary layer acted to distribute excess oxygen across the coral surface. He initially hypothesized that areas of higher chlorophyll concentration would be associated with areas of higher oxygen concentration given the active photosynthesis at these sites. Using oxygen-sensitive nanoparticles, he found that the opposite was true; a surprising result! He concluded that the ciliary action of coral polyps could alleviate oxidative stress in particular areas of the coral host.

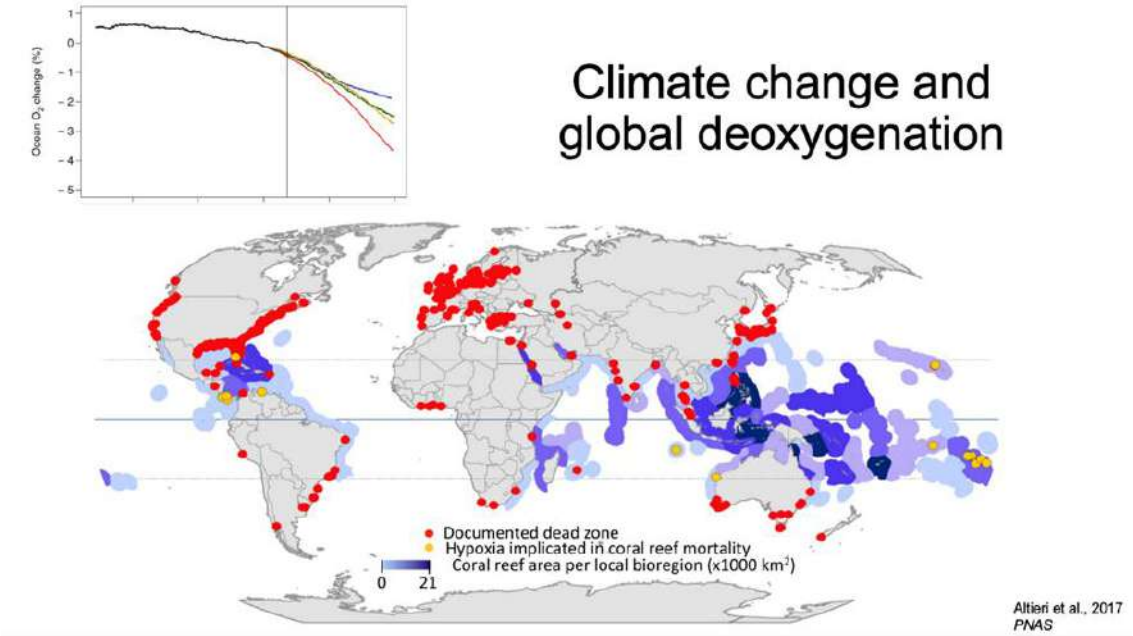
Another fascinating talk came from Dr. Nuria Teixido whose team discovered a naturally occurring CO_2 vent off the coast of Ischia, Italy, complete with coral species adapted to very low pH conditions. Interestingly, corals living near the vent were denser than their conspecifics existing at ambient pH sites. This result seems counterintuitive, given that low pH is known to degrade and weaken coral skeletons. Still, Dr. Teixido explained that a reduced number of coral polyps allowed for calcification efforts to be allocated to fewer polyps, generating a denser skeleton when compared to colonies at ambient pH sites. When asked how this site was discovered, Dr. Teixido mentioned that local fisherman and dive boat operators noticed bubbling at certain dive sites and brought this to her attention. This demonstrates the great value of utilizing local knowledge and working with community members who are very familiar with their environment.

In my opinion, the most interesting session focused on ocean deoxygenation as a key factor in regulating the global decline in coral reefs. Drs. Andrew Altieri and Maggie Johnson, experts in the field of tropical deoxygenation, led the session and gave presentations on their ongoing hypoxia research. Seven scientists (including myself) gave talks in this session, covering topics ranging from hypoxia impacts on coral physiology and survival, microbiome composition changes under oxygen stress, and even the effect of anoxia on sponges and their microbial communities. Dr. Altieri shared a surprising statistic in his talk: at the 2016 ICRS, 5 out of 2021 (0.2%) abstracts mentioned deoxygenation, while this year, a total of 12 out of 850 (1.4%) abstracts mentioned this topic. This shows that deoxygenation on coral reefs is severely understudied, even with a roughly seven-fold increase over the past six years.



A slide from Dr. Teixido's presentation, showing denser *Astroides calycularis* skeletons at the low pH site

Given the limited amount of peer-reviewed research on tropical deoxygenation, it was not surprising that at some point in their presentation, every presenter in this session showed an iteration of the same figure: a global map that highlights dead zone events and areas where hypoxia was



The infamous global deoxygenation map widely used to demonstrate where hypoxic events have affected coral reefs.

implicated in coral reef mortality. Since I was the last speaker of the day, I barely had to explain the figure as it had already been presented multiple times! Scientists in this session coordinated a 'coral hypoxia dinner' where collaborations between universities were discussed and friendships were formed.

Regarding the social aspects of the conference, I thoroughly enjoyed the mentoring event during which I had the chance to have lunch with Dr. Hollie Putnam. Dr. Putnam provided helpful perspectives when asked about careers outside of academia, job interviews, and women in science. I'm very grateful to Dr. Putnam for her time and thoughtful advice! While I did not attend ICRS night, Instagram stories and Facebook posts revealed that the event was, for lack of a better word, *lit*. ICRS night featured beer, pretzels and other German specialties, along with entertainment that attracted most attendees.

Unfortunately, I found the online platform slightly cumbersome, and heard similar comments from my colleagues, such that it was not easy to get a good look at all the talks occurring simultaneously on a particular day. May be we should have sought assistance from the very friendly University student helpers. But in my case, fortunately my colleague in science Sara Swaminathan (@SaraSwaminithan #NotJustSpreadsheetGirl) took it upon herself to create a spreadsheet showing all presentations organized by room for each day of the conference and shared it with her followers. Sara's well-organized spreadsheets became the preferred schedule for many attendees.

The conference itself went very smoothly. For the most part, presenters stayed within their time slots. A few presenters had to be cut off during the question portion given the highly engaged audience; a good problem to have! The conference hall was continuously refilled with delicious cookies, fruit, and plenty of coffee. I'm sure I speak for most attendees when I express my gratitude to the conference organizers who ensured that we were all fed, hydrated, and energized during conference hours. In my opinion, and despite contracting COVID for the first time, ICRS 2022 was a great success. From the perspective of an early career scientist, this conference offered valuable networking opportunities, enabling me to meet and mingle with scientists whose research I cited in my qualifying exams. In other words, a dream come true for this coral fanatic. I look forward to attending the next ICRS!

An Undergraduate Perspective

John Sablan, Undergraduate student, Northern Marianas College, Saipan, Northern Mariana Islands (johnmanuel.sablan@my.marianas.edu)

Selected as one of the student representatives from the Northern Marianas College to attend the 15th International Coral Reef Symposium (ICRS) in Bremen, Germany, I was excited, nervous, and a bit anxious considering I only recently entered the field of study at a collegiate level. As expected, it was a long trip getting to the ICRS, which included a 20-hour flight time, an overnight stay in Korea, several delays, and rough turbulence from thunderstorms! Thank goodness I made it safely to Bremen, and had the weekend to settle in. That gave me time to find my bearings and reflect on what I wanted out of the ICRS. I fully intended to utilize this opportunity to absorb as much knowledge as I could from experts in the field.

As the ICRS got underway, I was amazed at the sheer number of people gathered to speak on or learn about coral reefs. The number of sessions, workshops, and plenaries was overwhelming at first, and I wondered how to navigate my ICRS weeklong journey. Fortunately, there was an ICRS app available, which I fully utilized to arrange my schedule and organize my agenda.

I attended a total of 6 sessions, 4 plenaries, and one workshop throughout the week, where I learned about the latest conservation management ideas, and the latest methods of coral restoration. There was also the poster session, a packed event with over 100 posters highlighting coral reef research from different regions of the world! Poster presenters answered all inquiries from attendees, creating an atmosphere of collaborative networking between the most seasoned researchers and an undergraduate such as myself.

Of all the presentations I attended, my personal favorite was “What does it mean to say coral reefs have value?” by Elis Jones. It blended the importance of coral reef conservation with consideration of its economic value. This stood out to me because all of the sessions and plenaries I attended up to that point were about saving reefs or their current state. However, coming from Saipan, which is basically a tourism economy, I was surprised that nobody was addressing how to maximize profits from the reefs while at the same time keeping them safe.

All in all, the ICRS was an amazing experience that convinced me I can make a difference in the future of coral reefs. I hope to make the Marianas a coral reef conservation model for the rest of the world to follow, which is an ambitious idea coming from someone from a dot on the map. However, it was the ICRS that encouraged me to pursue this seriously, and to try to set this dream in motion in the coming year.

Si Yu’us Ma’ase (Thank you).

A First Timer’s Perspective

Allison Klein, PhD Student, Harbor Branch Oceanographic Institute, Florida Atlantic University (kleina2020@fau.edu)

Planes, trains, and automobiles don’t even begin to describe what it’s like traveling from the US to Europe in a post-covid world. From cancelled flights to lost luggage, we all felt like we’d lived a lifetime before the opening ceremony even began. However, all the jet lag and missed meals were well worth it as I attended my first ever international conference. Bremen is a beautiful city; one I was very excited to visit as I have family from Germany. I was pleasantly surprised to see how science-focused the area and its citizens seemed to be. Having Dr. Andreas Bovenschulte, the mayor of Bremen, speak at the opening ceremony made me feel more at home in this foreign city. A beautiful

attraction was the local museum, which had a striking coral reef exhibit on display. The city of Bremen was full of life, and I was delighted to see elements of its art being brought into the conference. The opening ceremony was nothing short of enchanting. A local artist group on stilts danced around the lecture hall embodying the beauty and grace of coral reef ecosystems, which set the tone for the subsequent plenaries and sessions.

The overall essence of the conference was warm; during breaks and cocktail hours, it seemed as though there were always grand reunions between friends and colleagues who had been separated during the pandemic. As it was my first international conference, and only my second conference as a graduate student, I too was excited to meet in person and network with people from all over the globe. The three sessions where I spent the most time were "Disease studies on coral reefs", "Drivers of similarities of microbiomes on reefs", and "Mesophotic coral ecosystems". My own work focuses on how coral diseases impact coral microbial communities. Within these sessions I learned about new techniques for extracting DNA, analyzing data and making sense of variable microbial composition within a host. One presentation of particular interest to me was by Colin Howe, entitled "Utilizing next-generation phylogenetics to categorize and identify core microbial communities across distinct Caribbean scleractinian families." Colin highlighted the Global Coral Microbiome Projects and discussed the importance of collaboration and transparency. Microbes, specifically coral microbes, can be temperamental to work with, so having protocols and analysis pipelines available on forums such as GitHub can enable colleagues to troubleshoot workflows together. I connected with Colin after his talk and we discovered similarities between our projects, and I look forward to working with him in the future as we navigate the complexity of the coral microbiome.

Although I attended many talks about corals themselves, I also wanted to explore outside of my comfort zone. This goal had me following my lab-mates into a presentation by Dr. Luiz Rocha, which focused on mesophotic reef fish. Dr. Rocha's talk, entitled "Taxonomy, biogeography, ecology, and conservation of recently discovered mesophotic fishes" ended up being my most memorable presentation of the entire conference. His take home message discussed how impactful involving local communities can be for reef restoration and designation of MPAs. Dr. Rocha and his lab have discovered numerous new species of gobies on deep reefs and when naming these new species, he incorporates the language of the local people. Dr. Rocha considered that if local communities feel more connected to the species on the reefs, they are more inclined to protect those habitats. This is so simple, yet I had never made that connection before. It is extremely important to always keep local communities involved and have representation from these communities when making laws and regulations for their surrounding reef habitats.

Bremen, the Cathedral Square, a beautiful and friendly city. (photo RO)

My experience at this conference made me even more motivated to continue my graduate career with a focus on coral reefs. There is so much more for me to learn, and I feel humbled to have been at a conference with so many incredibly intellectual individuals. I hope to build upon the connections and networks established at this conference, and I look forward to seeing everyone again, this time even farther around the world in New Zealand.

Storytelling with Corals

Manlin Zhang, PhD Student, School of Geography, Geology and the Environment, University of Leicester, Leicester, UK (mz224@le.ac.uk)

Although we can probably all agree that certain experiences which an in-person conference may offer are just irreplaceable, I am always very conscious that an international event like this comes with a high price to be paid by our environment. Hoping to reduce some carbon emissions, I spent 20 hours of exhausting travel by trains and buses to get from Leicester (UK) to Bremen (Germany) before I was finally able to print my badge for the 15th ICRS. Stepping into the exhibition centre, I was more than thrilled to find out that so much effort had been put into making the long-awaited in-person ICRS climate neutral.

At the Icebreaker, I was greeted by equally excited crowds and a specially tailored art performance, and I am happy to say that ICRS exceeded my expectations from the very start. I personally find getting to know people a Herculean task during virtual events, including the virtual ICRS last year. This year I was glad to be able to chat with wonderful people and learn about research topics with which I was not familiar. I had a few sessions marked down that I probably would not have chosen to attend, if not for the opportunity to talk to the authors. I didn't have time to join the lunches with mentors because I was too busy with exhibitions and posters, but I thought it was a very considerate initiative and a good opportunity for students. The best experiences for me were the workshops, as they allowed more time for in-depth discussion. The poster hall was also a great place to be, and it was always possible during daily breaks to seize someone for a chat about some exciting research.

The scientific programme at the 15th ICRS was overwhelmingly diverse and sometimes I genuinely wished I could split myself in two. Thanks to the conference app, planning the days was a lot easier. I ended up going to most sessions under the theme "Reef environments and climate of the past", but also went to many sessions focusing on ecosystem functions and services. I was intrigued by the research topics concerning the impacts of plastic pollution on coral reefs, especially the study on the combined effects of microplastics and global warming by Jessica Reichert and colleagues. As microplastic pollution has only been discussed in recent years, and a consistent, comparable database of microplastic abundance has not yet been developed, little is known about how reef systems will respond to microplastic accumulation in warming oceans. It was a relief to learn that not all species responded poorly to the coupled stressors! Another set of great talks in the session "Local drivers mediate coral reef ecosystem responses to climate change" gave insight into species-specific resilience and shed light on future paths to restore functional reef systems and mitigate the impacts of climate change.

An overwhelmingly diverse scientific programme – the main conference hall. (photo RO)

As my own research focuses on coral geochemistry, the sessions I was most excited about were 1E ("What can corals and marine calcifiers tell us about anthropogenic effects and trajectory of coral reef ecosystems under global change?") and 1G ("Can large-scale ocean and climate reconstructions from corals improve our understanding of past, present, and future extremes?"), both of which focused on geochemical research undertaken on corals to understand the past climate. I work with *Porites* specifically, so it was inspiring for me to see studies carried out with branching species and with cold-water corals. I can't list every excellent talk I attended, but I must highlight the one by Alexander Gagnon on the biological mechanism through which boron isotopes vary with changes in dissolved inorganic carbon (DIC) in cold-water corals.

One thing I particularly appreciated from the scientific programme was the emphasis on finding solutions. The plenary talk by Iliana Baums on coral adaptations really had me gasp. Diving into the genetics to look at the fuel for coral adaptations, I was impressed by not just the amount of fine work Dr. Baums and her colleagues had done, but also the fact that it seemed the more we know, the more we still don't know about corals. The talk had me thinking of the earlier plenary talk by Natalie Ban on marine conservation. Both were not to be missed (and can still be appreciated online)! It was fascinating to see that many approaches have been used and more can be applied to preserve and potentially restore coral reefs. I would like to think that at this stage, with joint effort, there is still hope at the end of the tunnel.

I had a great experience presenting my poster and was pleasantly surprised to find that so many people attended the poster session, even though it was quite late in the day. I had the opportunity to talk to people working at nearby field sites on completely different subjects and had a chance to reflect on my own research in relation to indigenous land use and culture. I was disappointed that only one poster session was arranged for the whole week. Considering that people had to pay much more to present a poster than to just attend the conference, it was slightly discouraging. Having served on the volunteer team for an international conference, I can imagine how much time and dedication it takes to achieve the brilliant organization of this meeting. Maybe just like running the scientific tours in parallel with some of the talks, hosting more poster sessions alongside the main programme would be a worthwhile addition. The only other complaint I heard was that the catering failed to accommodate adequately for people who were vegan or gluten intolerant.

Overall, the 15th ICRS was a memorable experience as the first in-person conference I've attended since the pandemic. I very much look forward to seeing the science and the people at the next ICRS gathering in New Zealand.

Science to Policy

Mariana Rocha de Souza, Knauss Fellow, NOAA, Global Ocean and Observing Program (mariana.rochadesouza@noaa.gov)

After 2 years of waiting, ICRS in person was finally happening. As a graduate student, so many things have happened in these 2 years! I defended my PhD, started a fellowship, and moved across the US. I was very excited to present my work on the response of coral symbionts to heat and acidification and to see many colleagues I had not seen lately!

I was particularly interested in the session on coral adaptation and acclimation. Dr. Andrea Grottoli opened the session by presenting a unified framework for manipulative and *in situ* experiments. The framework, the result of a workshop with many experts in the field, recommends metrics to report on every aspect of experimental design (e.g., light, temperature), common variables (e.g., description of bleaching phenotype and coral holobiont health), and relevant metadata. This is such an important and pressing topic, because having a unified framework increases our ability to compare studies and detect trends. There were so many other interesting presentations in that session, from reproductive physiology to the role of symbiont communities in adaptation and more.

The Science to Policy Dialogue – the Discussion Panel chaired by David Obura. (Photo RO)

I was also very inspired by the plenary talks and the Science to Policy Dialogue. This Dialogue was a follow-up to the ICRS policy paper describing a plan for action to save coral reefs with three main pillars: slowing climate change, improving local conditions to build resilience, and investing in coral restoration and innovation. Discussing how policy and science can be better integrated is key to scaling up our response to the coral reef crisis.

I appreciate all the work that goes into putting together such a large conference, especially with all the planning that happened during a pandemic! I can't imagine all the coordination that goes into organizing the venue, catering, happy hours, website, app and online participation for more than 1000 participants! Despite everything going so well, the mobile app had some glitches. The daily schedule would not load properly; but every day before the program started, an excel version of the daily schedule would circulate, which highlights how proactive, helpful and collaborative the community is!

Being able to attend ICRS was an amazing opportunity to present my work, learn about new research and meet new people in the field. It made me proud to learn that this was the first climate neutral in-person ICRS ever conducted. Hopefully this will set a standard for future ICRS meetings and other conferences in the field.

With (left to right) Monica Medina, Diana Beltran and Carlos Prada and performers at the ICRS icebreaker.

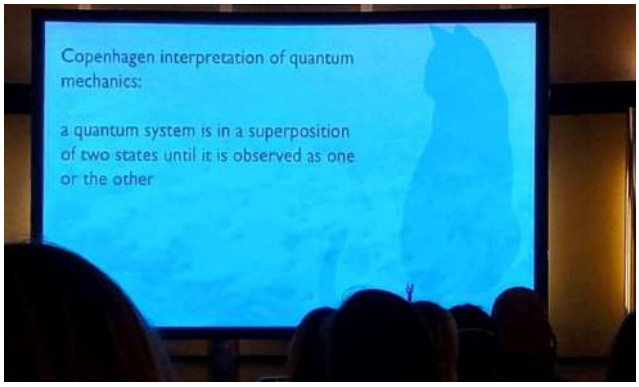
Corals to Cats to Fish

Allison Holevoet, Center for Marine and Environmental Science, University of the Virgin Islands (ajholevoet@gmail.com)

After a few years of staring at our computer screens and staying six feet apart, the in-person 15th ICRS in Bremen Germany did not disappoint. What a whirlwind experience of watching corals dance on stage, meeting Zackery Rago from "Chasing Coral" at the poster sessions, crowding into a small room to hear Dr. Andrew Baker talk about his new project, and having someone lean over to me and say, "Hey. See that woman over there? That is Greta Aeby. She is the grandmother of coral disease research!".

One of the most memorable talks for me was not initially about coral at all, but instead, about cats. Simon Brandl began his cat talk and the thought on everyone's mind was palpable … "What the…" Nevertheless, this clever presenter told an urgent story of Schrodinger's cat and shifting baselines of reefs today that had everyone on the edge of their seat. Simpson did a phenomenal job of accurately portraying the need for humans to be aware of their own misperceptions concerning reefs in a whimsical, comedic, and sophisticated manner.

Jumping from cats to fish, Dr. Steve Simpson and his team have spent many years doing just that: jumping in. More specifically, Dr. Simpson and his team study sound spaces, recording reef sounds



and determining what sounds juvenile fish are attracted to. Turns out, juvenile fish prefer the hustle and bustle of "reef city" life rather than the quiet "ocean countryside". What struck me were not so much Dr. Simpson's results, but instead how they made him *feel.* How his lab felt. The highlight of his talk for me was when he described how he and his team came together to combat eco-grief in the scientific community, in his lab, and around campus. Rather than leaving off on a gloomy note he showed pictures of smiling faces and cute signs with encouraging words. As everybody knows, there is some doom and gloom in what we do in science, but here was someone who was doing something about it in a brilliant way. If it had been appropriate, I would have given him a standing ovation.

ABBA tribute act at the end of conference party. (Photo by RO)

In contrast, the ICRS student chapter meeting proved very disappointing. The student hosts were cordial and the ice breaker was fun, but as an in-person student meeting it lacked substance. The hosts said they had already conducted surveys about what we ICRS student members want to see, what kind of events we wanted to participate in, and what the chapter could do differently in the future. However, rather than put any of those

survey responses to use in the meeting, the hosts took that time to let students voice the same responses aloud. This was my first international conference and I felt disappointed that to have gained nothing new or exciting from the student chapter.

Fret not! The last day of the conference ended the way all conferences should: with delicious local food, a giant dance party, and ABBA coming over the speakers., Although I am not currently studying coral, I felt grateful to be able to meet great folks and fill my brain with more coral knowledge than I knew how to handle. As I jumped around to “Super Trooper”, sweaty and out of breath from wearing a KN-95, I smiled knowing that the future of coral research is in capable hands and that for now, we could dance the night away because maybe, just maybe, researchers like Dr. Pete Mumby were out there dancing too.

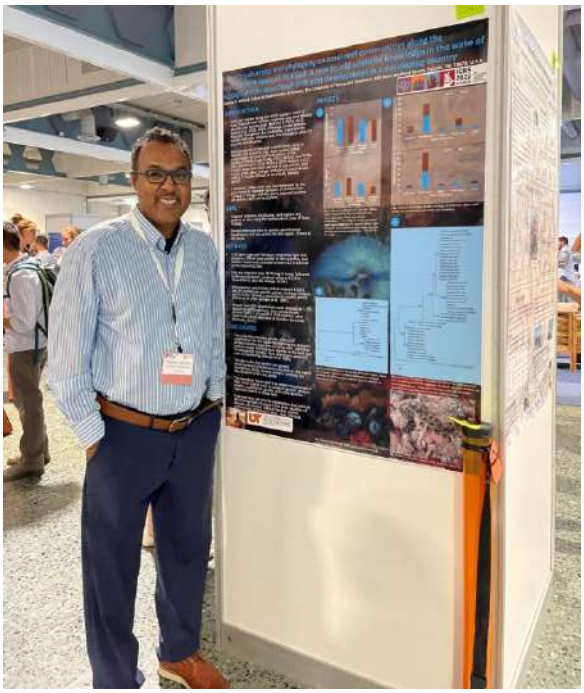
Posters for Science Communication

Stanton G. Belford, College of Mathematics & Science, The University of Tennessee Southern (sbelfor2@utsouthern.edu)

Arriving at the International Coral Reef Symposium (ICRS) conference venue at Bremen, Germany, gave me a feeling of victory on arrival, as if I had completed a marathon. Almost every conversation seemed to start with “made it after three flights and one cancellation”, or “I’m so glad I didn’t lose all my luggage.” Just to travel and arrive at the conference seemed a momentous task in itself. Attendees were eager to post their photos on social media, inviting others to share in their travelling victory. I too received many “likes/hearts”, and relished in the feeling of accomplishment, even before the proceedings had begun!

The opening plenary talk was by Dr. Nancy Knowlton, who was the first woman to receive ICRS’s highest honor, the Darwin medal. While Dr. Knowlton thus provided an impressive example for future female scientists, she soon also provided an example to me, for I soon saw her sitting outside the convention center talking to someone. As I walked by, I could hear her ask the student about her interest in a particular field of study, and felt a sense of joy at her clearly demonstrating the value of mentorship; a prestigious medal winner genuinely paying attention to and asking about a student’s own research.

"Greeters" in ICRS t-shirts posted throughout the convention center guided me to registration and answered any and all questions. Oral and poster presentations were located in spacious settings, and I could not wait to plunge into the knowledge of the marine science on display. However, I still needed to determine the times and rooms of specific talks, instead of pursuing the hit or miss tactic of jumping



The author standing by his poster

from room to room, so I headed to the hot pages of social media: Twitter! I was relieved when I found that a graduate student had taken it upon themselves to guide all the lost souls, myself included, to the times and rooms of each talk.

The task of selecting talks to attend coincided with my decision that, since I myself was presenting a poster, I would spend time studying the efforts of others also on show. I was very impressed by the poster on "Impacts of reduced human activity due to COVID-19 on reef fish populations in the Cayman Islands", by Gretchen Goodbody-Gringley and Alex D. Chequer. It was also a change to see work featuring the effect of an absence of human presence on a marine habitats and populations. Another poster, "Long-term changes in fish communities after lionfish arrival on mesophotic reefs inside and outside of marine protected areas in the US Virgin Islands", by Sarah L. Heidmann, Elizabeth Kadison, Viktor Brandtneris, Rosmin Ennis, Tyler B. Smith, and Richard S. Nemeth also piqued my interest, since they used a nice experimental design, the effect in the US Virgin Islands of invasive lionfish on native mesophotic fish populations both within and outside marine protected areas. Frustratingly no relationships were found. Also catching my eye was a poster presenting 13 years of Reef Check monitoring undertaken by Red Sea Diving Safari, a cluster of three diving resorts in southern Egypt, during their four-day eco-diving courses. Most interesting to me, however, was a poster called *Embryonic and larval development of the Red Sea clownfish, Amphiprion bicinctus*, by Micaela Justo, John Majoris, and Michael Berumen, since I previously studied the interaction between this species and its anemone hosts during a research trip to Aqaba, Jordan.

My own poster presentation concerned the potential demise of a research site due to port development. Over 257 species have been identified at the site thus far, with average cnidarian coverage ranging between 30 and 45%, yet 100% loss of its benthic reef community seems quite plausible. Such a tragedy can only be averted through a combination of effective science and a change in attitude of the authorities to the marine environment.

Enhancing Ocean Literacy through Art

Madyson Miller, Knauss Fellow, NOAA, Coral Reef Conservation Program
(madyson.miller@noaa.gov)

When most people think of Germany, I doubt coral reefs come to mind. But there we were, hundreds of coral reef students, scientists, educators, experts, and champions, excited to share ideas and learn from each other. From the minute I got off the plane, I was struck by the creative way the community of Bremen, Germany welcomed visitors. This included a local dance troupe that dazzled us with their unique coral reef costumes and a coral reef exhibit, at the Übersee Museum, made out of yarn provided by the community.

My journey to coral reef conservation was a long one, with seagrass and microplastics scattered along the way. I found my love for science communications, specifically focused on coral reefs, more recently, when I started working with the NOAA Coral Program, where I am currently the acting co-chair for the U.S. Coral Reef Task Force's Communications Working Group. Naturally, I was excited when my friend told me that, during the conference, she would be hosting a workshop focused on effective science communication and ocean literacy. Not only was this workshop a great way to connect with other communication-minded youth, but it provided great tools for making science accessible and understandable. My favorite part was the emphasis on incorporating more art into science. As we push farther into the future,

it will be more important than ever for scientists to become more engaged in policy and communications. I would like to see supporters of marine conservation empower more reef scientists to branch out into these uncharted waters. Art is just one approach that can be used to express scientific ideas. Art is not only a tool to help the public understand science, but it is also a way for scientists to unlock creativity, imagination, and visualization, which will ultimately help us see the world through a more diverse lens and allow us to make science more meaningful to a broader community.

Inspired by the Übersee Museum coral reef art exhibit. (Photo by Caroline Rodriguez)

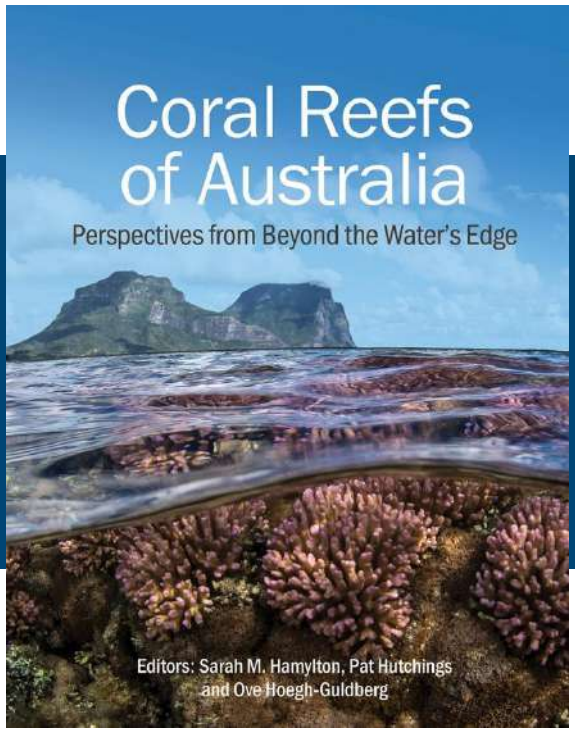
The Bremen Town Musicians

REEF SHELF

Coral Reefs of Australia: Perspectives from beyond the water's edge

Hamylton SM, Hutchings P, Hoegh-Guldberg O (eds) (2022).

Publisher: CSIRO Publishing, Melbourne.
344 pp



The curate's egg

It's a curate's egg, this book – good in parts. The good parts are very good indeed, and the bad parts – well, more of that later.

A very stylishly produced book, beautifully, even lavishly, illustrated, it presents itself as a celebration of the centenary of the Australian Coral Reef Society. While it's true that the ACRS is the 1982 successor of the venerable Great Barrier Reef Committee (GBRC) which was established in 1922, to claim succession is rather like the Tudors' claim to be the successors of the Plantagenets to the English crown. Instead let us, like Dorothy Hill (1985), call it a metamorphosis.

The editors say it is a curated work, and that post-modern phrase tells us something about what is to come. It is divided into a half-dozen or so big sections covering big swathes of territory – Australia's coral reef estate, the science, conservation, industry, indigenous perspectives, management, climate change and so on. And each section is built up from vignettes of a page or so each. These are each written by different authors, perhaps a hundred in all. And at the end of each section, there is a consolidated bibliography – an unusual setup.

Almost by default, with so many authors, the book is a Who's Who of Australia's coral reefs, and in full disclosure, I must add that many of them are my friends and colleagues, and not a few of them my co-authors.

The vignettes are, by and large, good. They are pithy and current and mostly well-written. And their references are excellent. Indeed, as a resource on the literature of Australia's coral reefs, the book is without parallel.

The vignettes I liked the most were the historical ones: the sometimes-tortured history of the research stations; the early scientific expeditions in what might truly be called the heroic age of coral reef science; the early fisheries including the pearling and bêche-de-mer; and the place of the reefs in the cultural life of indigenous people. And for the general reader the pieces that traverse Australia's coral reef estate and that give modern summaries about how reefs work will be very useful.

And yet there are some troublesome gaps, perhaps reflecting current interests.

The geology of Australia's reefs is barely dealt with even though, ever since Darwin, geological perspectives were considered co-equal with biological ones. Perhaps reef geology reminds us too much of oil drilling and such.

This is a sad omission, especially since much of the early work of the GBRC was involved in drilling expeditions to understand the Holocene and Pleistocene processes contributing to reef dynamics. The geology of both ancient and modern

reefs also featured strongly in the Second International Coral Reef Symposium in 1973. This was organised by the GBRC and held aboard the MV *Marco Polo*. And to it, today's reef scientists owe a debt, for that famous symposium established the quadrennial series of international meetings that continue to this present day.

The oceanography of our reefs is also passed over. This is very surprising given coral reefs are, by nature, extensive at scales of thousands of kilometres and are stitched together by their oceanography. There really are no clear boundaries anywhere across the whole reef tract of the Indo-Pacific. Perhaps this omission reflects the modern notion that reef management is a local affair – this marine park, that reserve – and that the marine environment can be cut up and managed in tidy blocks.

But even with those quibbles, we are left not with the question of whether this book should sit on your shelf – it should – but where it should sit. It is clearly pitched at the reading public rather than reef professionals – scientists, managers and so on. It has the tenor, say, of the synthesis reports of the IPCC rather than their detailed technical assessment reports. But it is clearly not the work of one mind, such as the books by Peter Sale (2011) or Callum Roberts (2020), nor is it truly a synthesis.

And that brings me to the lost opportunity that the book represents. Instead of a synthesis, the book presents a consensus even if it is never spelled out like that. And that consensus is the comfortable one that suits the interests of today's stakeholders – another post-modern barbarism – in coral reefs. The stakeholders are, of course, governments, NGOs, scientists and industry, particularly the tourism industry. Each has an interest in a narrative – these post-modernisms are infectious – that says reefs are under threat but with good research and good management their wise use is sustainable (last post-modernism, I promise).

It's a slippery story. Governments need to say they are looking after the reefs. NGOs need to say that, while the situation is dire, more regulation, more management, more activism and more money will save the reefs. Scientists, as usual, say that more research – read more money – is needed to save the reefs. And industry, not wanting to drive tourists away, say the reefs are fine and can only get better.

This is a cyclically reinforcing Panglossian story – each stakeholder reinforcing the other – and, sadly, the book is drenched in it. As it says in the Foreword, 'The good news is that it is not too late to reverse much of the harm and turn from decline to recovery.'

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. As Rob Seymour and I argued in 2009, coral reefs are just roadkill on the Anthropocene highway.

And it could be said that it's morally wrong to proffer a view that there is a future for coral reefs. There are few fully functioning coral reef systems left in the world today. Most lost their key components – large old corals and vertebrates – years ago. A marine protected area with a bunch of weedy little corals and pretty little fish is no more a coral reef than an English lion park is an African savannah.

The general public, the target of this book, deserve to be treated honestly. They deserve the truth no matter how depressing.

Scientists – especially in the Australian Coral Reef Society – need to say for coral reefs: There. Is. No. Hope.

Roger Bradbury
Australian National University

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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 with involved with coral reefs and associated ecosystems, other people with genuine interests in or concern for reefs, of any type, are welcome. The benefits of membership include:

- Receipt of the Society's scientific journal *Coral Reefs* (on-line)
- Free (on-line) access to all past issues of *Coral Reefs*
- 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
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ICRS Member Services
5400 Bosque Blvd, Suite 680
Waco, Texas 76710-4446 USA
Phone: 254-399-9636
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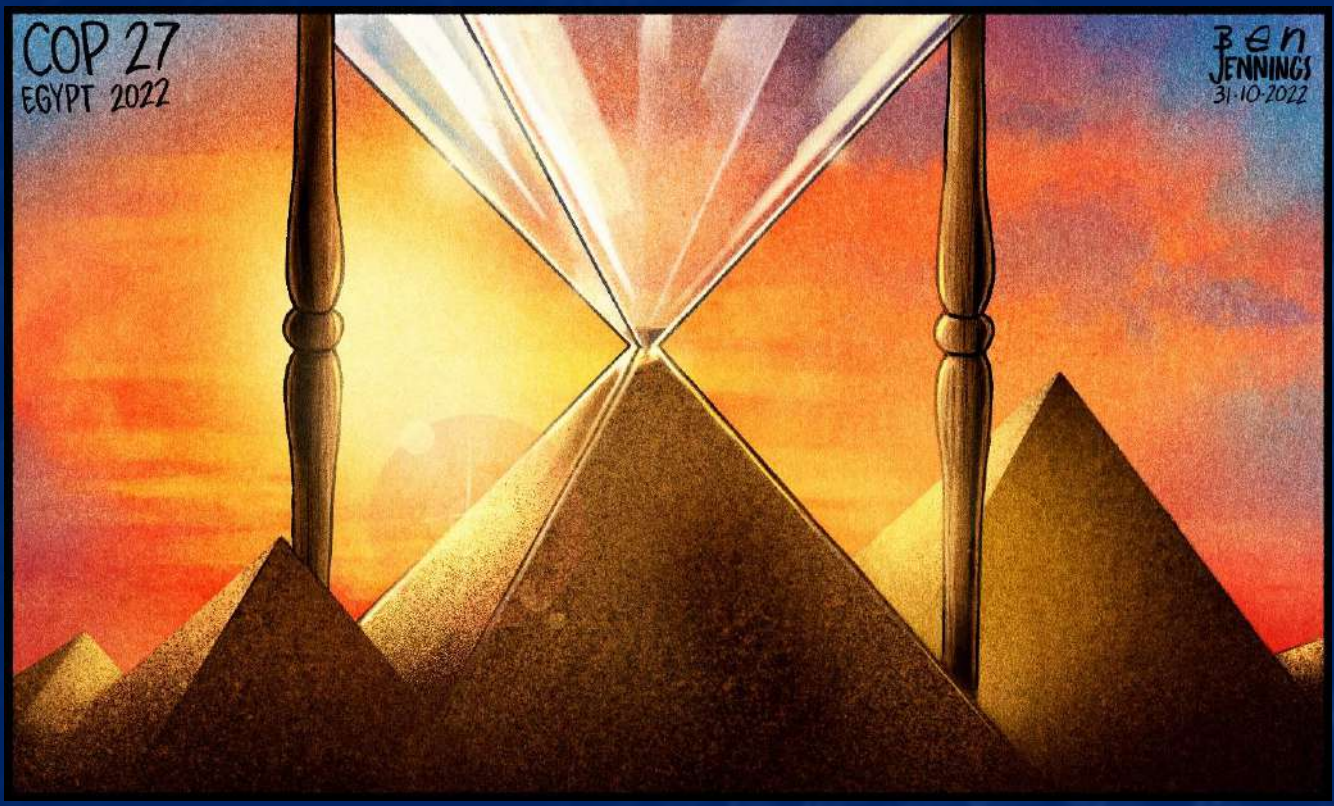
Reef Encounter welcomes in particular, (1) general overview articles (3-5 pages) on particular reef science topics in which the author(s) has a special interest, (2) short communications / scientific letters (1-2 pages) reporting recent observations, and (3) general interest articles describing personal 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 the 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).



Cartoon from the Guardian Newspaper, by Ben Jennings, alluding to the UN Framework Convention on Climate Change and its COP27 held in Sharm El Sheikh, Egypt during November 2022.
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