REEF ENCOUNTER

The news magazine of the International Coral Reef Society

REEF DEPARTURES

Jon Brodie, Joseph Connell, Peter Gayle

REEF PERSPECTIVES

Peter Sale on Shifting Baselines
Science for Reef Survival - the evolution of ICRS

REEF CURRENTS

Mangroves on Indian Ocean Atolls; Mesophotic Reefs of the Mexican Pacific; SCTLD in the US Virgin Islands

INTERNATIONAL CORAL REEF CONFERENCES

Bremen 2021/22
Auckland 2025/26

ICRS International Coral Reef Society

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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.

EDITORIAL & OFFICERS' REPORTS

SOCIETY ANOUNCEMENTS

CONFERENCES

CHAPTER REPORTS

ABOUT THE COVER | The cover illustration is of a reef site in Milne Bay, near Alotau, Papua New Guinea, taken by Myron Wang.

EDITORIAL

Rupert Ormond | Editor

Dear Colleagues and Reef Encounter Readers,

Welcome to our new edition of Reef Encounter. As you will see we have adopted a new look, with the intention of making our magazine more attractive and readable. At the same time, we are reducing the length of the typical issue in the hope that this will enable us to meet our target of publishing two issues per year on a more regular basis.

To help meet this ambition we also need members to submit articles. If you find yourself caught at home by Covid related restrictions, do please consider taking a few hours to write something. The three main types of article we welcome are:

- **General Interest Articles** including opinion pieces, historical accounts, etc. usually **3 -6 pages** long, that go into our **REEF PERSPECTIVES** Section
- **Overview Articles**, for our **REEF CURRENTS** Section, that are essentially short, up-to-date, reviews of a particular topic area in which the author(s) is interested or involved; these are typically a little shorter, say **3 – 5 pages**.
- **Short Communication** type scientific papers, that go into the **REEF EDGE** Section. These can describe one-off observations or preliminary results, that are unlikely to lead to a full scientific paper at least in the near term, but which members are keen to see published and other members will be interested to read. These are usually **1 -2 pages** long.

As always, a benefit of digital publishing is that we welcome a nice selection of images to complement each article. We also expect some citations, but not too many!

I am especially grateful to new editorial committee member Silas Principe, who offered to develop our new look. And again, as always, I am grateful to the rest of the team for helping to generate material and review submissions, and especially to my deputy Caroline Rogers for taking on so much of the reviewing and proof reading. Until we can be on reefs again "stay positive, test negative!"

ICRS Awards: Call for Nominations

Nominations deadline extended to March 15th

Given the on-going challenges of the global pandemic, the Society's awards committee has extended the deadline for nominations for Society awards until March 15, 2021. Please nominate your ICRS colleagues for their research and conservation accomplishments! These Society Awards are only available to ICRS members, so please encourage your colleagues to join us today.

- Eminence in Research Award
- Mid-Career Award
- Early-Career Award
- World Reef Award
- Coral Reef Conservation Award
- ICRS Fellow

Descriptions of each award, of the nomination process, and of the supporting material required can be found online at: http://coralreefs.org/awards-and-honors-nominations-2/. Note that the actual submission now needs to be made on-line (and not by email) as directed on the website. Further questions about the ICRS honors and awards can be addressed to the chair of the Awards Committee, Dr. Carly Randall (c.randall@aims.gov.au).

EDITORIAL & OFFICERS' REPORTS

PRESIDENT'S WELCOME

Andréa Grottoli, ICRS President

Dear International Coral Reef Society (ICRS) Colleagues:

The International Coral Reef Society is a scientifically and culturally rich organization and I am proud and honored to serve as its President. With the plight of coral reefs so dire, we have the opportunity to effect change, share our scientific discoveries, and work to better understand and protect coral reefs.

The year 2020 has been a year like no other: challenging, difficult at times, different all the time, and for many a year with deep loss and sorrow. The pandemic has altered so much for all of us personally and professionally. We delayed the 14th International Coral Reef Symposium, put off fieldwork, missed seeing friends and family, and for many of us our research and labs were shut down for months.

Yet despite these challenges, the ICRS has made great strides in 2020. Building on the launch of the updated ICRS mission and vision statements of 2019 (http://coralreefs.org/about-icrs/), ICRS in 2020 accomplished the following:

- ICRS launched the Plan of Action (http://coralreefs.org/plan-of-action/).
- ICRS launched the Pledge for Reefs (http://coralreefs.org/pledge-4-reefs/).
- ICRS held the first competition for a Science Communication Fellowship.
- ICRS has added a Donate button on the ICRS webpage (http://coralreefs.org/) and invested 50k USD with Morgan Stanley Investments. Donated funds and return on investments are used to increase support for awards, student research, ICRS operations, and regional and international coral reef meetings by the Society or our Chapter organizations.
- ICRS welcomed the Mexican Coral Reef Society as an ICRS Chapter http://coralreefs.org/committees-and-chapters/mexican-chapter/)
- ICRS welcomed the Mid-East Chapter to ICRS (http://coralreefs.org/committees-and-chapters/mideast-chapter/)
- ICRS selected the winning bid for the next symposium. The 15th International Coral Reef Symposium will be in New Zealand in 2025!

ICRS also became more engaged on the international stage in 2020 in the following ways:

- ICRS collaborated with the American Fisheries Society and 100 other societies on the drafting and release of a World Climate Statement (https://climate.fisheries.org/world-climate-statement/) on the need to take urgent action against human-caused climate change.
- ICRS is on the scientific advisory committee for the G20 Global Coral Reef R&D Accelerator initiative.
- ICRS has applied for Observer Status at the United Nations Climate Change Conference (CoP26).
- ICRS has three Council Members as co-authors on the International Coral Reef Initiative paper in development on Coral Reefs and Human Health.
- ICRS has several representatives on the International Coral Reef Initiative ad hoc committee that is working to have coral reefs and related ecosystems included within the CBD Post-2020 Global

Biodiversity Framework (https://www.icriforum.org/terms-of-reference-for-the-ad-hoc-committee-on-developing-a-recommendation-for-a-post-2020-coral-reef-target/) (the follow-on to the Strategic Plan for Biodiversity 2011-2020 and its associated Aichi Biodiversity Targets endorsed by the UN General Assembly), that is part of larger United Nations and CoP meetings and documents.

- ICRS has several representatives on the International Coral Reef Initiative ad hoc committee for Resilience Based Management of Coral Reefs (https://www.icriforum.org/resilience-based-management/).

As you can see, the ICRS has been busy. As President of the Society, I am incredibly grateful to the Officers and Council members who voluntarily work tirelessly for the Society, and to all ICRS Members for your continued support of the Society. Your dedication and commitment to reefs makes the above accomplishments possible.

Wishing everyone the best for 2021!

Dr. Andréa Grottoli, PhD
President, International Coral Reef Society
Professor, Ohio State University

TREASURER'S REPORT

Anderson Mayfield, ICRS Treasurer

Please allow me to first introduce myself as the Society's new treasurer. Given that my day job as a reef coral actuary involves a fair amount of "book-keeping," in which I track the health of my clients (i.e. corals) over space and time, it seems fitting that I now moonlight as the treasurer for the International Coral Reef Society (ICRS). Lest you grow concerned that our modest holdings have left the able hands of the former treasurer Dr. Erinn Muller, who did an exemplary job in shepherding the society through a period of marked growth in both capital and number of members, I can assure you that Erinn has spent countless hours explaining to me the "ins and outs" of the ICRS treasurer's duties. Furthermore, I began my coral biology career in the non-profit sector and have actually (legally) invested fellowship money in the stock market, where the principal was used solely for research expenditures. So, I trust I do have some relevant financial experience.

One thing I quickly appreciated as ICRS treasurer is that ICRS' income stems almost entirely from the membership fees paid by you members - no big government grants (though we did get $10,000 from the United States National Oceanic & Atmospheric Administration [NOAA] last year), no wealthy benefactors, just a series of $20 (students from low-income countries) to $160 (full membership with print journal access for developed country researchers) payments trickling in every few days; your dues in 2020 summed to ~$90,000 (Fig. 1) . Now that I see how much work the treasurer, council, and particularly the president and vice president put into the society in any given week (all unpaid volunteers), I can assure you that your money is being put to good use. For instance, of our ~$80,000 in normal operating expenses for a given year (much more in a "conference year," as 2020 was supposed to be), only about ~$3,000 are diverted to officers, and that is simply to discount their membership and conference registration fees. A large portion goes towards the clerical management required to process your membership payments. At $18,000/year, this was a surprise to me, and I am more than happy if anyone out there has suggestions on how we can reduce these costs and so have more funds to support students and conservationists, particularly those in developing countries.

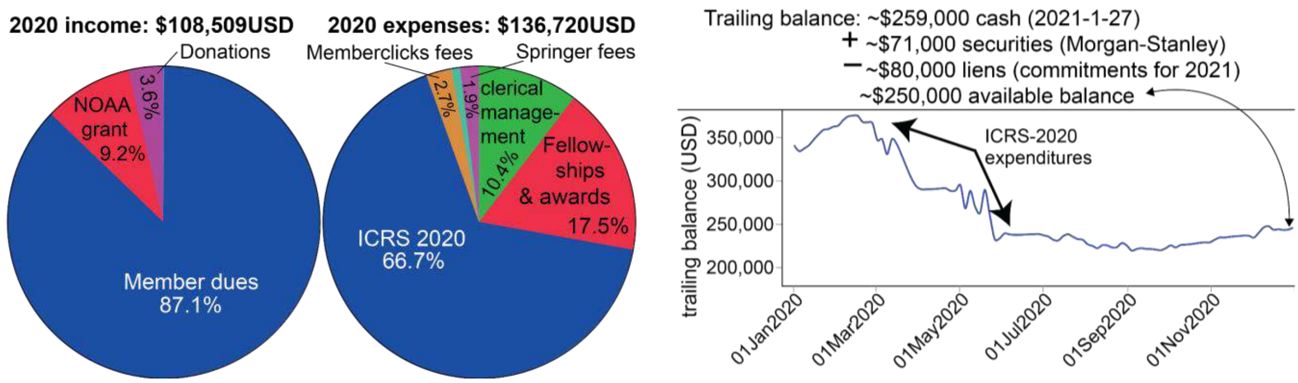

Fig. 1. Breakdown of ICRS' 2020 income and expenses, with the trailing balance over the year shown below. All amounts given in United States dollars (USD).

Despite 2020 being a rough year, given the pandemic, which forced us to push back the date for the 14th International Coral Reef Symposium (originally scheduled for summer of 2020 in Bremen, Germany), ICRS still managed to give out a significant number of grants in 2020. We awarded five $2,500 graduate student fellowships, a $5,000 Ruth Gates fellowship (using the aforementioned, matching funds from NOAA), and a $2,500 conservation award (with a second to be given in early 2021). We also recently awarded two science conservation fellowships ($2,000 each). I mentioned an overall operating budget of $80,000, and Fig. 1 shows ~$137,000 spent in 2020, but I have only mentioned $18,000 in clerical fees, $23,000 in fellowships, and $3,000 in officer expenses, equating to $44,000. So, what happened to the remaining ~$93,000? The meeting! $93,000 is of course only a fraction of what it takes to host an in-person ICRS meeting, and the local organizers and sponsors actually provided a much larger amount. Where ICRS invests more is in providing awards and subsidized rates for students to attend these meetings; $20,000 will be given out to individuals to offset conference costs (as a series of $1,000 & $550 fellowships). Thus, in total, we anticipate giving out $60,000 in grants in 2021 (including graduate student fellowships, conference travel awards, & the like).

Given that ICRS has limited financial holdings (~$250,000), I do think we've done a good job at channeling funds to some of the individuals who are making a difference with respect to coral reef research and conservation (and particularly those from developing nations with more limited access to research funds). I hope we can continue this ethos into the coming years and look forward to working with many of you.

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[1] All reported values are in United States dollars (USD).

SOCIETY ANNOUNCEMENTS

Society **elections**

The results of the Society elections held in late 2020 were as follows:
The following members have been elected to serve as officers in the posts indicated from 2021-2024 inclusive:

Anderson Mayfield (USA) Treasurer
Anastazia Banaszak (Mexico) Recording Secretary

The following members have been elected as members of Council, to serve from 2021-2024 inclusive:

Raquel Peixoto (Brazil)
Ilsa Kuffner (USA)
Nicole Browne (Australia)
Vikash Munbodhe (Mauritius)
Kennedy Osuka (Kenya)
Luis Eduardo Calderon (Mexico)
Nikki Traylor-Knowles (USA) (to replace Caroline Palmer who has resigned)

In addition, the following member has been provisionally co-opted to Council:

Sarah Davies (USA)

Michael Sweet, ICRS Corresponding Secretary

Science communication **fellowship**

The first winners of the ICRS Science Communication Fellowship were:

Tory Chase (USA) and
Denise Alcantara (Philippines).

As members will have learned from our email, the standard of applicants was so high that the Council agreed to appoint two Fellowships for this first year. The winners had clearly defined projects, showed innovation and originality, and enthusiasm to benefit coral reefs that aligned with ICRS's mission.

Andrea Grottoli, ICRS President
James Crabbe, ICRS Education Committee Chair

ICRS BREMEN 2020 / 2021 / 2022

The Latest Plans

Prof. Dr. Christian Wild [1]*

Background

By the beginning of March 2020, preparation for the 14th International Coral Reef Symposium - ICRS 2020 (originally planned for 5th-10th July 2020) and registration of delegates were both well underway. The overall budget was in balance, due to the recent commitments of key sponsors, and more than 2,600 participants had submitted abstracts, and about 3,000 participants were expected to be in Bremen, based on numbers attending the previous three ICRS events.

The COVID-19 pandemic then led to the inevitable decision to postpone the 14th ICRS from July 2020 to July 2021 (planned for 18th – 23rd), hoping that the situation would by then be normal. This decision was taken jointly by 14th ICRS organizers and ICRS at the end of March (2020) and widely communicated by the beginning of April.

Current situation

Unfortunately, as of now, the COVID-19 situation has become more difficult, rather than easier. Indeed, at the moment, the venue for ICRS 2021 is serving as the vaccination center for Bremen, and even though vaccination campaigns have started in many countries, experts do not expect the situation to improve much before July. Instead, it has become clear that distancing rules, hygiene measures, people number limitations, and travel restrictions, will likely be with us until the end of the year. For example, participants from Australia and some US universities (a major constituency of the ICRS) are already affected by travel restrictions lasting until the end of June 2021, and so are unlikely to be able to be in Bremen by July.

For these and related economic reasons, supporters and sponsors of the 14th ICRS have become hesitant to make financial commitments towards an ICRS being held this year. In fact, the postponement has caused significant additional costs, due to cancellation penalties and staff expenses within the 14th ICRS secretariat. As a consequence, our budget is deeply in the red, so that it has become impossible to run the 14th ICRS in July 2021 as hoped.

New plan

After much discussion and detailed evaluation of all options, it has now been decided, as of January 2021, to run both a 100% virtual 14th ICRS 2021 on-line, and an in-person 15th ICRS 2022 in Bremen, Germany. This strategy combines the opportunity to present scientific content on-line, as asynchronous pre-recorded talks and posters, with synchronous panel discussions, during the scheduled week of 18 – 23 July 2021, while also enjoying an in-person meeting during a 15th ICRS in summer 2022.

We are now working on a detailed concept for the on-line 14th ICRS in collaboration with professional companies that specialize in running virtual meetings, so that we can ensure such a virtual meeting will run successfully. We also need to consider how the two events can complement and support each other, so that any competition between events for participants is minimized.

It is anticipated that the registration fee for the virtual 14th ICRS will be ca. 50 % of what the in-person registration fees would have been. The oral and posters presentations will be professionally archived and accessible to all registrants for a year. The virtual meeting would not however include plenary sessions or ceremonies of any kind, as these events will be postponed to the in-person meeting in summer 2022. Nevertheless, exchange of scientific content and discussion of the newest findings can take place during the 2021 virtual meeting, and we are currently developing ideas for discounted combination tickets for the two meetings.

This new strategy certainly is laborious for us organizers, but it offers the opportunity to implement all components of the event as originally planned, since almost all predictions expect that the COVID-19 pandemic will be under control by early 2022 at the latest. There is also a good chance that working this way we can achieve a balanced budget and that the external pledges of financial support for the in-person meeting will be honored.

Abstracts and presentations

Abstracts submitted for ICRS 2020/2021 have all been evaluated and can be presented at the Virtual 14th ICRS 2021 and / or the in-person 15th ICRS 2022. We also plan to invite additional abstract submissions for the in-person 15th ICRS, which is now scheduled to take place over the week **Sunday July 3rd to Friday July 8th, 2022**.

With this new adaptive strategy, we will be able to:

- Include participants who cannot or do not want to join us in person, at least in 2021
- Provide the opportunity for scientific exchange and discussion in 2021
- Retain the priceless opportunity for personal exchange and networking in 2022

Our original dream was for Bremen to offer an unforgettable first ICRS in Europe. We still have this dream, despite the most challenging of circumstances.

KEY DATES

March 2021 Registration open for 14th ICRS

3-8 July 2022 In-person 15th ICRS 2022 - Bremen, Germany

Christian Wild
[1] Faculty of Biology & Chemistry (FB2), Universität Bremen, UFT, Leobener Str. 6, Room 2160, D-28359 Bremen, Germany
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*(on behalf of the ICRS14 organizing committee)

CONFERENCES

International Coral Reef Symposium 2025/6

Auckland, NEW ZEALAND

Professor Simon K. Davy [1]

New Zealand has been selected to host the International Coral Reef Symposium, following the up-coming Bremen meeting, and we are delighted to be able to invite you to join us here for a South Pacific version of this major conference. Although whether the event is best scheduled for 2025 or 2026 remains to be decided.

We have chosen to host the conference in Auckland with direct international flights bringing you to our largest, most multicultural city. We have selected a brand-new venue in the heart of the city, surrounded by hotels to fit all budgets within an easy walking distance. As it currently stands, upon completion, this will be the only carbon neutral venue in the Asia-Pacific region. Pre- and post-symposium field trips will be offered to Fiji, just a 3-hour flight from Auckland, while participants will also be able to visit NZ's stunning Fiordland, a UNESCO World Heritage Site, as well as New Zealand's numerous other natural wonders.

Bringing the conference to New Zealand will allow a focus on the plight of the South Pacific Islands for the first time, an area that, due to its remoteness, is often forgotten, despite the fact that its reefs are under considerable threat. We will ensure a unique and diverse programme, covering all the normal aspects of the symposium, but giving a localised flavour. We will offer delegates a unique opportunity to learn from Pacific Island knowledge and traditions. Looking at how indigenous cultures have traditionally managed coral reefs, where localized knowledge has been passed down through generations, will give delegates a fascinating insight, and spark fresh ideas arising from our local history. We will also promote the significance of the marine environment, and our high-latitude and deep-sea corals, to our Māori culture here in New Zealand. Highlighting our commitment to this aspect of the meeting, the New Zealand government will support travel scholarships for students from developing South Pacific Nations.

After what will have been a challenging few years, we look forward to seeing as many participants in New Zealand as possible, to continue global efforts to understand and save the world's coral reefs.

[1] President - International Symbiosis Society
School of Biological Sciences, Victoria University of Wellington, Wellington 6140, New Zealand

CHAPTER REPORTS

The Mexican Coral Reef Society

Guillermo Horta-Puga & Anastazia T. Banaszak

The Mexican Coral Reef Society was formed, in 1998, by Mexican coral reefs scientists after the International Coral Reef Initiative (ICRI) organized a meeting in Cancun. The aim of the meeting was to invite Mexico, through its environmental authorities, to become a member of ICRI and to join other countries in their efforts to conserve coral reefs worldwide. After the meeting ended, while celebrating in a bar with beers and tequila, Juan Manuel Vargas Hernández from the Universidad Veracruzana exclaimed: *I promise to organize a coral reef congress*!

Two years later the first Mexican Coral Reef Congress took place in the city of Veracruz, located in the Gulf of Mexico (Table 1). That congress was attended by 125 professionals and students and was such a success that it was decided another meeting had to be organized. The second congress was held in 2003 in Puerto Angel, Oaxaca, in the Mexican Pacific, organized by Gerardo Leyte at the Universidad del Mar. In the plenary session all attendees voted for the creation of the Mexican Coral Reef Society, led by elected officers: Pedro Medina Rosas (Universidad de Guadalajara), Juan Manuel Vargas Hernández (Universidad Veracruzana) and Miguel Ángel Román Vivas (Acuario de Veracruz). Pedro led the effort to register and legally incorporate the society and since then the meetings have been biennial, alternating between the Mexican Caribbean, Mexican Pacific and Gulf of Mexico (Table 1).

Table 1. Details of the scientific meetings of the Mexican Coral Reef Society

Cong.	Year	Host City	Host Institution	Organizers	Invited Speakers
I	2000	Veracruz	Universidad Veracruzana and Acuario de Veracruz	Juan Manuel Vargas Miguel Ángel Román	Ernesto Arias, Guillermo Horta-Puga, Gerardo Leyte Morales, Eric Jordán Dahlgren, Héctor Reyes Bonilla, Juan Manuel Vargas
II	2003	Puerto Angel	Universidad del Mar	Gerardo Leyte	José Carriquiry, Roberto Iglesias-Prieto, Claudia Padilla Souza
III	2005	Cancun	Universidad Nacional Autónoma de México and El Colegio de la Frontera Sur	Roberto Iglesias Prieto Juan Pablo Carricart Ganivet	Alina Szmant, Todd LaJeunesse, Pedro Alcolado
IV	2007	La Paz	Universidad Autónoma de Baja California Sur	Héctor Reyes Bonilla	Roberto Iglesias-Prieto, Peter Glynn, Juan Pablo Carricart Ganivet
V	2009	Tuxpan	Universidad Veracruzana	Carlos González Gándara	Paul Blanchon, Jorge Cortés
VI	2011	Ensenada	Universidad Autónoma de Baja California	José D. Carriquiry	Michael Risk, Stuart Sandin, Juan Pablo Carricart Ganivet, Lorenzo Alvarez Filip, Fabian Rodriguez, Marco A. Lazcano
VII	2013	Merida	Universidad Autónoma de Yucatán, Centro de Investigación y Estudios Avanzados and Universidad Nacional Autónoma de México	Rodrigo Garza Pérez	Roberto Iglesias Prieto, Judy Lang, Peter Sale, Ernesto Weil, Ernesto Arias, Andrew Baker, Jeremy Jackson
VIII	2015	Puerto Vallarta	Universidad de Guadalajara	Pedro Medina Rosas	Hector Reyes Bonilla, Monica Medina, Susana Enriquez, José Carriquiry
IX	2017	Chetumal	El Colegio de la Frontera Sur	Héctor Hernández Aranda	Ernesto Arias, Anastazia Banaszak, Julio Espinoza, David Paz García, Chris Perry
X	2019	Manzanillo	Universidad de Colima	Marco Liñán	David Abrego, Lorenzo Álvarez Filip, Ándres López-Pérez, Jacqueline Padilla-Gamino, Ross Robertson

Although the society originated in Mexico, it has consistently had an active participation from Latin American and European countries, as well as the United States of America. The meetings are usually held in Spanish although abstracts and presentations in English have always been welcome. Invited guest speakers have included Jeremy Jackson, Alina Szmant, Peter Glynn, Andrew Baker, Roberto Iglesias Prieto, Todd LaJeunesse, Judy Lang, Monica Medina, Chris Perry, Peter Sale, David Abrego, Jacqueline Padilla and Stuart Sandin, among others. Details of the meetings are presented in Table 1. On average, the meetings have hosted 178 attendees and 137 oral and poster presentations (Table 2).

Table 2. Congress statistics

Congress	Mexican Institutions	Non-Mexican Institutions	Countries Represented	Number of Participants	Oral Presentations	Poster Presentations
I	19	35	5	125	71	20
II	20	30	5	90	58	13
III	29	26	9	245	35	110
IV	35	10	6	189	46	49
V	34	12	7	99	68	63
VI	25	8	5	180	37	90
VII	56	67	18	220	152	97
VIII	34	24	11	250	60	51
IX	30	16	8	200	59	110
X	33	35	13	180	86	99
Average	**32**	**26**	**9**	**178**	**67**	**70**

In 2019, the tenth meeting was celebrated in Manzanillo, Colima. The International Coral Reef Society kindly provided scholarships for 30 students to attend the congress, awards for best student oral and poster presentations and an amount to help defray the expenses of invited speakers. PeerJ also provided an award for the best student contribution (see more here).

The winner was Serguei Rico-Esenaro, a PhD candidate whose research on coral physiology examined the calcification process response to environmental changes. The society, which was legally founded in 2005, has nearly 80 active permanent professional members (some of whom are members of ICRS), approximately 100 student members, a Facebook page https://www.facebook.com/groups/216686455273, and a web site www.somac.org.mx. The society also has five commissions (academic, outreach, social media, Pacific Ocean and Atlantic Ocean) and has always maintained a positive balance in its accounting. Through the dedication of Mexican coral reef scientists, the Society is active and growing. In 2020, the society officially became a chapter of ICRS. The society was planning on holding its eleventh meeting in 2021, however due to the COVID pandemic it has had to be postponed to June, 2022.

We cordially invite you to keep an eye out for the call for abstracts and, if you can, join us in the lovely city of Veracruz in 2022.

Figure 1. Welcoming banner, at the entrance of the Universidad de Colima, to the attendants of the X Mexican Coral Reef Congress.

Guillermo Horta-Puga
UBIPRO, FES Iztacala, Universidad Nacional Autónoma de México. Tlalnepantla, Mexico
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CHAPTER REPORTS

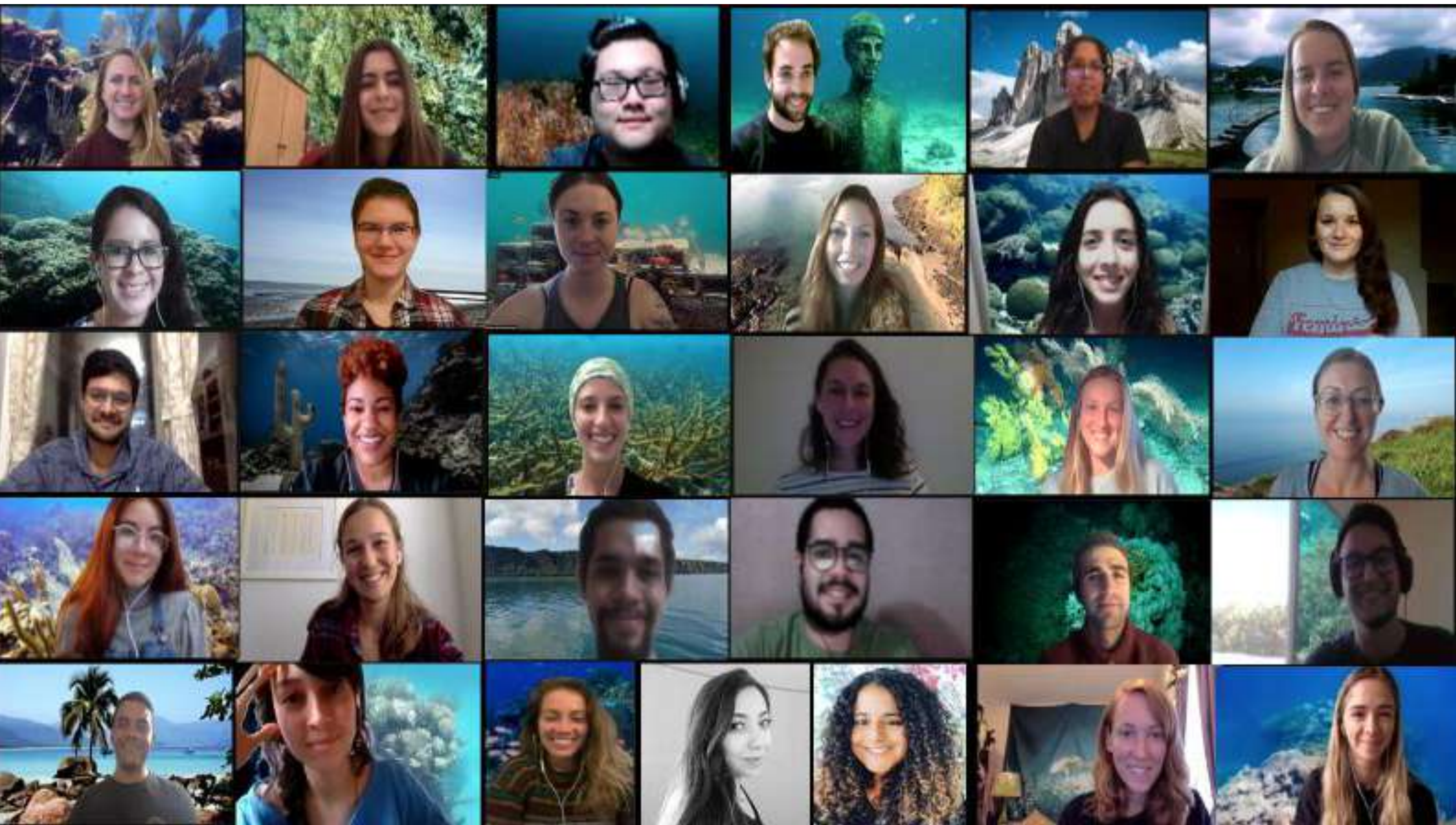
ICRS Student Chapter Annual Review (2020)

Jenny Mallon & Morgan Short

The ICRS Student Chapter is proud to announce that 2020 welcomed a new team of translators, education and outreach officers, and social media specialists to the committee. Our ~30 strong team represents the diverse, global community of both students and early career researchers (ECR) who are enthusiastic members of ICRS. The Student Chapter, originally founded by Sandra Schleier and Laura Richardson in 2016, and more recently chaired by Jessica Bellworthy (and Schleier), handed over responsibilities in August 2020 to Jenny Mallon (Chair) and Morgan Short (Co-Chair). The new committee aims to build upon established objectives and to develop novel initiatives. Broadly, our goals are to:

1. *Maintain a platform for students and early career researchers in coral reef research and study*
2. *Provide supportive resources for career development in the coral reef sciences*
3. *Increase both accessibility and diversity of resources and also participation of young marine researchers*
4. *Raise awareness of coral reef research and conservation*
5. *Support and promote ICRS activities*

▼ The ICRS Student Chapter



The first meeting of the (mostly) new Student Chapter committee was held over Zoom in September 2020. Immediately, Secretary Jenna Dilworth and Treasurer Violeta Martínez Castillo developed protocols for the smooth running of the chapter, including a new Slack channel to coordinate activities and guidelines for managing funds. We voted unanimously to recruit in 2021 our own Equality, Diversity, and Inclusion (EDI) officer(s), a role that we will develop under the guidance from the ICRS EDI Subcommittee. The EDI officer(s) will help us to improve inclusiveness, champion equality for all, and support under-represented groups within coral reef science. As a Chapter, we understand that diversity strengthens our field, and we seek to make the coral reef community a supportive space where everyone is included. The major theme for the ICRS Student Chapter this year is *diversifying science through communication*, which we are implementing as follows:

Throughout the transition to the new committee, the editors of the ICRS student blog *Reefbites* (www.reefbites.com) (Sandra Schleier, Cassandra Wilson and outgoing member Maha Cziesielski) have not missed a beat. With new members Bobbie Renfro (post coordinator), Henrique Bravo (lead content creator), Paige Strudwick and Julia Briand (content creators) and writers Tim Bateman, Brad Allen, Carla Elliff, Danielle Moloney, Matthew Tietbohl, Sofía Pérez and Evan Quinter, *Reefbites* continues to take the latest in coral reef science and make it accessible for all audiences. This year so far, *Reefbites* posted 60 articles with 18,302 views from 11,186 visitors in 154 countries. New additions to the blog include science communication and coral-related webinars, blog article translation, more video content, features of coral reef research of non-profit organizations or marine laboratories around the world, and new collaborations. *Reefbites* welcomes new writers who share a passion for science storytelling and engaging the public audience with coral reef science.

Figure 2 : Recent bilingual Instagram posts (https://www.instagram.com/icrs.students/)

The ICRS student website, developed by longstanding member Emma Strand, will be launched early in 2021, with the help of our new Webmaster, Nicola Kriefall. The website showcases resources for international student researchers and promotes outreach, such as the postponed ICRS Student Workshop, now due to take place during ICRS2022. The workshop will create a network of coral reef science students and early career researchers for careers support, advice and guidance.

To connect with a greater diversity of researchers, our new network of translators will share broad cultural and linguistic backgrounds to translate *Reefbites* and social media content. The team; Gustavo Seichi (POR), Diana Carolina Vergara (ES-IT), Ana Grillo (POR-ES), Catalina Ramirez (ES), Hedwig Krawczyk (GER-POL), Nussaibah Raja (FR-GER), Selma Mezger (GER-ES), Rubén Niño (ES), Thomás Banha (POR), Francisco Gutierrez (ES), Gabriela Lopez (ES), Alexandra Lago (POR-FR), Luke O'Reilly (IRSH), Lorena Ramírez (ES-POR), Rama

Chandra (HIN), Daisy Flores (ES), and Sara Gagliardi (IT-FR) aim to make *Reefbites* and ICRS Student Chapter online content available in more languages. Aims for 2021 include expanding to include a broader variety of languages (including local dialects) to increase content accessibility.

The continuing expansion of the ICRS Students' social media following shows the need for a virtual space where reef-based students can network and communicate. We are enthusiastic to be leading this effort. @icrs.students Instagram account has been handed over from Carlos Carvajal Garcia to Rebecca (Bex) Turner, Gabriela (Gaby) López Carrasco and Nussaibah (Nuss) Raja-Schoob. @icrs.students communicates science to a wide audience on the Instagram platform, creating accessible video abstracts and multilingual posts. A major goal is to provide a multilingual translation of the pledges set by the ICRS. Currently @ICRS students Instagram content includes fun facts on corals (Fig. 2) and insights from different people involved in coral research and conservation, live Q&A's, and Insta takeovers, with guests from a range backgrounds providing different perspectives on coral research and conservation.

The @ICRSreefstudent Twitter account initiated in 2017 by Hannah Reich and Claire Lewis was passed in October 2020 to Rachel Alderdice, Katrina Munsterman, Danielle Nembhard, Luke O' Reilly, and Igor Pessoa. The aim is to share information about opportunities in coral reef sciences, disseminate and celebrate new publications by graduate student researchers and early career researchers, highlight research conducted by underrepresented groups in coral reef science, provide motivational posts and resources, and spark interest in coral reef science by posting facts that are easily accessible to diverse groups. In addition to highlighting work by other ICRS Student Chapter initiatives, the @ICRSreefstudents Twitter account provides original content representing a broad range of topics in coral reef science. Content is posted daily: Monday - Motivational post, Tuesday - Coral facts, Wednesday - highlighting resources, Thursday - showcasing lab groups, and Feature Fridays.

The establishment of our education and outreach initiative led by Rama Chandra Khandavilli, Ruben Niño, and Noelle Helder, will facilitate the development of educational materials, student workshops, seminars, and professional development opportunities. This includes writing 'how to' guides, sharing helpful tips for early career students, creating a careers information page on the ICRS students website, and developing peer-to-peer mentoring programs for ICRS attendees. . The aim is to provide open-source, reef-related educational resources that will support the launch of the ICRS Student Chapter website in 2021. Long-term plans include delivering workshops and webinars to create career development opportunities for students and early career researchers.

So, the Chapter has made huge progress, for which a huge "Thank You" to our outgoing committee members. We are enthusiastic to build upon your hard work and innovative ideas.

Jenny Mallon
University of Glasgow,
Scotland, UK

Morgan Short
NovaSE University,
Fort Lauderdale, Florida

Get involved with the chapter

instagram.com/icrs.students

twitter.com/ICRSreefstudent

This is the Welcome Page of the Mideast Chapter's most recent newsletter. To access all 12 pages please see below.

Mideast Coral Reef Society

Issue 10 Oct. 2020

Editorial

Welcome to Mideast Coral Reef Society's (MCRS) 10th newsletter! We hope that you are all managing during these challenging times. The global pandemic has affected all parts of the society and, along with the wider scientific community, MCRS members also have had to adapt to the new reality. Limited access to field sites and laboratories made practical work difficult. On the other hand, many of us learned new skills to keep the research going while working from home. Staying connected is certainly one of them and in the meantime everybody has mastered platforms like "Teams" and "Zoom". In fact, these new technologies are surprisingly helpful to build bridges over the barriers set by geographical distances and travel bans.

We would like to take the opportunity to facilitate the communication between MCRS members even further and introduce you to the MCRS Facebook page [https://www.facebook.com/MideastReefs] and the new MCRS email list-serv through which you have received this Newsletter. This list-serv is a moderated email platform intended to enable MCRS members to communicate topics within the remit of the MCRS (https://www.mideastcrs.org/) directly with the wider society. Please note that messages that fall outside of the society's framework will not be posted.

Staying with the topic of communication (p. 2-3), we have the pleasure in this newsletter to present an exciting report by Reem Al Mealla on "Scientific Stories" that bring regional science and conservation topics to a broad public audience via YouTube. Also, we highlight the special issue on "Reefs in marginal and extreme environments" that was recently published in "Coral Reefs". This special issue is again a great testimonial of the productivity of MCRCs members and their collaborators, showcasing the significance of regional coral communities for the global understanding of coral reef functioning.

On the following pages, MCRS members are providing scientific updates on four topic areas: **1) Fish:** We learn more about fascinating fish behavior, the effect of bleaching on fish communities and the link between herbivorous fish abundance and reef health in the contributions by Matthew Tietbohl, Mohammad Reza Shokri and Lucia Pombo-Ayora (p. 3-4). **2) Conservation:** We thank Daniel Mateos-Molina, Karine Kleinhaus and Liz Goergen and collaborators for reporting on coastal marine habitat mapping in the northwestern United Arab Emirates, on the efforts to protect the Red Sea's unique coral reef and on the first coral nursery in Qatar (p. 5-7.) **3) Stress:** We learn more about coral diseases in Persian/Arabian Gulf, the stability of host-symbiont association after bleaching in this region and a new experimental approach to map the coral thermal resilience in the contributions from Greta Aeby, Emily Howells and Chris Voolstra. We also report an incident of colourful coral bleaching in the Gulf (p. 7-9). **4) Mideast Reefs:** We are grateful to Mohadeseh Parsaiyan and Mohammadreza Shokri, Florian Roth, Eslam Osman and Remi Ketchum for introducing us to the coral reefs in Hengam Island, the role of benthic pioneers communities in energy and nutrient dynamics, the microbiomes of corals in the northern Red Sea and the population genomics of Echinometra urchins in northeastern Arabia (p. 10-12).

We hope you enjoy the newsletter! Stay safe!

Prof. J. Burt

Prof J. Wiedenmann

The MCRS Initiative is jointly hosted by the New York University Abu Dhabi and the University of Southampton.

Our Goals

- Promote collaboration among researchers
- Promote Knowledge Exchange with stakeholders outside academia
- Generate a deep understanding of Middle Eastern coral ecosystems
- Promote their conservation and sustainable use

Inside this issue:

Join us!

Become a MCRS member and subscribe to receive the newsletter by sending an email to:

joerg.wiedenmann@noc.soton.ac.uk

We welcome contributions about meetings and conferences relevant to the Mideast Coral Reef Society (MCRS), as well as outreach events and links to recent publications.

Follow the MCRS on Facebook: https://www.facebook.com/MideastReefs

REEF PERSPECTIVES

Baselines still shift, reefs still degrade, most of us don't really care.

Is there a future that includes coral reefs?

Peter F Sale, sale@uwindsor.ca
University of Windsor, Canada

A degraded reef at Lizard Island, Northern Great Barrier Reef, Australia. Photo by Tim Gordon, University of Exeter, on EurekAlert (AAAS).

Shifting Baselines and Reef Decline

In 1995, in a one-page comment in *Trends in Ecology and Evolution*, Daniel Pauly coined the term shifting baseline syndrome. He defined it with reference to fisheries science and fisheries management. In his words, "each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the beginning of their careers, and uses this to evaluate changes. When the next generation starts its career, the stocks have further declined, but it is the stocks at that time that serve as a new baseline. The result obviously is a gradual shift of the baseline, a gradual accommodation of the creeping disappearance of resource species…" Jeremy Jackson subsequently took up the torch, expanding the meaning beyond fisheries science to coral reefs (Jackson 1997) and then to all our perceptions of decline in the natural world (Jackson 2001, Jackson et al. 2001). We are just not that good at detecting changes which occur slowly over long periods of time, even when, as scientists, we collect quantitative data able to reveal the trends. Overfishing, pollution and mismanagement of coastal and inshore development were degrading coral reefs in many places around the world well before modern reef ecology commenced in the 1950s. And I can state as fact, that until the 1990s, most of us doing ecological research on reefs were blissfully unaware and uncurious about this process of loss. That is, we all knew of places with exceptional degradation, but we assumed the default condition of most of the reefs we studied was close to 'pristine'.

> We assumed the default condition of most of the reefs we studied was close to 'pristine'.

In 1985, at the 5th International Coral Reef Symposium held in Tahiti, I remember hearing Peter Glynn speak on the first mass bleaching of corals along the Pacific coast of Panama and in the Galapagos in 1982-83 (Glynn 1985). He had published the first account a year earlier (Glynn 1984). During that event, coral cover in the Galapagos was reduced by about 97%. It has never recovered except at the northern Darwin and Wenman islands. This bleaching, and the die-off of *Diadema antillarum* across the Caribbean about a year later (Lessios et al. 1984), both made impressions on me, but I and many other ecologists saw these as one-off regional events. It was not till 1997-98 during the then strongest El Niño on record, when reefs bleached around the world, in many places for the first time ever, that most of us finally realized something serious was happening.

In April 1999, in Fort Lauderdale, the newly formed National Coral Reef Institute hosted the International Conference on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration. It was smaller than the Tahiti ICRS with only a few hundred people attending, and while I remember the conference, I remember little about it, including the content of my own paper. Only a few of the papers presented were subsequently published but going through these it's interesting to see what was preoccupying us and what was not. Sally Yozell, then Deputy Assistant Secretary for Oceans and Atmosphere at NOAA gave the keynote. It was a typical administrator's report summarizing recent actions by the US government to support coral reef science and management, including the formation in 1998 of the US Coral Reef Task Force. But nowhere does her text include the word 'climate.'

The one paper I remember at that conference was by Bob Buddemeier, titled simply, "Is it time to give up?" (Buddemeier 2001). His thesis was that coral reefs were already well on the way to elimination from the planet. Overviewing factors like warming, acidification, human population growth, nutrient pollution and so on he concluded: "The idea that reef conditions of the mid-20th century are a feasible goal [for reef conservation] is a very dangerous myth."

Buddemeier explicitly advocated use of triage, deciding objectively which reef regions are worth the effort to conserve. Many of us thought he was identifying some important and worrying trends, but we also thought he was exaggerating – it hasn't come to triage yet!

I remember very clearly the conversations at the conference. Whether at poster sessions, social events or lunchtime, these centered on the recently completed circumtropical bleaching event. But while we were concerned at the enormity of the damage done, we were also buoyed by optimism that an event this conspicuous and global would surely be the wake-up call the world needed to get busy on climate change. We began to think proudly of coral reefs as the canaries that would save us all from climate change.

Australian Reef Research Fifty Years Ago

But I'm getting ahead of myself. Let's briefly remember the state of Australian reef research when I arrived there in 1968. To call it limited is an understatement. The Great Barrier Reef was unprotected and under-used. There was just one "research facility" along its whole length, the Heron Island Research Station, owned and operated by the Great Barrier Reef Committee (now the Australian Coral Reef Society). Now a part of the University of Queensland and far more impressive, the Heron Island station was established as a basic field facility in 1952, and the Australian reef research community was small enough that we could all enjoy a meal together in that research station's small dining room, if we were so inclined (Figure 1).

None of us thought that reefs were globally under extreme threat. Our research dealt with many aspects of how these mind-bogglingly complex ecosystems were put together and functioned. We were all having a ball being paid to play on coral reefs while asking intellectually challenging questions. Of course, there was some science and a lot of heat and smoke coming out of Brisbane concerning the crown-of-thorns starfish, seen by some as a devilish rogue species that was going to wipe out the entire GBR. But even the crown-of-thorns concern was considered a problem for the GBR rather than for reefs globally. We didn't see it as part of a worrying global trend. Indeed, many of us saw the starfish as not much more than a great device for generating research funds, and (along with the threat of oil exploration) it did help kick off the enormous growth in funding for reef science and management that took place in Australia starting in the early 1970s. This story is well told in Bowen and Bowen (2002).

By the mid-1970s all coral reef scientists knew there were degraded reefs in some parts of the world. We knew there were conservation challenges. We knew reefs were far more valuable economically than was generally acknowledged, but mostly we worked on interesting questions about the functioning of reef ecosystems, and mostly we avoided working on reefs in decline. The 1970s and

Figure 1. In 1970, wallabies (three of them) were as abundant as scientists at the Heron Island Research Station, and the modest kitchen/dining building could have comfortably accommodated the entire Australian reef research community, if we'd coordinated to all be there at one time. Come to think of it, we could all ride round the island together on the aging station tractor and trailer. Photos © P. Sale.

1980s were a time in Australia of rapid growth in size and competence of the reef research community, coupled with an equally stunning growth in management/conservation capacity. Yet still we did not concern ourselves with the global threats to reefs.

The report of the first mass bleaching off Panama and in the Galapagos in 1982, which was followed by the mass die-off of Diadema throughout the Caribbean, began the process of waking us up. My own awakening commenced with my first research trip to the Caribbean in 1984 where I saw reefs in much sorrier state than those on the GBR. The contrast, to my eyes, was particularly sharp because I flew to the Caribbean just one week after returning from a trip to the Swains, in which over eight days we saw perhaps two other vessels on the horizon and hundreds of kilometers of reef slope. Naturally, I concluded that there was only a Caribbean rather than a global reef problem. My awakening was completed at that 1999 conference.

Why Did Reef Scientists Fail to See Global Reef Decline

Why did we scientists not see sooner what was happening? Shifting baselines account for scientists' failure to see. The central ecological paradigm of the 1970s and 1980s was niche theory, and the balance of nature was a widely accepted belief. Sure, there were active researchers who argued against the circularity of much of the research being done (Peters 1976, 1991; Hubbell 2001), including earlier Australian ecologists Andrewartha and Birch (1954). But niche theory, despite its expectations and assumptions of closed systems and stationarity was then, and remains still, the unspoken default whenever ecologists think about their science. While ecologists often assumed stability, stationarity itself means there are no important temporal trends in conditions, and if you assume stationarity in the structure of an ecological system, time becomes unimportant, and you fail even to look for patterns of change through time.

> Why did we scientists not see sooner what was happening? Shifting baselines account for scientists' failure to see.

Those who studied ecology of coral reef systems in the 1970s and 1980s mostly didn't look for long-term trends in richness, abundance, coral cover or other metrics. Not until the evidence became dramatic and global. Now, of course, the pattern of reef degradation (I should say patterns, because there are different causes and trajectories around the globe) is so evident to us that it sometimes seems that scarcely any research is being done that does not claim to be about this trend and how to reverse it. Thinking about how we mostly failed to see what was happening for so long reminds me of Canadian communications guru, Marshall McLuhan, who said, "If I had not believed it, I never would have seen it."

Why Don't Other People Care About Coral Reefs?

Contrary to our expectations at that 1999 conference, coral reefs did not become canaries, and the world did not awaken to what was happening. So, why don't the majority of people care about what is happening on coral reefs?

I need to explain that statement first, because many will say reef decline is often in the news, and reef decline has been effectively introduced into discussions of the global environmental crisis. Both those points are true, and many reef researchers have played important roles in getting the plight of reefs recognized. But when I say most people don't give a damn, I mean they see reef decline as just another sad nature story, something to think about briefly, before getting on with their lives. Why is this the case? It comes down to three things: Messaging, denialism, and what Canadian psychologist Robert Gifford calls our seven dragons of inaction (Gifford 2011).

Despite efforts of a few gifted individuals, scientists' messaging concerning human impacts on coral reefs, including, but not only, global warming, has been poor. Randy Olson (Olson 2018, 2019) has pointed out that we scientists mostly are not very capable communicators, and we often provide complex, confusing, or boring messages, that are all easily forgotten (Figure 2).

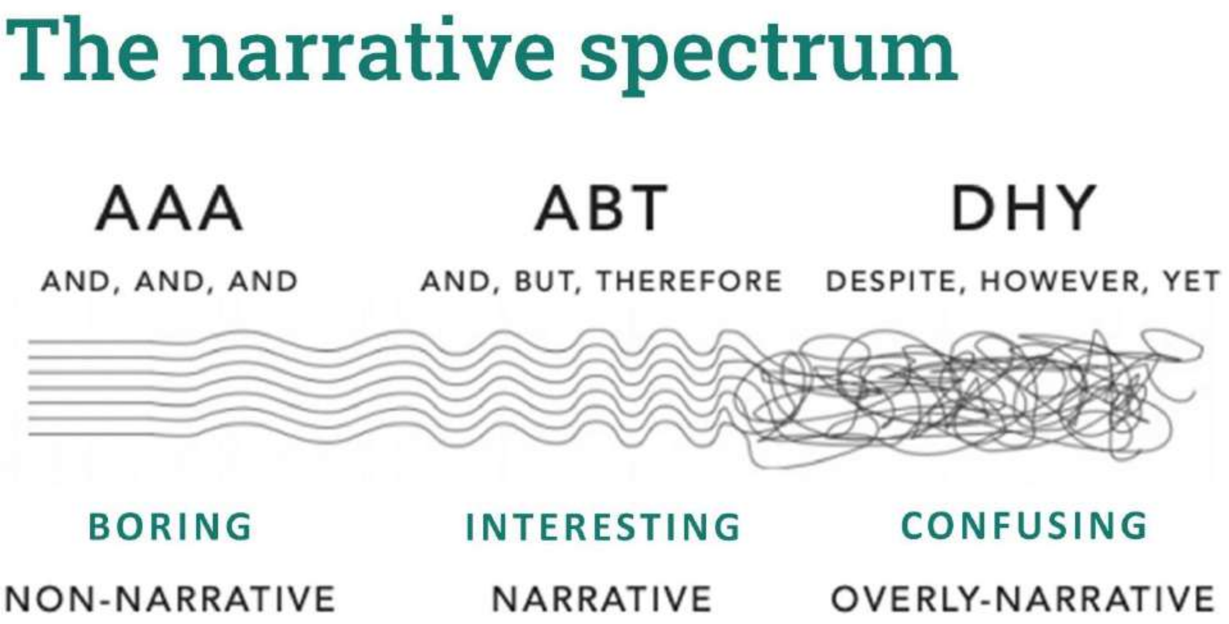


Figure 2. Randy Olson has discussed the narrative spectrum, making the painful (to scientists) point that scientists tend towards the AAA end of the spectrum in their writing and oral presentations, while a few of us go to the other extreme DHY end. Relatively few of us manage to hit the ABT, interesting middle, yet it is messages with an ABT structure that most engage audiences. Image © R. Olson, used with permission.

We could be doing a much better job. Many journalists have cheapened investigative journalism by simply grabbing one voice from each side of any opinion, regardless of the credibility of the source; the overwhelming agreement on the reality of climate warming can be countered by the disbelief of a single opposing voice. And the public (because of the general failure to teach critical thinking skills) is poorly equipped to evaluate the messages delivered. Given that coral reef messages almost invariably are accompanied by beautiful images of coral reefs even when reporting degradation, the public downplays the significance of what the messages are trying to communicate – that reefs are becoming a lot less beautiful. (It's particularly ironic that some images of newly bleached reefs have an ethereal beauty that the uninitiated cannot see past.)

Particularly when it comes to climate change, powerful vested interests have been providing, since the 1970s, a coordinated program of denialism which feeds into and muddies the messages being delivered. This at least loosely coordinated program is global and was well described by Oreskes and Conway (2011). I understand that significant numbers of politicians of the three major political parties in Australia have been so well supported by the fossil fuel industry over the years that they now cannot imagine a future time when fossil fuels will no longer be used. Of course, Australia must mine and export its fossil fuel reserves! Just as Canada must mine and export its tar sands bitumen. Countries have a moral imperative to use their natural resources! For most people, such views, delivered with straight faces, are effective counters to the dire claims from the science community.

Our dragons of inaction (Gifford 2011) are a group of psychological quirks that determine how we respond to messages received by our sensory system. Surprise, surprise, we do not respond to messages by carefully evaluating the evidence and making rational decisions. Robert Gifford has grouped the quirks into seven dragons, each of which impedes rational responses. His seven dragons can be reduced to the claim that we have evolved to jump out of the way of sabre-toothed cats, not to plan ahead to avoid slowly encroaching sea level rise. And to the fact that we are more willing to believe someone from our own tribe than someone from away, even if the person from away is patently better informed. But these quirks are real, and communicators must find ways of dealing with them if they want to be understood. Scientists delude themselves when they assume that delivering the facts is all that is needed.

Social media have been wonderful in bringing us together in new ways and putting information at our fingertips. However, it seems to me they have also heightened tribalism and the erosion of critical thinking to the extent that, for all intents and purposes, there really are alternative facts from which most of us pick and choose. They give our psychological dragons free reign.

Add these dragons to the denialism and the failures of communication and it is hardly surprising that acting on climate change has been a tough sell. When it comes to coral reefs, those of us who live and breathe reef research, management and conservation, need to remember that reefs are part of the Other. Most people on the planet have never seen a coral reef, could not tell a degraded one from a pristine one, and do not see reefs as an important part of their lives. Why give a damn about reefs when I need to worry about the rent, my job, getting my kids through their teenage years, and whether I still have more friends than enemies on Facebook? In a world where most of us, for one reason or another, cannot conceive of anything terminally bad happening to us, reports about the decline and future disappearance of coral reefs seem of only minor importance. So far covid-19 does not appear to be changing our faith in our own bright futures despite the mounting evidence of Anthropocene horror around us.

Reef Science and Retaining Reefs into the Future

Is there a way to ensure coral reefs will be with us into the next century? Science tells us the window of opportunity for salvaging them is vanishingly small and absolutely requires that concentrations of greenhouse gases are reduced in the atmosphere. In 2018, notably conservative IPCC reported that if we succeeded in keeping global warming to an average of 2.0oC, 99% of coral reefs will be lost by 2100, but that if we kept warming to 1.5oC, 95% of coral reefs are still likely to be lost (IPCC 2018). If we are to retain any coral reefs through the end of this century, we need to move back towards an atmospheric CO_2 concentration of 350 ppm or lower, while we also do a lot of other things to ease our local impacts – overfishing, overuse by tourism, pollution, inappropriate development of coasts and coastal waters – local issues we have known about for decades. It's a huge task, but one we should feel morally obligated to tackle in earnest.

The good news is that we know what the problems are, and we already have the means to correct them. New technologies will certainly be developed and will make our ability to correct these problems more powerful; we need no new technologies to bring positive change to coral reefs if we have the will to act. However, new, deeper understanding of how coral reefs function is likely needed if we are to be able to sustain reefs as climate change continues to threaten them. Paradoxically, this need promises some exciting opportunities in reef science in coming decades.

The task of wrestling climate change to the ground is immense, and it won't happen by accident. I am now convinced that the most difficult part of that task is going to be the need to radically revise our worldviews, especially in how we see ourselves relative to the rest of the biosphere. Substantial numbers of us must come to recognize the importance of a Holocene-like biosphere – a world much like it has been until recently - as essential to the future of the human experiment. Otherwise, we will take token steps to correct problems while continuing our path through an Anthropocene in which conditions continually worsen for us and coincidentally for reefs. Baselines will continue to slip and coral reefs will all disappear.

The challenge of nurturing coral reefs through the valley of doom also requires that we must upgrade our understanding of what conservation entails. The sad truth is, we will never succeed in efforts to restore coral reefs to the way they were in the 1950s, because the environment of the past is gone. We are going to have to conserve by assisting reefs to evolve in ways that are adaptive in the Anthropocene world we are creating. That conservation will include re-wilding – we need undisturbed, wild reefs. But it will also include assisted evolution and assisted migration, helping coral reef ecosystems to continue to be rich, productive, bizarrely unexpected oases of high biological and economic value in tropical coastal seas as the environment changes around them. The current enthusiasm for reef restoration suggests there is a pool of worthy people ready and willing to shoulder the tasks involved, but they need to be guided towards tasks with some hope of materially improving the odds for reefs. Growing nubbins of fast-growing, branching corals in 'nurseries', and setting them out on reefs to be hit by diseases or killed by bleaching, merely diverts effort from activities that could help sustain reefs.

In addition to adopting new goals for reef conservation, we will have to recognize, and fill in, the enormous gaps that remain in our understanding of how coral reefs function as hypercomplex ecosystems. We have learned a lot about reef ecology over the past century (the Royal Society GBR Expedition to Low Isles was in 1928-1929), but we have much further to go. We'll know we have arrived when we cease to consider a stable, ecological equilibrium, with high coral cover and oodles of other species present, as the default state for coral reefs.

We will have to develop new, far more complex ecological models than the simple three-or-four component, linear-response models that have characterized most ecological modelling, and build new, richer concepts of ecosystem resilience, persistence and state. In short, reef ecology must embrace the non-linear, non-equilibrial, real world with its phase shifts, non-reversible pathways, and second-, third- and higher-order interactions among species in an environment that is itself undergoing continuing change. Expanding and deepening our ecological understanding of coral reef systems also will require that ecologists continue to embrace those many other fields of study – from taxonomy to molecular genetics to the physiological dynamics of the coral microbiome, to approaches of many kinds to the rich interspecific, even cross-phylum interactions that organize reef systems. In short, reef ecology needs to become ever more interdisciplinary, and far more intellectually sophisticated, while also becoming much less taxon-specific: reef ecology rather than coral ecology or fish ecology.

There are some gratifying signs that these transitions are now beginning in reef ecology. The special topic issue of Functional Ecology in 2019 (Williams and Graham 2019, plus seven associated papers) provides entry to this discussion of the new science needed if we are to steer coral reefs successfully through the Anthropocene. Paradoxically, the degradation of coral reefs seems nevertheless likely to spawn an intellectually vigorous future for coral reef science, as the reef science community strives to retain them. Naturally, I hope that reef scientists can retain the joy of working with these exuberantly magnificent examples of just what evolution can produce, and that efforts to conserve coral reefs are ultimately successful. ▸

About the author | Peter Sale is a marine ecologist and worked primarily on reef fish ecology and on management of coral reefs. He is Professor Emeritus at University of Windsor.

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REEF PERSPECTIVES

Science for reef survival

The evolution of the International Coral Reef Society

A compilation of contributions from Rolf Bak[1], Charles Birkeland, Barbara Brown, Terry Done, Richard Dunne, Daphne Fautin, Betsy Gladfelter, John Ogden, Rupert Ormond, Nick Polunin, Robert Richmond, Caroline Rogers, Brian Rosen and Peter Sale, edited by Sue Wells

Introduction

Just over forty years ago, in December 1980, the International Society for Reef Studies (ISRS) was launched at a conference on the theme of "Reefs: past and present" at Churchill College, Cambridge, UK - a location thousands of kilometres from a living reef and indeed a long way from the ocean. This birthplace nevertheless was appropriate, given the long tradition of reef research at the University of Cambridge. Charles Darwin was first a student and then lived at Cambridge for two years on his return from the *Beagle* voyage (1831-36) while he sorted out his scientific collections (fig. 1) - his seminal monograph on reefs was published in 1842. Stanley Gardiner, who helped to lay the foundations of modern coral reef science in the UK (Brown, 2007), was also a student and subsequently Chair of the Zoology Department (1909-1937)[2]. Numerous Cambridge students and researchers have studied reefs in more recent times.

The first elected officers of ISRS were David Stoddart (then in the Geography Department at Cambridge) as President, Peter Spencer-Davies (Glasgow University – formerly home to Sir Maurice Yonge, who led the first modern scientific work on the Great Barrier Reef) as Treasurer and Barbara Brown (University of Newcastle) as Secretary. The aims of the Society were to co-ordinate and promote coral reef research, primarily through publication of a peer-reviewed journal (*Coral Reefs*) and by holding meetings and conferences. The idea for the Society arose in the mid-1970s, as reef scientists were finding it increasingly difficult to fund their research or even have their discipline taken seriously. Then, as perhaps now, working on coral reefs sounded too much like a holiday.

Figure 1. The house where Charles Darwin lived in Fitzwilliam Street, Cambridge, on return from the Beagle expedition.

From 1971-1980, David Stoddart led the Coral Reef Committee of the International Association of Biological Oceanographers (IABO) which organized the quadrennial international coral reef symposia that had started in 1969. He spear-headed an initiative to find more funding and promote greater collaboration and focus for British reef scientists that led to the establishment of a Working Party and a series of discussions and meetings, involving over a dozen reef scientists, at Churchill College, Cambridge. One recommendation from these deliberations was for the establishment of an international society which, following wider discussion, was born at the 1980 meeting.

Subsequent meetings were held to discuss the name and remit of the Society, and particularly whether fossil reefs should be included. The original name - International Society for Reef Studies – was chosen

[1] Contributors are listed in alphabetical order
[2] Current reef students and interns may be interested to know that they follow in a sound tradition of providing free labour in the cause of reef science. In her account, Barbara Brown quotes the conditions laid out for Gardiner's participation in the UK's Royal Society's expedition to the Pacific in 1896: "Mr. S. Gardiner will accompany the Expedition as a volunteer with the sanction of the Committee, paying his own expenses and selecting his own subjects for study, with the general understanding that he will lend such aid as may be in his power to Professor Sollas ….".

to signal that the society was primarily research-oriented, and aimed at attracting not only ***coral*** reef scientists, but also those working on other types of reefs. The change of name to the International Coral Reef Society, by referendum at the end of 2018, was regretted by some but reflected the fact that only a few, if any, *non-coral* reef researchers were by then members. The older name did not appeal to the growing number of coral reef scientists who see that the Society needs to be active in fields beyond research, if reef survival is to be secured for the future.

Early struggles to build membership

Like all initiatives dependent on good will and voluntary effort, the Society has had its ups and downs. With its UK roots, the Society was founded under UK charity law in order to secure tax advantages and, as a result, annual general meetings (AGMs) were a requirement. These were combined with scientific meetings, designed to increase membership and international interest in reef research and to solicit papers for the journal. The 1980 Cambridge meeting, well lubricated with quality wines liberated by David Stoddart from his university college cellar, was followed by a second in 1981, held courtesy of Rupert Ormond, at the University of York, UK. In those early years, David Stoddart provided a unique convening energy that contributed hugely to bringing people together from all over the world. Bob Richmond (the Society's President some 30 years later) recalls his first ICRS meeting in Miami in 1977 and "*being awestruck by this impressive individual standing on a table with a pitcher of beer in one hand, providing a booming oratory - and learning it was David Stoddart.*"

The following years saw ISRS annual meetings in numerous locations and the introduction of regional meetings, which allowed scientists to meet regularly at lower individual cost. In 1984, when Ian Macintyre (Smithsonian Institution, USA) was elected President, the Society had about 250 members. Membership continued to hover in the low hundreds well into the early-1990s. The Society had no formal link with the quadrennial coral reef symposia which might have driven an increase. *Coral Reefs*, as a fledgling journal, received few manuscript submissions, and a subscription to it was a low priority for many researchers. The internet had not been invented, and e-mail did not exist for most people, making communication among members of Council, the executive, and the Society as a whole limited. Barbara Brown remembers only too well the hard work involved: "*.. typing and posting letters out to potential members, organising AGMs and annual meetings in the UK and Europe (I even had my parents licking envelopes!) ….*".. Stationery and postage stamps also made communication costly.

> The internet had not been invented, and e-mail did not exist for most people, making communication among members of Council, the executive, and the Society as a whole limited

There was a constant struggle to make ends meet. The task of Treasurer is always difficult in a membership body of this nature. Rolf Bak recollects that, in the mid-1980s when David Stoddart informed him at the ISRS meeting in Marburg - in the corridor, such was the informal nature of Society business then - that he was to become the next Treasurer, he had no idea of what he was letting himself in for. "*As I found out soon, ISRS was going bankrupt. … Council members started to recruit new members to help but, alas this only increased my worries. Individual membership fees were well below the cost that Springer* [the publisher producing the journal] *was charging the Society each time a new member was recruited.*"

Presidents (see Fig. 2) and elected officers found themselves stepping well beyond their normal research routines to keep the Society going. Peter Sale, who took on the Presidency in 1989, having moved from Australia to North America, where he was based far from any reefs at an institution with little tropical marine exposure, rapidly appreciated the financial problems. Peter included his e-mail address in his presidential remarks for the December 1991 *Reef Encounter*, and pleaded for members to do likewise, so postage costs could be trimmed. Grasping at any opportunity, while attending the XVII Pacific Science Congress in 1991, he commissioned the printing of T-shirts promoting the Society, which he peddled during coffee breaks and poster sessions. He then had to buy an additional suitcase to take the unsold shirts home, to sell to members at subsequent meetings,

Vaughan's Ruler – *extract from Reef Encounter*

Thomas Wayland Vaughan was a geologist and coral taxonomist who worked at the Smithsonian Institution in Washington, D.C., in the early decades of the 20th Century. The Society's second president, Ian Macintyre, discovered the ruler with 'Vaughan' written in ink on the back. He donated it to the Society during his term as President, and it has been passed on to his successors. The plaque is inscribed with their names. Photo shows Terry Done with the ruler.

although many ended up as student prizes – sales recouped the cost, but made little profit for the fledgling society. Society souvenirs have seldom been a successful money-maker.

Figure 2. A cluster of past ISRS Presidents – from left to right: Peter Sale, Ian Macintyre, Bernard Salvat, John Ogden, Chuck Birkeland and David Stoddart

Daphne Fautin (Treasurer from Jan 1992 to Dec 2000) and Bernard Salvat as President ensured the Society's survival at that point. John Ogden remembers[3]: *"In early 1992 we were very loosely organized under an outdated Constitution. The election of that year was challenged on several grounds, creating a constitutional crisis which was resolved by our leadership, who directed the drafting of a new Constitution"*. Daphne and Bob Buddemeier (by then her husband – they met each other at the second ICRS in 1973!) led this revision which was adopted at the Vienna AGM in 1993.

[3] President's message, *Reef Encounter* 17, April 1995

There was also a highly proactive recruitment of new members, with Daphne and Bernard fearless about ensuring members renewed their subscriptions. With the increase in membership in the USA, in 1995, the Society was registered as a US non-profit organisation[4], and approved by the US Internal Revenue Service as a tax-exempt organization[5]. This also meant that there was now no requirement for the AGMs which were proving a major obstacle and expense. Council meetings were of course still important to keep the Society running, although for many years, they were few given the cost.

By the mid-1990s, membership had reached almost 700 but Society officers were still putting in a huge amount of effort. During the quadrennial symposia, Council members would take it in turns throughout the entire meeting to sit at the Society's desk to recruit new members, offering incentives where they could. In 2000, at the Bali ICRS, Carden Wallace donated a copy of her *Acropora* field guide to anyone who enrolled – that year membership reached 1000. John Ware took over as Treasurer from Daphne, and worked with three different presidents, becoming a great source of knowledge for the Society as a whole. Along the way, he produced one of the Society's most popular sales items, still in use with some older members: a mug decorated with a coral that disappears when a hot drink is added (Fig. 3).

[4] Initially the Society was registered, unusually, with the US Federal Government only; this limited its ability to apply for certain funds and so, in 2019, it was also registered with the state of Florida.
[5] The Society's UK tax-exempt status subsequently lapsed which, in retrospect, has been regretted.

Figure 3. The "bleaching coral" mug produced as a souvenir for members and ICRS conference delegates. The coral and fish visible inside the logo (above) disappear when a hot drink is added (below).

Nevertheless, when Bob Richmond took on the Presidency in January 2012, with Don Potts as Treasurer, once again insolvency was close and membership had dropped to about 500. Allen Press, a small and efficient US marketing and publishing company, was running the Society's business as well as the logistics of distribution of the journal (still printed by Springer). With the support of the Council, these tasks were moved to the Schneider Group (SG), on the recommendation of the leadership of the Association for the Science of Limnology and Oceanography. Rupert Ormond came up with a new membership fee structure to encourage students and those from developing countries to join and further revisions were made to the constitution to address sustainability; by the end of ICRS13 in Hawaii in 2016, the Society had almost 2000 members.

Under Ruth Gates' presidency, a further revision of the constitution included a change that allowed on-line video meetings of Council, which are now routine, along with online voting. The first website had been launched in about 2005 and, following a competition for a new logo, this was updated and revised in 2020. Membership is now over 2000, although there are always fluctuations, with significant increases at the time of the symposia when members are offered reduced registration fees.

The journal Coral Reefs

In 1981, over a feast of roast goose and ample wines, David Stoddart and Konrad Springer (doyen of the Springer publishing house) finalised the idea for the journal *Coral Reefs* as a joint venture between the Society and Springer-Verlag. There had been earlier concerns among some members as to whether Springer would be the best choice, given its relatively high costs and a perceived lack of flexibility. Nevertheless, the first volume was published in 1982 with David Stoddart as Co-ordinating Editor, Peter Spencer Davies as Liaison Editor, Ian Macintyre as Geological Editor, and Yossi Loya as Biological Editor, assisted by a team of 20 Advisory Editors. The journal had teething troubles: Springer had limits on the size of issues; there were long delays in publication of accepted papers; few universities subscribed; there was little incentive to promote the journal as it was not generating income for the Society; and the impact factor was initially low, so that people were reluctant to submit their best papers.

In 1995, with Bernard Salvat, Daphne Fautin agreed to a revised contract with Springer with what were thought by some to be better financial terms for the Society. With John Ogden as President, the new publication arrangements were finalized by Daphne in September 1996[6]; as John Ogden recollects: "*I carried her luggage to the meeting in Berlin and she took it from there*". Although in 1992, *Coral Reefs* had been listed the very top of the 56 journals in the marine and freshwater section of the Science Citation Index, throughout the rest of the 1990s it had a fluctuating but generally low impact factor. In 2004/5 then President Nick Polunin, an experienced editor of his own journal, recognized that *Coral Reefs* needed to be brought into the 21st century. The newly appointed Editor in Chief, Barbara Brown, was tasked with achieving this together with her husband Richard Dunne. Over the following year a new electronic manuscript submission system was implemented, and Springer agreed to greater financial support, the removal of colour printing charges, a large increase in the journal size, and a free open access paper per issue. Combined with a revamped editorial team, this led to much shorter publication times.

[6] President's message, *Reef Encounter* 20, March 1997

In 2008, with the system running smoothly, Rolf Bak and Betsy Gladfelter took over, and ran a tight ship; they had direct contact with all authors and editors, and were able to help many researchers get their papers into print. The journal then passed to Howard Lasker in 2013 who, with Don Potts and Bob Richmond, played a major role in yet further negotiations with Springer to try and resolve the on-going financial issues. By this stage, suggestions were being made for a new journal with the copyright owned by the Society, as there were options with other publishers for a better share of profits. Ultimately, Springer made changes that made it worthwhile to stay, although many of those who have lived through this often painful publishing relationship feel that, in retrospect, other options might have proved preferable. Nevertheless, the journal started to become a first port of call for coral reef papers, and the impact factor rose steadily, and now fluctuates at around 3 (see Fig. 4). *Coral Reefs* has established its scientific pre-eminence, and a survey carried out by the current Council in 2020 showed that the membership clearly think that it is the best journal to submit their work to.

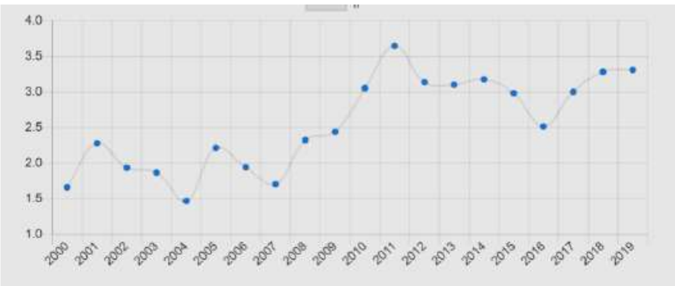

Figure 4. *Coral Reefs* two-year impact factor trend (https://www.scijournal.org/impact-factor-of-coral-reefs.shtml)

The Society and the international quadrennial symposia

The need to formalize links between the Society and the Symposia was an early concern, given that the same players were involved in each process. David Stoddart had always felt that ultimately the Society should run these events but this was not as straight forward as it might have seemed. Barbara Brown remembers drafting several proposals to IABO and the ICSU (International Council for Scientific Unions), but progress was slow. Peter Sale recounts how, at the Tahiti ICRS in 1985, the same individuals dutifully put on their IABO hats to discuss the conference, and then put on their ISRS hats for the AGM, creating a somewhat surreal situation with the separate structures preventing people discussing issues, even with themselves. Nevertheless, ISRS played an important role in the earlier Symposia, essentially as co-host.

Terry Done remembers the work involved, as the Society's president, helping to organise the 9th ICRS in Bali. This was in 2000, coinciding with the East Timor conflict, which made communications and planning with Indonesia, the host country, particularly difficult. Extensive efforts on the part of the Society's officers nevertheless ensured that the conference could take place and everyone assembled at the venue. However, Terry's and the organizers' problems had not ended. News came through of a terrorist threat to the conference itself, with the suggestion that scientists from, or associated with, Israel should not enter the country for their safety. Everyone in that category had in fact arrived; it was the weekend; and, to complicate matters, Terry was to present Israel's best-known coral reef researcher, Yossi Loya, with his Darwin Medal. ISRS officers worked over the weekend, finding suitable contacts to assess the situation and the risks. In the event, the conference passed peacefully, with Terry taking the opportunity to drive home the other global threat that was beginning to occupy everyone "*… I gave my opening speech, throwing in a bit about how much fossil fuel we had all burnt getting here, and how many tonnes of carbon we had added to the atmosphere. Climate change had arrived bigtime, after barely getting a look-in at earlier ICRS meetings.*"

It was not until 2012 that it was felt appropriate for the now much more mature and internationally representative Society to take on full responsibility for the Symposia. Part of the financial rescue plan put together at that time was to have ISRS "own" the Coral Reef Symposia, and run them by SG, which also had the expertise to run large international meetings. Discussions were held at the Cairns ICRS in 2012 and, thanks to the persistence of Bob Richmond, then ISRS President, and the members of the IABO coral reef committee, by the time of the Hawaii ICRS13 in 2016, the Society was taking the lead. This ICRS resulted in a sound financial basis for the Society, and the largest conference to date (over 2,400 attendees from 104 countries). This of course does not necessarily mean that the quadrennial symposia go smoothly, as the current Conference Convenor Christian Wild and Society officers are finding, as they struggle with the ever evolving complications of the Covid-19 virus pandemic and the postponement of major events.

Promoting reef research – scholarships and awards

Since its foundation, the Society has considered an awards system as a key mechanism for promoting excellence in research. The most prestigious award is the Darwin Medal, awarded once every four years to a senior Society member who is recognized worldwide for major scientific contributions throughout their career. It is named of course in recognition of Charles Darwin's contribution to reef science (and is not to be confused with the more recently popular tongue-in-cheek Darwin awards[7]). There have been nine medallists to date: David Stoddart (1988), Peter Glynn (1992), Ian MacIntyre (1996), Yossi Loya (2000), Charlie Veron (2004), Terry Hughes (2008), Jeremy Jackson (2012), John Randall (2016) and Nancy Knowlton (2020). Since 1987, a much valued award has been the Best Paper Award, awarded to the authors of the best scientific paper in *Coral Reefs* for the calendar year, as determined by the journal's editors; winners can be seen on the ICRS website[8].

Under the original byelaws, the class of lifetime Honorary Membership was established to honour retired senior scientists who have made outstanding contributions to their field and/or ISRS. Over time some 16 Honorary Members were elected (in 1981, Harry Ladd, Sir (Charles) Maurice Yonge, and Francisco Nemenzo; in 1985, Raymond Fosberg, Siro Kawaguti, and John Wells; in 1987, Georg and Annelise Scheer; in 1992, Joseph Connell and Joshua Tracey; and subsequently, David Stoddart, Jack Randall, Ian Macintyre, Gray Multer, Bob Ginsburg and Don Kinsey)[9], all of whom have sadly passed on. With the development of a wider range of awards, this category has been revived with slightly different criteria (members/individuals who have rendered special service to the society or otherwise distinguished themselves in the field of reef science) and in 2019 Prince Albert of Monaco was awarded Honorary Membership.

In 2015, the more secure funding base of the Society allowed the expansion of the awards system to reflect the achievements of the many reef scientists at different career stages. These include an Eminence-in-Research Award (for senior researchers), a Mid-Career Scientist Award, an Early-Career Award (for those with no more than 6 years post-PhD experience), and a World Reef Award (for scientific or conservation achievements by an individual from a minority group within the Society). The category of ICRS Fellow was introduced to recognise scientific achievement and/or service to reef conservation or management and/or service to the Society over a significant period of time; it may be awarded to up to 15% of members and the long list can be seen on the website. More recently, the Coral Reef Conservation Award was added, in recognition of a regionally or globally significant contribution to the protection of coral reefs, and the Science Communication Fellowship, for an ICRS member at any career stage in any type of position wanting to gain science communication skills.

The Society has also always had ambitions to promote research opportunities, conference participation and exchange visits for young scientists and students. In 1996, John Ogden found philanthropic funding for what was initially called the ISRS Sollins Coral Reef Ecosystem Fellowship[10]. With further funding, this evolved into the series of Graduate Fellowships which are offered to graduate students to assist with fieldwork or laboratory expenses; six are now available annually, with at least half awarded to students from low-income countries. Gray Multer was instrumental in setting up the ISRS Student Travel Award Programme in 1998[11] which supported students to attend meetings, and he was retained as a Council member for several years to help with this. This programme, with the Best Student Presentation Awards, now specifically supports

[7] In the spirit of Charles Darwin, the Darwin Awards commemorate individuals who protect the human gene pool by "making the ultimate sacrifice of their own lives. Darwin Award winners eliminate themselves in an extraordinarily idiotic manner, thereby improving our species' chances of long-term survival". https://darwinawards.com/

[8] http://coralreefs.org/awards-and-honors/best-paper-award/

[9] Information on Honorary Members up to 1992 is available in an article by Ian Macintyre in Reef Encounter 16, Oct 1994; information on later awards has been collated from subsequent issues of *Reef Encounter*

[10] Note on the new fellowship in *Reef Encounter* 18 (dated Dec 1995, this issue actually came out in 1996): Professor Phillip Sollins of Oregon State University had provided a donation of about US$13,000, in partnership with the Center for Marine Conservation; Melanie Dotherow Mcfield was the first recipient.

[11] Articles on ISRS Awards in *Reef Encounter* 24, Dec 1998 and *Reef Encounter* 37, Jan 2009

student members to attend and present at the ICRS and regional, Society-recognized coral reef conferences. In 2019, the Ruth Gates Memorial Award was established to provide research grants for students and early-career scientists involved in solution-orientated research relevant to the coral reef crisis.

Diversity – an issue for the Society as much as for reefs

Making the Society a truly international body that reflects the distribution of reefs themselves, as well as those working on reefs, has always been a challenge. Inevitably, scientists from higher income countries have dominated membership and elected officers. There have been numerous efforts to redress this including, in 1994, gifting of ISRS memberships to reef scientists in low income countries. More recently, in 2012, championed by Rupert Ormond, membership fees were structured so as to be increasingly discounted for members from middle-income and low-income countries (based on World Bank rankings), and in 2015 a proportion of Council places reserved for members from different global regions. The need for regional meetings to reduce costs of attendance was recognised early in the Society's history, and the more recent introduction of regional Chapters should encourage active membership from a wider range of countries.

> Making the Society a truly international body that reflects the distribution of reefs themselves, as well as those working on reefs, has always been a challenge.

In the early years of the Society, as in many walks of life at that time, there was a notable gender bias (photo of ex-presidents). Nevertheless, there were many active female reef scientists (see review in this issue by Barbara Brown of Sidnie Manton's journals, for a totally forgotten researcher). In the Society, Barbara Brown, Daphne Fautin, Betsy Gladfelter and Caroline Rogers in particular, played vital roles (see also box on Peter Sale's *Reef Reminiscences*). Finally, in 2015 the Society elected its first female President in the person of Ruth Gates, a British reef scientist who was Director of the Institute of Marine Biology at the University of Hawai'i. A charismatic and high-powered researcher, whose term as President was sadly cut short by her death, she supported many of the modernizing moves that Society members had been suggesting, and helped to move the focus of the Society to conservation. By then a majority of both officers and Council members were women, as they are now, and Andrea Grottoli, who succeeded Ruth as President, in 2020, oversaw the production of the Society's first policy statement on diversity[12].

The evolving focus of the Society – and what happened to geology?

The Society was initially set up very much as an academic body, with the mandate to "*promote, for the benefit of the public, the production and dissemination of scientific knowledge and understanding of coral reefs, both living and fossil.*" In the first half of the 20th century, coral reef scientists were by and large equally split between the disciplines of biology and geology. Indeed, many reef scientists worked for oil companies, given the link between limestone and oil. *Coral Reefs* began with one geological editor and one biological editor, reflecting the two equal-sized volumes of the proceedings of the 3rd International Coral Reef Symposium (Miami): one geological and one biological. Coral reef scientists were an interdisciplinary group that interacted to address basic questions about how reefs work.

The focus of the Society on geology slowly waned, a result of both awareness of human impact (including climate change) on coral reefs, and the growth in life sciences. As of 2021, *Coral Reefs* has four biology editors, two ecology editors, and no geological editor. The geologist, Denny Hubbard was always concerned about this. He expressed his view, in 2008[13]: "*As we get closer to hanging a sign that says, "Last coral out, lock the door and turn off the lights", we've shifted our focus to "saving the reefs". This is understandable, but I wonder if we've lost a little of the excitement we had on gleaning a piece of the reef story just for the sake of the*

[12] http://coralreefs.org/about-icrs/diversity-statement/
[13] A geologist's lament. *Reef Encounter* 36, June 2008.

A record of the trials, tribulations and excitement of early research

Many reef scientists today will have little idea what research was like in the early days, before big grants, sophisticated equipment and the endless red tape associated with diving safety. The 2012 booklet, *Reef Reminiscences*[1], put together by Peter Sale and Alina Szmant, was an attempt to give a glimpse of reef research in the 1960s and early 1970s through the recollections of a dozen scientists in their own words, most stalwarts of the Society. Peter Sale remembers sending e-mails to prospective contributors asking them explicitly NOT to talk about the research they did, but about their impressions working on reefs in their early years. The goal was to capture the experiences, and accounts of what reefs were like, rather than reports of old research. All but a couple of the people approached responded enthusiastically, sending stories that capture what life for reef scientists was like back then. In addition to Peter Sale and Alina Szmant, the contributors were: John Randall, Bernard Salvat, Michel Pichon, Frank Talbot, Charlie Veron, Barbara Brown, Rolf Bak, Peter Glynn, Judy Lang, John Ogden and Charles Birkeland. Unfortunately, David Stoddart was one of those who did not respond – the approach had been made too late for him. *Reef Reminiscences* deserves to be followed up because history disappears too easily.

knowledge gained. Who knows what bit of information will provide the answer for issues not on our radar screen today? …… If the lack of action since the first IPCC report tells us anything, it is that science is irrelevant in the absence of public consensus and political will. In the meantime, might we be better served by asking esoteric questions such as "How will reefs exist in a 500 ppm CO_2 *world?" or, "How do we get someone in Cleveland that just lost their job at that polluting steel plant to care about coral reefs?" – rather than who is right about what stress factor holds primacy? This is only my opinion, but in the end, I'll win anyway. Unless we do something dramatic regarding public and political engagement, you're all going to have to become geologists if you want to study reefs, because they will exist only in the past."*

Brian Rosen, a palaeontologist, has similar concerns pointing out that *"…earth scientists still actually have much to contribute to reef conservation and have long been doing so, even if this has declined in an ICRS context. Reef geologists tend now to be found lurking under the umbrella of societies and conferences devoted to sedimentology or carbonate sedimentology…. Consider questions like - How did climate change affect reefs and reef organisms in the past? On what timescales do reef processes operate?… How do different organisms contribute to reef structures and how has that been affected by climate change, loss of keystone species or loss of particular functional groups? How much of modern reef structure is due to current reef growth and how much of it is actually a fossil (i.e. antecedent) structure?"* In his view, this may be something for ICRS to consider in its future deliberations.

Of equal concern was the schism between applied and pure science, a cause for angst for many in the 1960s and 1970s. This started to disappear by the late 1970s and early 1980s, as global environmental problems began to become overwhelming and the need for good communication of science to the public became clear (interestingly, the latter still a topical issue in 2021). Charles Birkeland remembers *"Back in the 1970s, we lived in a sublime fantasy in which we studied reefs for the intriguing complexity of their functions and interactions. We could be pure scientists. Now we are all focused on major practical biological and ecological problems and the slower geological processes, which used to get equal attention, have been put on the back burner. Like dialing a telephone or manually winding car windows up or down, most young coral reef scientists are probably unaware of this schism, given the need to demonstrate to funding bodies the relevance of their research and to communicate them to society. As late as 1992, at a meeting of the editors and the editorial board of Coral Reefs, a recommendation was made that the journal should stick to "pure science". Papers on "applied" topics such as the effectiveness of MPAs, the reliability of survey methods, etc., should be sent to journals for conservation or fisheries management. But the tide was turning by then, and the overwhelming majority at the meeting agreed that as long as it was good peer-reviewed science pertaining to coral reefs, then whether it was "applied" or "pure" was not an issue".*

There were many in the Society however who were already concerned. Ex-president Nick Polunin remembers attending the 1980 inaugural meeting as a young graduate student, and presenting his work on coral reefs in an urban Indonesian setting, to an audience used to research on remote locations such as Tahiti, Phuket and Carrie Bow Cay. The first issue of *Reef Encounter*, in 1983, carried articles on coral reef bleaching and on "The Great Barrier Reef

Reef Encounter – the Society's newsletter

The Society was always eager to promote the exchange of news and views and to encourage collaboration. Brian Rosen, at the London Natural History Museum, came up with the concept for a newsletter and the name *Reef Encounter* – which is written in the singular, not in the plural as common transatlantic usage tends to have it). Reflecting stereotypical British humour, it originated as word play on what was, at the time, a well-known post-war film – "Brief Encounter"[a]. Brian gives a detailed explanation of his thinking behind the choice of name in his letter published in *Reef Encounter* (Rosen, 2010), a classic contribution in terms of its erudition on tangential reef matters. The first newsletter came out in October 1983, edited by Brian, assisted by Barbara Brown. Initially two issues were produced a year, but these dropped to a more irregular but generally annual production in 2002. The pros and cons of an electronic version had been debated since the early 1990s and, in 2007, the first electronic version was produced. Following Brian Rosen, *Reef Encounter* editors have included: Barbara Brown, Jeremy Thomason, Sue Wells, Callum Roberts, Maggie Watson, David Obura, Kristian Teleki, Maria Joao Rodrigues, Karenne Tun, William Precht, Martha Robbart, Beth Zimmer, Steve Coles, Mike Arvedlund, Adel Heenan, and Rupert Ormond.

In the early days, news and announcements prevailed since there was no internet via which such items could be more quickly broadcast. The content was intentionally humorous (*Reef Encounter* 3 carried a description of a new species, Captain Coral), and there were many cartoons, often drawn by members (figs. 5 & 6). Terry Scoffin's Black Dog cartoons were a notable regular feature, focusing on a benighted reef scientist or two stranded on a desert island. *Reef Encounter* has also been the Society's main vehicle for members to share information about the threats to reefs, and to debate this concern – in the early days Society members included some sceptics.
In recent years, the newsletter has become more of a scientific journal, with both general interest items and short articles, including some by researchers who may find it difficult to meet the standards required for *Coral Reefs*, due to lack of experience or language difficulties. Increasingly, if sadly, *Reef Encounter* also records the obituaries of the scientists that built up and ran the Society. The newsletter provides a useful record of the progression of coral reef science over the years and of the researchers who undertake it.

Copies of all past issues are available at: http://coralreefs.org/society-publications/reef-encounter/

(a) directed by David Lean and based on a screenplay written by Noël Coward, it starred Celia Johnson and Trevor Howard

and Sustainable Development". The Great Barrier Reef Marine Park, established in 1975, was becoming an icon for nascent attempts at reef conservation, and Richard Kenchington achieved an international reputation through his 1990 book, *Managing Marine Environments*. He and other Society members helped to set up the International Tropical Marine Ecosystems Management Symposia (ITMEMS)[14]. In 1989 the Society produced its first statement on "Coral Reefs and the Greenhouse Effect" at the initiative of Bob Buddemeier, a geochemist[15]. The 1993 Miami colloquium organized by Bob Ginsburg, notably a geologist, firmly put conservation on the agenda, with Bob remarking[16]: *"For coral reefs, the major problem with climate change is that it is unlikely to be severe enough to eradicate humans"*.

At its 1995 annual meeting, the Society endorsed the newly formed International Coral Reef Initiative (ICRI), now the leading body promoting reef conservation at the global level, with John Ogden and subsequent Presidents/Council members playing an active role. Under Nick Polunin's presidency, in 2004/2005, the Society began issuing briefing papers – summarising the science behind difficult management questions – with the recognition that outreach and better communication of the science was a vital role for the Society. By the 2008 ICRS11 in Florida, about 50% of the papers presented were relevant to management, although there were still discussions about the topics that *Coral Reefs* should cover, as recalled by Rolf Bak (Editor in Chief, 2008-2013). With the rapid roll-out of other journals covering the more applied aspects, *Coral Reefs* continues to maintain a rigorous scientific focus on reefs, whilst now also addressing the critical need for sound science to underpin conservation efforts.

[14] In the late 1990s, there was a contentious but brief discussion within the Society about merging the quadrennial symposia with ITMEMS, prompted by worry about losing too many members to a competing symposium. In retrospect wisely, the two remained separate.
[15] *Reef Encounter* 5, Aug 1989
[16] *Reef Encounter* 14, Oct 1993.

Figure 5. One of the famous Reef Encounter cartoons: “siesta”

Figure 6. Another of the old Reef Encounter cartoons: “turtles”

The role of the Society has progressively expanded, with the production of consensus statements on reefs and climate change for the conferences of the parties (COPs) to the United Nations Framework Climate Change Conference (UNFCCC) (notably for the key 2016 CoP in Paris) and subsequently for the Convention on Biological Diversity (CBD). The 2016 ICRS13 had the theme “Bridging Science to Policy”, Bob Richmond having drawn the then Council’s attention to the fact that “*while the knowledge of coral reefs and number of publications relating to them had grown exponentially over the previous decade, the state of reefs had declined on the opposite trajectory over the same period*”. In an effort to draw global attention to coral reefs – by then widely recognized as the ecosystem most at risk from climate change – the executive officers managed to obtain the participation of three presidents of sovereign nations at the 2016 ICRS13 in Hawaii: His Excellency Tommy E. Remengesau Jr. (Republic of Palau), Her Excellency Hilda C. Heine (Republic of the Marshall Islands) and His Excellency Peter M. Christian (Federated States of Micronesia). They took part in a 3 day leaders’ summit, held as part of the symposium, and signed a joint call-to-action to work with the scientific community and move from science/knowledge to policy/action. The call to action was presented at the final session organized by Val Paul and Joanie Kleypas, and a follow-up meeting was held with the Pacific Judicial Council in Guam in 2017. This regional effort is still ongoing.

The Society now has a Plan of Action and a new Mission focused on “the acquisition and dissemination of scientific knowledge to secure coral reefs for future generations”. It is a valued member of ICRI as the “voice of science”, and has been contributing to planning of the Convention on Biological Diversity’s post 2020 Global Biodiversity Framework, ensuring that global attention is maintained on coral reefs. The period when the Society’s relevance to modern day concerns was questioned is now firmly in the past. ▸

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REEF CURRENTS

Stony Coral Tissue Loss Disease (SCTLD) in the US Virgin Islands:
a collaborative response

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Even for those familiar with coral disease outbreaks, the first response to a sudden outbreak is shock. No matter how much preparation and monitoring are already in place, changes in reef condition can be more rapid than ever expected. For researchers from the University of the Virgin Islands in St. Thomas, US Virgin Islands (USVI), a routine monthly visit in January 2019 brought that shock, on a reef unaffected by disease just the month before; it was the first report of Stony Coral Tissue Loss Disease in the USVI (Fig. 1). While the appearance of this disease was an event that resource managers hoped they would never see in the USVI, the prompt actions taken to unify the territory to respond to this threat have been productive and have laid the groundwork for responses to other diseases or stressors in the future.

Stony Coral Tissue Loss Disease (SCTLD) was first identified in 2014 in the Upper Keys of the Florida Reef Tract (FRT) (Precht et al. 2016; Walton et al. 2018). SCTLD quickly eclipsed many other concerns because of its severity, affecting over 20 Caribbean coral species (NOAA 2018). Infected corals may experience tissue loss at rates (Fig. 2) of an order of magnitude higher than reported rates of other diseases such as White Plague Disease (Meiling et al. 2020). Large reef-building corals can be completely killed in a matter of weeks to months, and smaller, less abundant species face local extinction in many areas. The sudden appearance of this reef threat in Florida soon re-structured and re-prioritized the reef management strategy and has been a continuous threat to the reefs across the FRT since its first observation (Graulty 2020).

While SCTLD is currently the most immediate major threat to reefs in the USVI, it is not the first that scientists, managers, and conservationists have faced. Mass bleaching events in 2005 and 2010 (Wilkinson and Souter 2005; Smith et al. 2013), with subsequent disease outbreaks of White Plague (Miller et al. 2009; Brandt et al. 2013), identified a key need for effective threat response and mitigation: inter-agency collaboration. In 2016, the Virgin Islands Department of Planning and Natural Resources revitalized the Virgin Islands Coral Reef Advisory Group (VI-CRAG), a collaborative organization geared towards information sharing among local agencies, federal agencies, non-governmental organizations, and research bodies.

Figure 1. Response diver examines a large *Orbicella faveolata* affected by SCTLD. Some treatment has been applied to halt the lesions. Photo by Joseph Townsend

Following that first confirmed SCTLD report by local coral disease expert Dr. Marilyn Brandt, the report was immediately relayed through VI-CRAG network notifying all levels of reef management. Within days of that observation VI-CRAG created a dedicated sub-committee labeled the Virgin Islands Coral Disease Advisory Committee (VI-CDAC) which held its first meeting in the beginning of February 2019. Since that first meeting VI-CDAC has conducted weekly meetings with the goal of collaboration in reporting, research, data collection, and ultimately response activities.

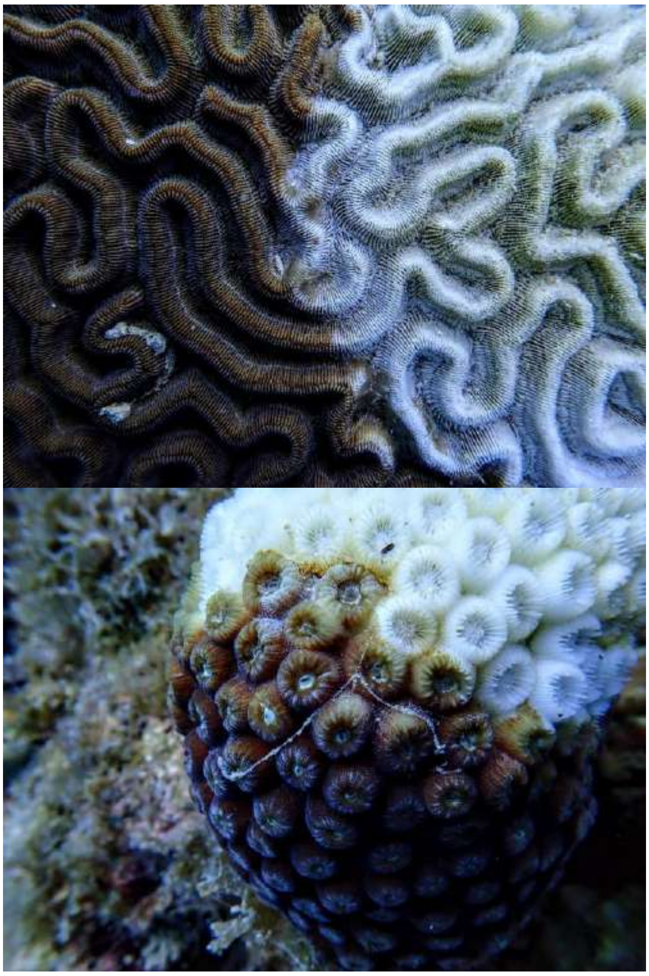

Figure 2. Close up of contrasting coral species affected by Stony Coral Tissue Loss Disease (SCTLD). Above: *Colpophyllia natans*. Below: *Montastraea cavernosa*. Photos by Sonora Meiling

Following a regional disease response workshop in November 2019 (Fig. 3), a new official Virgin Islands Coral Disease Outbreak Response Plan was created, dividing the goals and priorities of VI-CDAC among five specialized teams: (1) Field Interventions, (2) Data Management, (3) Communications, (4) Research and Epidemiology, and (5) Restoration. The plan summarizes the current ongoing activities of each team and sets forward a specific action plan for continued SCTLD response. Each team also has a different designated lead agency to ensure team goals are met. SCTLD Management was further centralized with the hiring of a full-time, dedicated Coral Disease Response Coordinator, seated within the local Department of Planning and Natural Resources but actively fostering collaboration across all agencies actively working within VI-CDAC.

Through the VI-CDAC collaborative effort, the response to SCTLD is now a unified and focused effort across the territory of the Virgin Islands. Spatial spread of the disease is carefully tracked through surveys by highly trained volunteer “strike teams”, along with a centralized reporting system, which, since the first observation, has received over 1,000 reports and surveys indicating where in the territory SCTLD is present and its relative severity. Since its first report at Flat Cay on St. Thomas, SCTLD has spread across St. Thomas, and appeared on St. John one year later in January 2020. Surveys now confirm SCTLD around the entirety of St. John, two years from initial reporting in St. Thomas. On St. Croix, the first reports of SCTLD were received in May 2020. Through extensive surveys VI-CDAC confirmed that two separate outbreaks of SCTLD had occurred on St. Croix, the first in the south (starting in May), and the second isolated outbreak starting in the North in September 2020. By 2021, two years following the initial observation in the USVI, all three islands had confirmed SCTLD, and, with the exception of the eastern side of St. Croix, the disease had spread to coral reefs across the entire territory.

Within the first year of SCTLD appearance, the changes to the reefs had already been made apparent. Careful monitoring of Flat Cay, the site first observed with SCTLD, revealed a greater than 50% loss in coral cover over the course of six months (Brandt et al. unpublished data). Similarly studies across the northern USVI have documented a significant loss of rare coral species that are highly susceptible to SCTLD after the disease has been present for longer than 8 months (Costa et al. unpublished data). Observations captured by strike team reconnaissance surveys indicate the coral species that are most susceptible; *Meandrina meandrites*, *Dendrogyrus cylindrus*, *Dichocoenia stokesii*, and *Eusmilia fastigiata* have been nearly entirely eliminated from areas where SCTLD has been documented for longer than 18 months (www.vicoraldisease.org). Additional concern in the USVI now is the observed impact to large, critical “reef building” corals of the species *Orbicella faveolata*, *Orbicella franksi*, *Orbicella annularis*, and *Montastraea cavernosa*. While there is no evidence these coral species will be driven extinct by SCTLD, partial tissue loss and whole colony mortality of these larger individuals will have disproportionate impacts to the local reef ecosystem.

Figure 3. Members of VI-CDAC met during a regional coral disease response workshop in November of 2019, discussing territorial needs and the development of the US Virgin Islands Coral Disease Response Plan. Photo by Dan Mele

In addition to identification and mapping of observations and impacts, VI-CDAC has worked to create a unified response and intervention effort to mitigate the effect of SCTLD to coral reefs of the USVI. Using the most applicable intervention techniques developed by Florida's long standing disease response teams, USVI strike team divers apply amoxicillin to areas where corals are being affected by SCTLD, using a specialized ointment compound known as Base2b (www.oceanalchemists.com) (Fig. 4). Developed by Ocean Alchemists, this paste has been specifically designed to provide appropriate dosing of amoxicillin to the lesions on corals affected by SCTLD, halting the progression of the disease, and keeping the corals alive. While this approach does not halt the spread of the disease across the reef, it has been a key tactic in saving large and critical reef building colonies. To date, over 2,500 treatments using Base2b and amoxicillin have been applied in the US Virgin Islands.

To address the challenge of sudden and rapid loss of smaller, less abundant or cryptic species, strike teams have also prioritized these species for in-water treatments. However, members of the Field Interventions team of VI-CDAC have had success in saving these individuals by removing them from the reef and providing them with treatment in experimental aquaria on shore, through prescribed dosing of the system using dissolved amoxicillin. Following recovery from infection, corals that have been "rescued" this way can easily be fragmented and propagated using modern coral restoration techniques; however, it remains unclear whether outplanting may result in re-exposure to SCTLD and hence reinfection. To date, over 50 individuals of 11 different species have been rescued and are in long-term care.

One of the keys to success for SCTLD response in the US Virgin Islands has been through management of unified data and information across all three islands. In addition to dedicated teams focused on collaborative research and response efforts, VI-CDAC devotes one of its sub-teams entirely to data management and organization. With leadership by NOAA, the data management team has worked to make all data regarding SCTLD in the USVI centralized and accessible. Following a data management workshop in September 2019, all SCTLD-related data not under peer-review were centralized in a cloud storage system that could be accessed by any relevant party. Some information is specific to each of the teams within CDAC, other information is for territory-wide application, such as reporting or intervention. The team has also created public-facing data dashboard tools that are updated weekly, summarizing both new reports and any recent interventions.

With centralized information available to all CDAC members, there was also a need to provide information and awareness to the general public and to communicate the ongoing effort to combat SCTLD in the territory. A team of communications specialists and knowledgeable experts within VI-CDAC have created a dedicated USVI coral disease website (www.vicoraldisease.org), hosted by the Center for Marine and Environmental Studies at UVI. The website allows for all information regarding SCTLD to be easily relayed to the public and to be centrally located. This information includes but is not limited to ongoing news, new reports of disease, recent interventions, and resources for learning more about SCTLD itself. Built into the website is a form where anyone can easily report sick corals and add to the continued effort to report SCTLD across the territory. To date, over 400 coral health reports have been received from citizen scientists, some of which were the first reports of disease in an area.

As responses continue, a central focus of VI-CDAC has been support for understanding SCTLD through increased intensive research programs, led by the University of the Virgin Islands. The research team investigates fundamental questions about the nature of the disease, such as species-specific progression, transmission, and characterizes the emergence of the disease in the VI. This research is further enhanced through a multitude of collaborators from agencies and research bodies across the United States. Working with partner facilities and researchers, the research team is also investigating the disease's molecular nature, the microbiome, gene expression, the influence of currents, pro-biotic resistance, and the possible role of ballast water in disease introduction.

With January 2021 marking two years since the first observation of SCTLD in the territory, the response is ongoing and constantly evolving, based on the needs and priorities across each island. With the collaborative space of VI-CDAC to assist in information sharing, collaborative projects and programs, and centralized messaging, SCTLD response continues to be a major priority across management agencies in the USVI. Challenges, such as observed failures in applied treatments, lack of available resources for restoration/rescue, and lack of comparative information from around the Caribbean, nevertheless continue. Moving forward, VI-CDAC will address these concerns across the collaborative teams.

The research and epidemiology team is looking to understand failed treatments, and to develop new treatment methods such as the use of probiotics that could help slow disease progression. The success of the preliminary coral rescue program has renewed hope of not only halting disease progression on the reef, but also mitigating its effects through SCTLD-conscious restoration. While SCTLD-resistant outplanting and other SCTLD-conscious restoration strategies are still in the research stages, collaboration between the research team and the restoration team will allow for seamless transition from research to implementation. The incorporation of SCTLD in restoration will then tie outplanting directly to areas most affected by SCTLD, as well as areas where reef-scale restoration will be most effective.

As with many challenges and threats facing modern coral reefs, SCTLD is not likely to disappear anytime soon. In the Virgin Islands, prompt recognition of and response to SCTLD was important, however the formal organization process and the creation of VI-CDAC have been crucial steps to take for long-lasting and effective disease response. Taking the time to establish a formal and dedicated organization has made an efficient and unified response to SCTLD possible. This organization has created a platform where governmental agencies, private agencies, and the public can look for up-to-date and reliable information. This is crucial for inter-organizational

Figure 4. SCTLD-infected *Diploria labyrinthiformis* being treated using Base2b ointment infused with amoxicillin. Treatments can be applied on corals infected with SCTLD to halt lesion progression and save the colony from total mortality. Photo by Kitty Edwards

sharing, cross-agency and cross-jurisdictional collaboration, and public outreach, resulting in a unified and widespread action network. VI-CDAC is paving the way for SCTLD response in the VI and will continue to act as an example for other jurisdictions now facing SCTLD, as well as future response efforts to any threats to coral reef ecosystems.

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Mangrove conservation on Indian ocean reefs and atolls

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While coral reefs are well known for their high biodiversity, mangrove forests with which they are often associated are also relatively productive and species diverse. Mangroves grow intertidally, their roots sticking up out of the mud, with fish, crustaceans and other invertebrates living among the roots or on the tree trunks. Among these, mangroves may also serve as a haven for various coral species (Yates et al. 2014) (Fig. 1). Indeed, corals residing near and among mangroves on reefs may be among the most capable of surviving the ocean warming, acidification and deoxygenation anticipated as a result of climate change and these habitats are still largely unexplored in the context of their role in supporting corals potentially adapted to future climates (Camp et al. 2019) (Fig. 2a).

At the same time mangroves on offshore reefs and atolls are "Biodiversity Cool Spots" rather than "Biodiversity Hot spots" in relation to mangrove diversity and infauna, since they tend to harbour fewer species than continental mangrove forest, but have a high proportion of species facing local extinction (Thaman 2008). There is a shared evolutionary history (Renema et al. 2008; Hemingson and Bellwood 2018) and ecological connectivity (Yates et al. 2014; Woodroffe 2018) between mangroves and coral reefs, and mangroves are often associated with coral reef atolls, but are more usually absent from lagoon-less reef islands (Thaman 2016). In atolls mangroves

Figure 1. Image illustrating the often close association of coral and mangrove communities on Indian Ocean reefs and atolls.

may flourish along protected lagoon shores or in behind-beach basins, and in both locations can play an important role in geomorphic development, coastal protection and carbon sequestration (Yamano et al. 2020). Yet, while the ecological services and socio-economic benefits of mangroves in terrigenous settings have been well recognized in the recent decade (Lee et al. 2014), the value of those growing in an atoll setting have in the past been largely ignored. However, recent studies have highlighted the ecological value of small island mangroves, irrespective of their extent (Curnick et al. 2019). For instance, recent studies have demonstrated the higher carbon storage potential of mangroves in carbonate settings than in other environments (Rovai et al. 2018; Twilley et al. 2018). Most of the world's atolls are in the Pacific Ocean, but they are also widespread in the Indian Ocean, in the Maldives, Lakshadweep Islands, Chagos Archipelago, outer Seychelles and the Keeling Islands. In contrast the Atlantic Ocean has no large groups of atolls. This article overviews the extent and significance of mangroves found on Indian Ocean reefs, especially on or within atolls.

Occurrence of Mangrove Species on Indian Ocean Islands

The Maldives. The Maldive Islands consist of a chain of about 1,200 coral islands, grouped into atolls. Mangrove species diversity in the Maldives is impressive compared to other offshore Indian

Figure 2a (left) Coral Biologist, Emma Camp, sampling in the reefs adjacent to mangroves (Photo Credit: Emma Camp); 2b (right) Two of the authors (Ragavan and Sivakumar) sampling mangroves growing on coral reefs at Neil Island, Ritchie's Archipelago, the Andaman Sea. Photo Credit: Sivakumar

Figure 3. A stand of the mangrove *Pemphis acidula* (indicated by the yellow arrow) growing on Bangaram atoll (2016).

Ocean reefs. They support 15 of the 17 species reported from Indian Ocean islands: *Acrostichum aureum*, *Avicennia marina*, *Bruguiera cylindrica*, *Bruguiera gymnorhiza*, *Bruguiera sexangula*, *Ceriops tagal*, *Derris heterophylla*, *Excoecaria agallocha*, *Heritiera sp.*, *Lumnitzera racemosa*, *Pemphis acidula*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Sonneratia caseolaris* and *Xylocarpus sp.* (Jagtap and Untawale 1999; Ahmed and Aminath 2003; Bluepeace 2007; Selvam 2007; UNICEF 2008; Spalding et al. 2010). *Nypha fruticans*, the mangrove palm has also been reported.

The Lakshadweep Islands. Lakshadweep constitutes the only coral atoll chain in India. It harbours four mangrove species: *Avicennia marina*, *Bruguiera cylindrica*, *Ceriops tagal* and *Pemphis acidula*. Three of these have been reported only from the Minicoy atoll, but *Pemphis acidula* also occurs on Bangaram (Fig. 3) and a few other atolls (Nasser et al. 1999).

The Seychelles. The Seychelles is an archipelago of nearly 155 islands. Mangroves occur in small pockets on many islands, but larger mangrove areas occur only around the central granitic islands and on the very large atolls of Aldabra, Cosmoledo and Astove, located in the far south-west of the nation's territory (Fig. 4). Of the nine mangrove species found in the Seychelles, *Avicennia marina* is the most widely distributed. Aldabra, however, harbours eight species, which grow on the most sheltered sections of seaward coast, as well as widely within the large central lagoon. *Avicennia marina*, *Bruguiera gymnorhiza*, *Ceriops tagal* and *Rhizophora mucronata* are common, while in a few localities, *Lumnitzera racemosa*, *Pemphis acidula*, *Sonneratia alba* and *Xylocarpus granatum* also occur. The mangal fern *Acrostichum aureum* is also common on Aldabra (Macnae 1971; FAO 2005).

Figure 4. Aerial view of Aldabra, the largest raised atoll in the Indian Ocean (Photo Credit: Seal Superyachts, 2017).

The Chagos Archipelago. The Chagos archipelago is a group of more than 60 islands situated about 500 km south of the Maldives. They harbour, however, only two mangrove species: *Lumnitzera racemosa* and *Pemphis acidula*. Both species occur on

Moresby Island, and there is also a small patch of *Lumnitzera racemosa* on Eagle Island. Given this restricted distribution, it has been argued that restoration activity is required to prevent the loss of mangroves from Chagos (Royal Botanical Garden 2010).

The Cocos Keeling Islands. The Keeling Islands, situated in the eastern Indian Ocean, 2750 km northwest of Perth, Western Australia, comprise two atolls of 27 islands. Two species of mangrove, *Rhizophora apiculata* and *Pemphis acidula*, have been reported (Williams 1994). Interestingly, a voucher specimen of *Pemphis acidula* was collected from there by Charles Darwin and is deposited in the Cambridge University Herbarium.

The Environmental Value of Mangroves

Mangroves, as well as coral reefs and seagrasses, represent important natural assets for the planet, in particular for oceanic islands and nations (Guannel et al 2016). However, the ecological and economic benefits of the mangrove habitats of the low-lying islands of the Indian Ocean have largely gone unrecognized (Dhunya et al. 2017). In contrast, the ecological role of Pacific island mangroves has been well recognized (Gilman et al. 2006), even though they constitute only 3% of the global mangrove area. They are described as supporting a unique mangrove community and providing valuable site-specific services and products, such as coastal protection, water quality, fish breeding habitats and raw materials such as dyes used in treating traditional tapa bark-cloth, other textiles, nets, and fish traps (Gilman et al. 2006).

The carbon storage potential of mangroves has also become a subject of interest in the past decade. Recent studies have suggested that mangrove soil organic carbon stocks have been underestimated by up to 44%, while those of river deltas have been overestimated by up to 86% (Rovai et al. 2018: Twilley et al. 2018). These findings imply a significant role for atoll mangroves in carbon sequestration.

Nevertheless, despite their ecological and economic significance, the atolls of the Indian Ocean are experiencing increases in both acute and chronic environmental stressors. In particular sea-level rise is an increasing threat to low-lying islands in the Indian Oceans as well as the Pacific. Mangroves have the potential to reduce the effect of sea-level rise through vertical accretion and horizontal expansion of sediments. But both processes are greatly influenced by local abiotic (sediment inputs and local geomorphic settings) and biotic factors (plant productivity, peat development and the accumulation of refractory mangrove roots and benthic mat materials). Anthropogenic impacts remain the root cause of the loss and degradation of mangroves both worldwide and within atoll nations such as the Maldives (Das Gupta and Shaw 2013; Dhunya et al. 2017). It is always challenging for developing nations to balance the demands of economic development and nature conservation, but the potential economic benefits of nature conservation are often overlooked. It has been recommended that price-based instruments, such as carbon credits, payments for ecosystem services, and taxes on deforestation should be introduced to favour the retention of mangroves rather than their conversion to other uses (Lee et al. 2014).

Mangrove Protection in Indian Ocean Island Nations

Given the foregoing arguments Indian Ocean island nations have introduced conservation measures to protect mangroves. In the Lakshadweep Islands, the Union Territory of Lakshadweep (UTL) Administration is playing, through the Department of Environment and Forestry and Department of Science and Technology, a key role in conserving the coastal and marine ecosystems of the islands and creating new Marine Protected Areas (MPAs). The Department of Science and Technology and Department of Biotechnology, Government of India, has meanwhile supported work on genomics as well as the search for novel metabolites.

A Lakshadweep Action Plan on Climate Change (LAPCC) has been formulated in accordance with the principles and guidelines of the Indian National Action Plan on Climate Change (NAPCC). The LAPCC integrates environmental measures with both current and proposed development programmes for the UTL, along with the eight principles and guidelines listed in the NAPCC. In addition, the Integrated Island Management (IIM) programme of the National Centre for Sustainable Coastal Management (NCSCM), of the Ministry of Environment, Forest and Climate Change, Government of India, will also promote the future socio-ecological sustainability of the Lakshadweep

Figure 5. The author, Sivakumar Kannan, at Bangaram atoll, Lakshadweep.

by implementing an Integrated Island Management Plan.

In the Maldives the Government is contemplating the establishment on Huraa Island (Gaafaru Atoll) of a field gene bank intended to conserve the genetic diversity of mangroves, and also considering changes in land use planning so that mangroves are better protected. A multi-part initiative, Mangroves for the Future (MFF), is assisting in the development of a National Integrated Coastal Management approach that integrates with the Maldives National Adaptation Programme of Action on Climate Change. The Environment Protection Agency of the Ministry of Home Affairs and Marine Research Centre are also involved in the conservation of mangroves, as is Bluepeace, the oldest non-governmental organization (NGO) in the Maldives.

In the Seychelles, Integrated Coastal Zone Management (ICZM) has been emphasized. At a local level, a Seychelles National Coordinating Body (NCB) has been formed through which government bodies, NGOs, private sector organisations and local communities are working together to conserve and restore coastal ecosystems. A National Project Coordinator has also been recruited to oversee the operationalization and implementation of the United Nations Development Program (UNDP) Small Grant Facility.

In relation to the Chagos Archipelago, as a result of the Chagos Conservation Trust recommendations in 2020, the greater part of the Chagos Bank was declared a no-take Marine Protected Area, extending to 640,000 km^2.

In the Keeling Islands, Pulu Keeling National Park (PKNP) has been established; it contains rainforest, lagoon and other marine habitats, as well as mangrove, and is listed as a wetland of international importance under the Ramsar Convention. PKNP is one of Australia's smallest national parks; nevertheless, it is a place of considerable international conservation significance. As an isolated coral atoll in an almost natural state, its relatively pristine environment is an increasingly scarce feature in the tropics.

Conclusions

Coral reefs and mangrove ecosystems together play a key role in protecting emergent mid-ocean shorelines from the destructive forces of wind, waves and driven debris, and of sea-level rise. To a large extent, both habitats help form and shape the shorelines, and to buffer the Indian Ocean region against the hydrological forces of the oceans and periodic extreme weather events. The loss of relatively small patches of mangrove may seem less concerning than the large-scale deforestation that has occurred in continental areas, but, these small patches are especially important to low-lying island nations vulnerable to climate change and sea-level rise (Lee et al. 2014; Curnick et al. 2019). Given the recent Intergovernmental Panel on Climate Change's projections (Hoegh-Guldberg et al. 2018), we cannot afford to lose more mangrove forests, irrespective of their size.

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Mesophotic Reefs of the Mexican Pacific: a ray of hope for benthic macroinvertebrates?

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Resumen

Los macroinvertebrados bénticos son esenciales para los ecosistemas marinos. Proveen hábitat para diversas especies de peces, destacan en los procesos más impactantes de simbiosis, y tienen roles importantes tanto en interacciones ecológicas como en los ciclos biogeoquímicos. En el ambiente actual, donde hay muchos cambios, el impacto antropogénico y el cambio climático amenazan la salud y la diversidad de los macroinvertebrados bénticos. Anteriormente los científicos pensaban que los ecosistemas profundos, incluyendo los arrecifes mesofóticos, servirían como refugio para ellos. Sin embargo, la evidencia actual sugiere algo distinto.

Questioning the Deep Reef Refugia Hypothesis (DRRH)

The DRRH—proposed by Dr. Peter Glynn back in the 90s—stated that deep reefs could potentially 1) serve as refuges for different species against shallow disturbance, and 2) serve as sources of reproduction for shallow zones after disturbance. This hypothesis was very innovative for the time and sounded very promising to conservationists. However, the evidence gathered in the past decade suggests that living at depth has its own drawbacks—especially for benthic macroinvertebrates.

It is true that wave energy decreases with depth as it dissipates across the water column, attenuating mechanical impact from a storm or hurricane, for instance. However, this does not exempt deeper-water organisms from disturbance. There is evidence that storms and hurricanes create strong currents that move great masses of water which can reach deep zones and affect the communities there (Smith et al. 2019). In addition, benthic macroinvertebrates are particularly vulnerable because they often rely on reduced motility (e.g. hydrozoans, polychaete), so they may not escape the effects of debris accumulation either. Other organisms may be structurally fragile, or have slow growth rates, greatly affecting their fitness. Under climate change, storms will likely increase in frequency and intensity, which means impact may transcend to deeper regions (Knutson et al. 2015).

There is also evidence of thermal stress below depths that were previously assumed to be affected. Negative effects of ocean warming, El Niño Southern Oscillation events (ENSO) and marine heatwaves (MHW) reach mesophotic depths causing coral bleaching (Bongaerts et al. 2010) or direct mortality of other benthic macroinvertebrates (Giraldo-Ospina et al. 2020). Water below the thermocline can be matter-rich, providing food for filter feeders. Some macroalgae may benefit from cooler temperatures, which sustains grazers, and many invertebrates may find relief from warming. However, cool temperatures may also bring negative effects. Some organisms are intolerant to low temperatures. What is more, high nutrient levels and reduced aragonite saturation may be detrimental for calcifying organisms (Norzagaray-López et al. 2017). Other sources of disturbance at depth include diseases, algal blooms, and invasive species outbreaks. There are no reports of macroinvertebrate diseases in the Mexican Pacific; however, corals frequently suffer from bioerosion and unexplained tissue loss (Rodríguez-Villalobos et al. 2015).

Depth *per se* does not shape mesophotic ecosystems: instead, it is important to consider other variables such as temperature, ocean dynamics, turbidity and species pool. Because geomorphology, substrate, and seasonality vary between sites, disturbances at a given depth may differ in type, magnitude and frequency. It is important to study these differences to understand mesophotic ecosystem functioning.

Main features of mesophotic reefs

Mesophotic reefs are typically defined as ecosystems from 30 to 150 m in depth (Hinderstein et al. 2010). There has been debate, however, on whether this is a proper definition. Some authors claim that this range was established based merely on diving limitations, rather than using physical or ecological criteria (Pyle et al. 2019). Mesophotic means “middle light” (mesos: middle, photic: light), which one can easily interpret as “the depth at which there is half of surface light intensity”. Although there is a correlation between depth and light, the linear distance from the surface at which one finds this condition is inconsistent around the globe. Hence, it has been suggested to define mesophotic depth in terms of light intensity (Eyal et al. 2019). In our study area we determined the upper limit of mesophotic depth as that at which light intensity was 50% of that at the surface. In bays with low turbidity mesophotic depth started at 16 m, but in bays with a naturally high turbidity it started at depths as shallow as 2.5 m.

The existence of mesophotic reefs was discovered five decades ago, using submersible facilities, such as the Asherah[1], but most studies have been published in the past decade. One of the most interesting has been the HMS Challenger Project, which has identified 230 species found in Mesophotic Coral Ecosystems (MCEs), including 50 new species, from among those collected by the Famous HMS Challenger Expedition of 1872-1976 (HMS Challenger Project 2017). Although Mesophotic Coral Ecosystem (MCE) is a commonly used term, we prefer a broader scope because in some places in the Eastern Tropical Pacific (ETP) there are also important mesophotic rocky ecosystems. What is more, while studies describe how scleractinian corals may be present in what researchers call MCEs, other groups may actually be dominant (Pyle et al. 2019). In any case, mesophotic reefs are characterised by displaying a conspicuous shift in benthic macroinvertebrate community composition, likely associated with changes in light and temperature regimes (Pyle et al. 2016).

Common organisms on mesophotic reefs

On some mesophotic reefs of the Caribbean, scleractinian corals play important roles in the benthic macroinvertebrate community composition, providing both substrate and complexity to the reef. Common species are *Orbicella*, *Helioseris*, *Agaricia* and *Siderastrea*. Despite this, other species may be dominant. The sponge *Xestospongia*, for instance, is dominant on some mesophotic reefs in the Gulf of Honduras, and the Octocoral *Swiftia* very common in the Gulf of Mexico.

In the ETP, common scleractinians are *Madrepora*, *Caryophyllia* and *Lophelia pertusa.* Nevertheless, gorgonians are dominant at other sites. *Muricea fruticosa*, for instance, is dominant in many sites in the Isla del Coco, Galápagos Islands and Panama. In the Mexican Pacific, mesophotic reefs remain largely unexplored. However, *Pocillopora wa*s known to be present, and sponges such as *Aplysina* and *Haliclona* expected to be abundant, with rugose rocks providing reef complexity.

The Mexican Tropical Pacific

The tropical mainland coast of the Mexican Pacific extends from Sinaloa to Chiapas (a distance of ~2000 km). This region is well known for having a low coral diversity and limited coral reef development. However, there are sites in which coral reef development is actually important, such as on the coasts of Nayarit and Oaxaca. Reefs here reach up to 5 m in height and extend to several hectares. These areas are near upwelling centres, which influence light penetration and nutrient

[1] Asherah was the first commercially built American research submersible, owned by the University of Pennsylvania and used in particular by archaeologist George F. Bass. It was named after Asherah, an ancient Semitic goddess, known as "she who treads on the sea"

availability. The most common corals in these areas are species of *Pocillopora*, *Porites* and *Pavona*. Due to the possession of efficient symbionts that cope with low light availability, high nutrient uptake, and phenotypic plasticity, pocilloporids are clearly dominant.

What is more, coral reef dynamics in this zone are different from other regions, given their natural history (e.g. pre-Holocene events, ENSO events). Many vertebrates, for instance, are not as dependent on corals as in the Caribbean, because they evolved separately. Coral colonies may displace other important benthic macroinvertebrates, preventing them from carrying their ecological roles such as filtering, or algae control. Ecologists recognise the importance of coral reefs for the ecosystem services they provide: mainly shoreline protection in this turbulent area and biogeochemical cycling. The importance of rocky reefs, however, has been historically underestimated. Given the lack of quantitative studies and the fact that mesophotic areas of the tropical mainland Mexican Pacific were largely unexplored, we planned research to assess the role of deep ecosystems in this part of the Eastern Tropical Pacific (ETP).

Our expedition started in the Bahías de Huatulco, in Oaxaca Province, near the most southern point of the Mexican coast (Fig. 1). This area is an upwelling centre, so it is remarkable for its productivity and turbidity. There is evidence of coral bleaching in the ETP because of thermal stress during “El Niño” years, when seawater temperature rises significantly. Bleaching may also occur during “La Niña”, or during the upwelling season, when seawater temperatures are lower. Alarmingly, this phenomenon is becoming more common because of climate change, seawater temperatures increasingly reaching extreme values. Corals are limited to species of *Pocillopora*, *Porites* and *Pavona,* although pocilloporids are the more successful and abundant. Reefs at Huatulco are exposed to natural disturbance with high frequency and great interannual variability. Disturbance includes seasonal upwelling, algal blooms, high turbidity, hurricanes, ENSO fluctuation, and sea urchin outbreaks.

The Bahías de Huatulco area has a narrow continental shelf that prevents the growth of large coral reefs such as those found in the Mexican Caribbean. One of the main characteristics of this place is high seismicity. Lithic and tectonic structure are related to regional metamorphism, caused by convergence between the North American and Cocos plates. Tectonic plates are very active, making this geographical area highly mutable. In 2020, for instance, an earthquake made the shoreline rise nearly half a meter. Other sudden changes have caused reef elevation and coral death due to low water exposure. There are places up to 5000 m deep, but they are yet to be explored. Within the Bahías de Huatulco there are nine smaller bays: Chachacual, Riscalillo, Órgano, Cacaluta, Santa Cruz, San Agustín, Chahué, Tangolunda and Conejos (Fig.1). We could work only in Órgano, Cacaluta and Chahué, given the accessibility. Storms and cyclones are frequent, so that erosion in shallow reefs is common and terrestrial input of fresh water a critical influence. Wave energy is very strong, so mesophotic reefs are likely affected by high sediment flux. To understand benthic macroinvertebrate composition is important to appreciate how marine ecosystems are shaped under these unique conditions.

Figure 1. Map of the coastline of the Bahías de Huatulco area, showing the locations of the individual bays that were surveyed.

Studies at depth

Modern technical diving with mixed gases allows divers to reach 100 m, but there are still risks due to the pressures and depths involved. The use of modern technology such as remotely operated vehicles (ROVs) allows us to explore deeper zones with no hazard. In our expedition, we used a ROVEEE (Roboteknik), which has 3200 lumen lights and a camera. We attached two additional high-resolution cameras and a data logger enabling us to measure light intensity and temperature through the depth gradient. With the ROV we were able to cover transects that were a nautical mile long, recording nearly a hectare of seabed per dive.

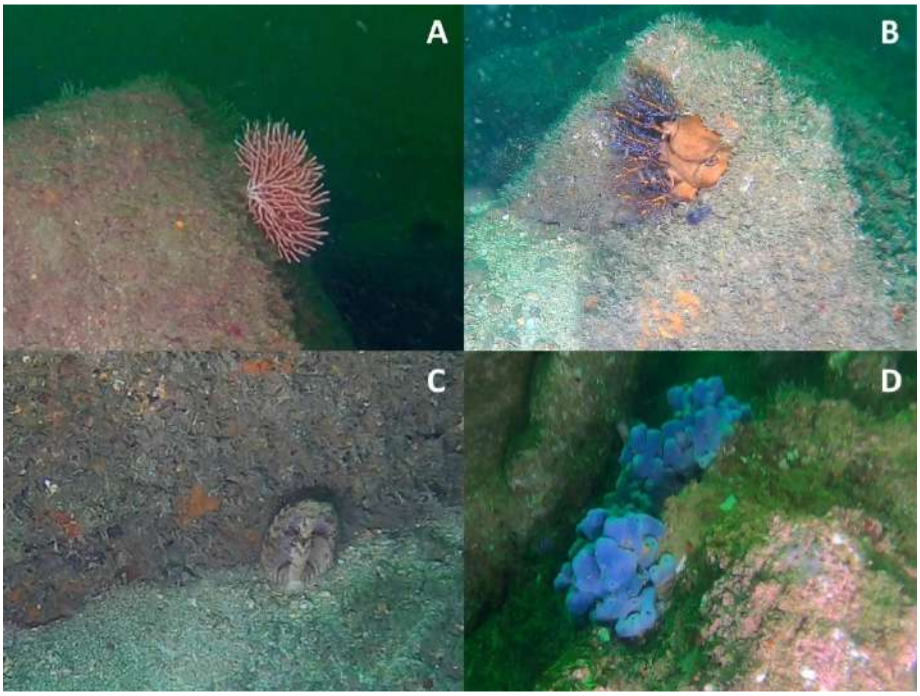

Figure 2. (A) The brittle star *Ophiothela mirabilis* living on a colony of *Leptogorgia alba* at 35 m deep on a rocky reef in the Mexican Pacific (Bahías de Huatulco, Mexico). (B) The sea cucumber *Cucumaria flamma* at mesophotic depths in the Mexican Pacific (Bahías de Huatulco, Mexico). (C) The sea-pen *Ptilosarcus undulatus* at mesophotic depths in the Mexican Pacific (Bahías de Huatulco, Mexico). (D) The sponge *Haliclona caerulea* at mesophotic depths in the Mexican Pacific (Bahias de Huatulco, Mexico).

The main purpose of the work was to investigate variation in species composition across depth, and assess species overlap between shallow and deep ecosystems. If there are no shared species, then deep ecosystems are unlikely to serve as refuges for shallower water species (Laverick et al. 2018). Knowing this one can consider ecological interaction and energy flux across the ecosystem. Where the population of sea urchins is low, grazing pressure may decrease, causing algae to bloom and overgrow other important benthic macroinvertebrates. Conversely, where sea urchin populations are high, competition may increase. This translates to displacement and food web imbalance, for instance. Further, the degree of community overlap varies between geographical regions, so that additional ecological studies are essential to define them. Studying the relationship between depth, temperature and community composition is essential if we are to unravel the physical and biological interactions taking place.

Our findings

We found that there are two types of reefs in the study area: coral reefs and rocky reefs. On coral reefs, macroinvertebrate species richness decreases with depth. While in shallow areas one can find *Pocillopora, Porites, Pavona, Toxopneustes roseus, Isostichopus fuscus* and *Tripneustes depressus*, corals on deep reefs are limited to plate pocilloporids. This is likely due to lower temperature and food availability. In addition, reef complexity decreases with depth: *Pocillopora* sp. abundance decreases and, in some places, there is no hard substrate available. Environmental disturbance was found at shallow depths, with evidence of bleaching and bioerosion.

On rocky reefs, in contrast, the macrobenthos in shallow areas was limited to *Leptogorgia alba* or *Tubastraea coccinea* and ascidians, whereas at depth one can find these species plus a rich sponge and echinoderm assemblage (*Cucumaria flamma, Eucidaris thouarsii, Astropyga pulvinata, Asteropsis carinifera* and *Pentaceraster cumingi*) (Figs 2, 3). This is likely because on shallow rocky reefs the slopes are steep, limiting light and nutrient absorption, as well as hindering organism settlement. Disturbance was found at both depths: at shallow depths, there is a high wave energy hitting the reef. At deeper zones, sediment accumulation threatens macroinvertebrate diversity.

In conclusion, the deeper reefs of the Gulf of Tehuantepec region do not seem to offer hope of a refuge for shallow-water benthic macroinvertebrates. This is firstly because there is evidence of disturbance on deep rocky reefs: mainly debris accumulation, and mechanical impact to molluscs and corals. Although echinoderm richness increases with depth on rocky reefs, this is likely a result of the gentler slopes at depth and increasing rocky substrate complexity, rather than of good environmental conditions. The sea-urchin *Eucidaris thouarsii* was very abundant, as well as sponges. Both groups are highly related to disturbed environments (Cabanillas-Terán et al. 2016). Other echinoderm species seem to be negatively affected and sessile organisms vulnerable to burial. Hence, we could not conclude that these are safe places or refuges for invertebrates, but rather a space where highly resilient species are successful if proper substrate is available.

Secondly, deep coral reefs do not share species with shallow coral reefs. Although one could conclude that depth provides a refuge for pocilloporids, the reality is that they are very resilient to shallow disturbance, meaning they can easily recover. Further, *Pocillopora* colonies have high substrate cover and this is a dominant species, so *they* are not the ones that *need* a shelter.

Finally, it should be emphasised that while environmental factors shape community composition, geomorphology plays a very important role. Sedimentary dynamics through the water column should also be considered. Considering the evidence worldwide, we cannot rely merely on deep ecosystems for biodiversity conservation. Our data are undergoing statistical analyses expected to sustain our conclusions; hopefully we will publish them soon.

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REEF EDGE

Hume & Voolstra

reefMapMaker - convenient creation of user-defined regional maps with coral reef locations

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Coral reefs are globally distributed in tropical and subtropical oceans around the world, roughly between 30 deg S and 30 deg N latitude (Fig. 1).

Figure 1. Coral reefs of the world. The map was made using reefMapMaker and the UNEP-WCMC global distribution of warm-water coral reefs dataset.

Despite the availability of datasets that detail the global distribution of coral reefs around the world, it is not straightforward to produce user-defined regional maps with coral reef locations indicated. Making such maps is often undertaken using R- or Python-based packages/scripts or professional GIS software such as ArcGIS (https://www.arcgis.com/). However, doing so can often be time consuming and requires considerable experience/familiarity with the mapping libraries/software in question. We have developed reefMapMaker, a conda-installed Python script that uses the UNEP World Conservation Monitoring Centre's (UNEP-WCMC) global distribution of warm-water coral reefs dataset to produce a map figure (.png and .svg format) of a user-specified region annotated with coral reef locations as well as user-specified sites (e.g., Fig. 2).

After a guided installation (see https://github.com/didillysquat/reefMapMaker), reefMapMaker conveniently runs on computers running Mac OS, Windows OS, Linux OS. reefMapMaker generates its maps by integrating the UNEP-WCMC's reef data with features from Natural Earth (naturalearthdata.com) using the Python package cartopy (scitools.org.uk/cartopy). Full documentation for installation and usage can be found at the GitHub repository here: https://github.com/didillysquat/reefMapMaker

reefMapMaker is designed to simplify the task of producing publication-ready map figures and to enable users with no prior experience in scripting languages or GIS software to make use of the available online resources to support their research.

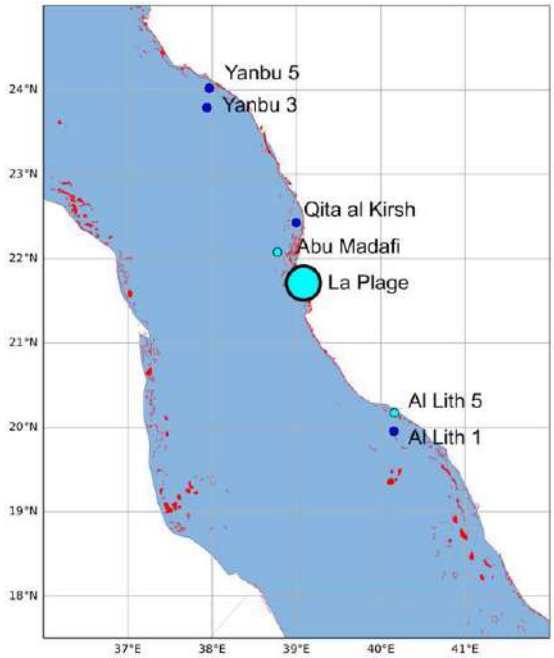

Figure 2. Example of a Red Sea ocean map detailing user-specified sites with reference reefs using the reefMapMaker package.

Future releases will enable integration with additional data sources such as NOAA's Coral Reef Watch (https://coralreefwatch.noaa.gov/crtr/data_resources.php). Watch this space!

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Precht et al.

Corals survive the burial stress of seasonally shifting sands

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Sedimentation is often considered one of the main stress factors in coral environments, affecting coral populations by reducing their percent cover, diversity, growth rates, colony size, and overall recruitment success (Rogers 1990). As part of a repeated measures monitoring program associated with the Port Miami Deep Dredge project (DCA 2015), our scientific dive team observed and photographed a significant sedimentation event associated with the passage of the first winter storm recorded in early November 2013. It should be noted that this event occurred some three weeks before the onset of any dredging activities. This event buried a massive area of nearshore hardbottom habitats in migrating, rippled sands. In this note we document this event, its persistence over time, and the remarkable resilience of corals buried for many months that re-emerged unscathed from this prolonged seasonal burial event.

The response of sands that move in time and space is causally related to the physical hydrodynamic processes occurring in the nearshore sedimentary environment. Nearshore sand bodies are dynamic features which change their shape, amplitude, and position in response to changing wave conditions. Storm waves usually strip sediments from the beach, and deposit them in the subtidal environment. After a storm, low-energy swells drive the sediments landward. Thus, beach topography and sediment volume vary with changes in wave-climatic regimes. Because of this direct relationship with changing wave conditions, beach erosion and beach reconstruction are often cyclic in nature and are often in phase with the seasons where winter storms erode beaches while lower-energy summer swells rebuild them (Shepard 1950; Davis 1985; Dalrymple 1992). Seasonal changes in beach morphology are traditionally ascribed to a variation in the incident wave energy level with calm conditions in summer resulting in wide beaches with pronounced subaerial berms and the energetic conditions in winter causing narrow beaches with a corresponding morphology of sand bars and nearshore sand flats that migrate offshore (Fig. 1).

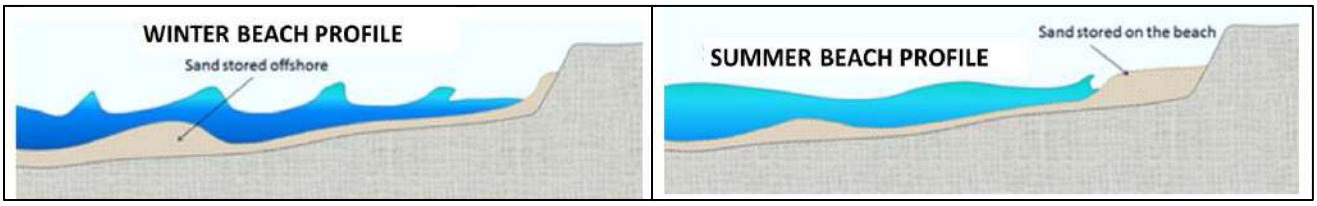

Figure 1. Cartoon depiction of winter versus summer beach profile. Note the abundance of sediment deposited offshore during the winter season. Figure modified from original in Webb (2019).

Specifically, off Miami Beach, Florida, during the summer months, there is a slight northward longshore sediment transport along the beach which is due to the prevailing southeasterly trade winds; this results in sand building up against the beach. However, these beaches subsequently erode in winter when the longshore sediment transport is reversed toward the south due to more intense easterly and northeasterly winds and increasing wave heights (Figs. 2 & 3). Thus, the direction of incoming waves and wind seasonally transport masses of sand both across and along the shore (Davis 1985; Komar 1998; Short 1999). This movement alternately builds beaches and berms during the usually gentle waves of summer months, from sand stored in nearshore sandbars, and builds offshore sandbars and broad migrating sand flats from the eroding beaches and the nearshore bars during the winter season (Darling 1965; Aubrey 1979). These migrating sands ephemerally cover and uncover adjacent subtidal hardbottom habitats (Lybolt and Tate 2008). Throughout southeast Florida many of these nearshore hardbottom habitats are covered with a benthic community assemblage replete with a host of eurytopic species including stony corals (Lirman 2013; McCarthy et al. 2020).

Between November 1 – 7, 2013 the first major storm of the winter season passed over the Port Miami project compliance monitoring sites (Fig. 3). Large sand waves moved from west to east during this period, burying a nearshore hardbottom site that we were monitoring (Site HBN1-CP; see DCA 2015). This site was located approximately 750 meters from the Miami Beach shoreline and about 10 meters north of the Port Miami shipping channel (a.k.a. Government Cut). In all, 23 tagged corals, all *Siderastrea siderea* or *Solenastrea bournoni* that we were monitoring at that site were completely buried in this event (Fig. 4). Over the next few weeks, the depth of sediment at the site continued to increase eventually burying not just the corals but their adjacent numbered tags. A return visit to the site in February 2014 showed that > 95% of this habitat remained covered in a thick veneer of rippled sand (Fig. 5). Subsequently, in the summer of 2014 as wave conditions diminished, the sands slowly migrated in the opposite direction from east to west, re-exposing the hardbottom as well as all 23 tagged corals. Initially, the corals were bleached white from being buried for a period of as much as eight months. Remarkably, all the corals regained their color (zooxanthellae) within a week or so of being re-exposed. During our final monitoring event performed in late July 2016 all corals were still alive and looked almost identical (both in shape and size) to our initial observations made in October of 2013. Another interesting point is that none of these corals contracted stony coral tissue loss disease (SCTLD) which was active and ravaging coral populations throughout the offshore waters of Miami-Dade County, Florida from the fall of 2014 until the end of our monitoring program in 2016 (Precht et al. 2019).

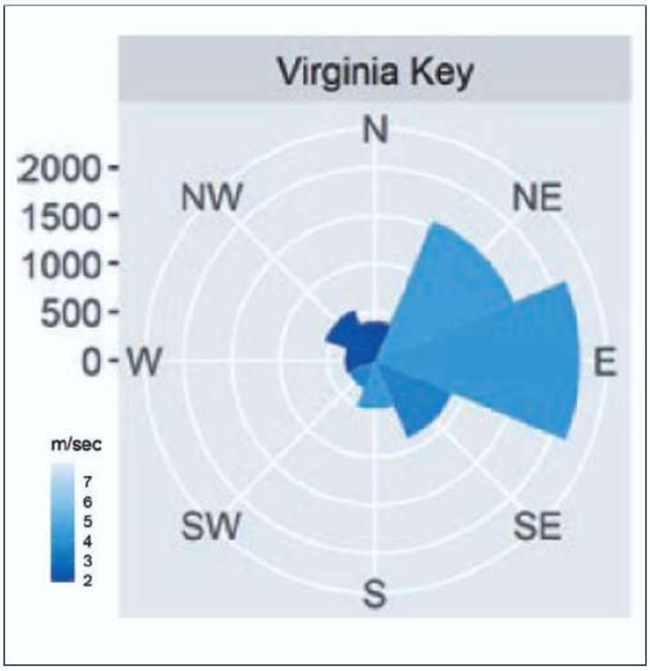

Figure 2. Median wind speed and direction recorded at Virginia Key, Florida (25˚43.9′ N Latitude). Length of pie sections on the chart indicates the frequency of wind from a particular direction over time. Color coding indicates average speed, the lighter the shade of blue the more intense the wind. (Modified from original in McCarthy et al. 2020; source https://tidesandcurrents.noaa.gov/)

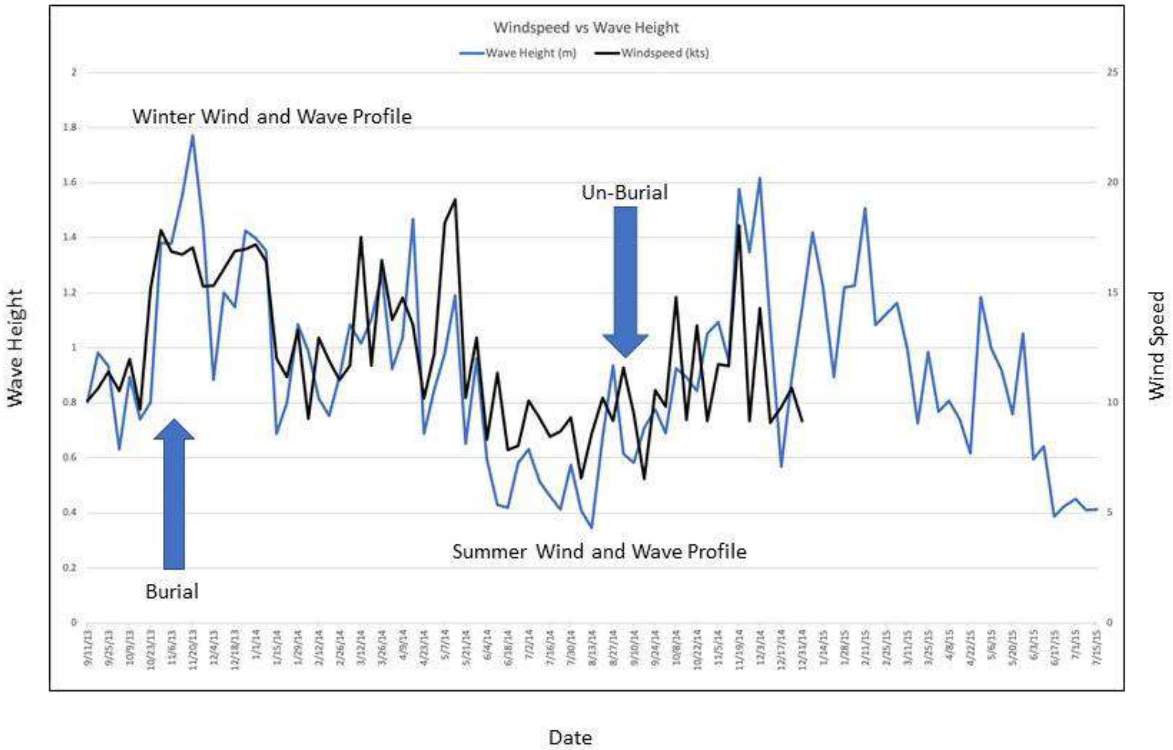

Figure 3. Mean wave heights recorded from a buoy offshore (16.8 m water depth) of Fort Pierce, Florida. Wind speed data was downloaded from NOAA National Data Buoy Center, NOAA National Data Buoy Center, Fowey Rock Station (FWYF1) located due east of Soldier Key. (Source http://www.ndbc.noaa.gov/). These were the closest available offshore data to our site off Miami Beach. Although these buoys are located approximately 130 miles (210 km) from each other, note the amazing correspondence between the curves. Blue arrows correspond to the approximate dates of burial and subsequent unburial of the site associated with seasonal changes in wind regime and wave height.

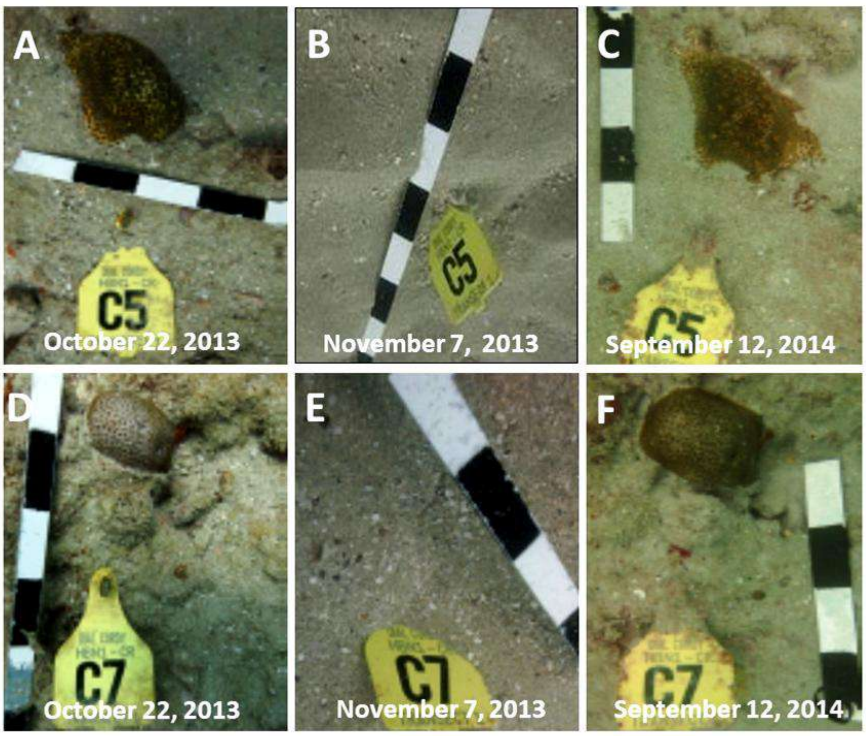

Figure 4. (A) Photo of *Solenastrea bournoni* colony taken at the start of baseline monitoring. (B) Same view two weeks later after mass burial by migrating sand waves; only the tag marking the coral is visible at the surface. (C) Same coral re-exposed almost nine months later. (D) Photo of *Siderastrea siderea* colony during baseline monitoring. (E) Same coral after burial by seasonal storm; note course grained texture of sediment with abundant reef derived *Halimeda* plates admixed with siliclastic/carbonate beach sands. (F) Same *S. siderea* colony after re-exposure in September of 2014. Scale-bar is in 5 cm colored increments.

While many coral scientists have observed the remarkable resilience of certain coral species to sediment stress and even complete burial (Laborel 1970; Nugues and Roberts 2003; Lirman et al. 2002, 2003; Lybolt and Tate 2008; Lirman and Manzello 2009; Bahr et al. 2020; Longo et al. 2020), most of these corals were buried for durations spanning from only a few hours to a few weeks at a time. However, the fact that these corals could remain completely buried for many months shows the remarkable resilience of these corals to annually recurring natural, but extreme conditions.

These long periods of burial also may help explain why no large colonies (> 15 cm in their longest dimension) were found at this site. We are currently in the process of requesting permits from the State of Florida to collect individual colonies from this site in hopes of reconstructing their annual growth rates through sclerochronological analysis, following the methods of Macintyre and Smith (1974) and Hudson et al. (1976).

Figure 5. Oblique angle underwater view of site in February 2014. Note rippled sand sheet covering the hardbottom. A coral tag is barely visible in the lower left corner of the photograph. Live octocorals and sponges with buried holdfasts are also present, but rare at this site.

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Successful recruitment of *Astrangia haimei* in the Gulf of California

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Introduction

Coral larval recruitment is the process that goes from larval settlement to the deposition of a $CaCO_3$ skeleton by the coral recruit (Elmer et al. 2016). During sexual recruitment, corals release propagules that are scattered by water flow and settle near their origin or reach new regions (López-Pérez et al. 2007). Generally, this process is influenced by some ecological interactions (e.g., substrate availability, competence, predation; Ritson-Williams et al. 2009) and the environment (sedimentation, lunar cycles, Sea surface temperature; Glynn et al. 2017).

Larval recruitment of scleractinian corals has been widely studied in areas such as the Caribbean and the Indo-West Pacific (Wallace 1985; Hughes et al. 1999; Ritson-Williams et al. 2009; Arnold and Steneck 2011; Elmer et al. 2016; Price et al. 2019). Sporadic studies have also addressed coral sexual recruitment in the Eastern Pacific (EP), the first being conducted in Central America (Wellington 1982; Richmond 1985). Recently, several studies have addressed coral recruitment in the Mexican Pacific (MP) and report *Porites panamensis* as the most abundant species recruited (Medina-Rosas et al. 2005; López- Pérez et al. 2007; Santiago-Valentín et al. 2018; Cabral-Tena et al. 2018; López-Pérez and Solís-García 2019).

Bahía de Los Angeles (BLA; 28° 95' N, 113°55' W), in the Gulf of California (GOC), is a Natural Protected Area under Mexican regulations. BLA has low sea surface temperatures during the winter (<15°C), highly productive, turbid waters, and low seawater pH during the upwelling seasons (Halfar et al. 2005). Although these oceanographic conditions inhibit the survival of most reef building coral species (and development of any substantial reef framework), they favor the occurrence of azooxanthellate coral species, whose communities are analogous (in terms of ecological function) to shallow reefs, thus making them a key component of biodiversity in some cold water or deep regions (Reyes-Bonilla et al. 2008). Nine stony coral species have been documented in BLA (Reyes-Bonilla and Cruz-Piñón 2000); two of them are reef-building species (zooxanthellate), and at least seven azooxanthellate coral species, including *Astrangia haimei*. The stony coral community of BLA is considered a high-latitude coral community (HLCC). HLCCs are generally located at latitudes above 25° (Moyer et al. 2003), and because of their existence in harsh environmental conditions (Glynn et al. 1996) they have the potential to be better adapted for survival in a rapidly changing environment (Riegl and Piller 2003); they may therefore act as refugia for low-latitude species during environmental stressful times (Moyer et al. 2003). Despite their common occurrence and their importance in the discussion of global change, patterns of coral community development (Perry and Larcombe 2003) and their oceanographic controls remains poorly documented in high-latitude sites. Thus, the study of coral recruitment in such environments constitutes a priority for the conservation and management of coral reefs. This study reports recruitment of *Astrangia haimei* on an artificial substrate at two sites in BLA during one year of evaluation.

Materials and Methods

Coral Recruitment was measured at two sites (Llave and Rasito) in BLA, located in the northern part of the Gulf of California (29°01'15" N, 113°31'O). Six terracotta tiles (21 x 5.7 x 9.4 cm; 1125.18 cm2) were placed to estimate the number of recruits at each site, tied to rocks with tarred rope, with a meter of separation between each tile, in such way that all faces were available for the settlement of recruits. Between August 2018 and October 2019, the tiles were replaced each season: Summer-Autumn, 90 days (August 20 to November 19); Autumn-Winter, 111 days (November 19 to March 22); Winter-Spring, 86 days (March 22 to June 16); Spring-Summer, 140 days (June 16 to October 28) in order to evaluate temporal and spatial variation in recruitment. In total, 42 tiles were placed across the two sampling sites, 18 at Rasito and 24 at Llave. The tiles were extracted and fixed in 4% formaldehyde for further processing in the laboratory. In the laboratory, the organic matter on the tiles was removed by means of 20% sodium hypochlorite for 24 hours, after which they were then dried in the sun and the recruits counted with the help of a stereoscope. The identification of the coral recruits was carried out with the aid of specialized literature (Durham 1947; López-Pérez et al. 2004; Reyes-Bonilla et al. 2008; Bertsch and Aguilar-Rosas 2016; Cabral-Tena et al. 2018). Each tile was considered as an independent experimental unit. Recruit density was calculated as the number of recruits within the area of each tile ($0.074 m^2$) from which annual ($ind\ m^{-2}\ yr^{-1}$), and seasonal ($ind\ m^{-2}\ d^{-1}$) recruitment rates were also calculated.

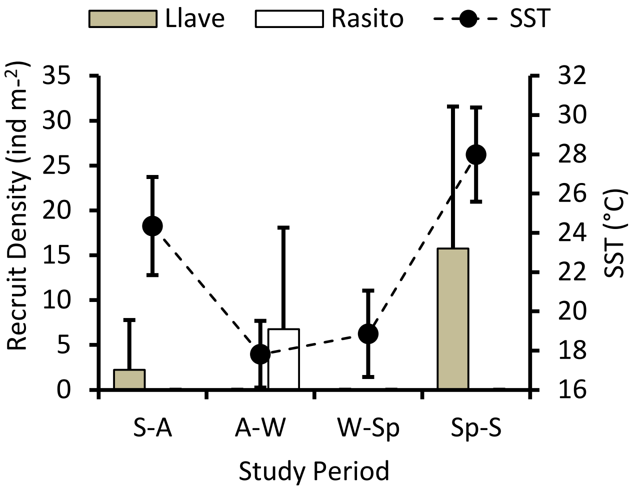

Figure 2. Density of coral recruits and Sea-Surface Temperature (SST) per site and study period. S, Summer; A, autumn, W, Winter; Sp, Spring. Error bars represent standard deviation.

Results and Discussion

A total of eleven *Astrangia haimei* coral recruits (Figure 1) were recorded in the study; eight of them were recorded at Llave (Density: 4.50 ind m^{-2}, Rate: 3.85 ind m^{-2} yr^{-1}) and three at Rasito (Density: 2.25 ind m^{-2}, Rate: 1.93 ind m^{-2} yr^{-1}).

Figure 1. Photograph of an *Astrangia haimei* coral recruit. The photographs were taken using an optical microscope, 4x.

At Llave, the highest recruitment was recorded during the Spring-Summer study period (Density: 15.77 ind m^{-2}, Rate: 0.18 ind m^{-2} d^{-1}). In contrast at Rasito, the highest recruitment was during the Autumn-Winter study period (Density: 6.76 ind m^{-2}, Rate: 0.06 ind m^{-2} d^{-1}). No recruitment was recorded during the Winter-Spring study period at either site (Figure 2). Maximum coral recruitment coincided with the warm season (Figure 2).

This is the first record of the recruitment of *Astrangia haimei* in the Eastern Pacific. A previous study (Fadlallah 1982) of the reproductive ecology of *A. haimei* (syn. *Astrangia lajollaensis*) in Pacific Grove-California showed a failure in the recruitment process of this coral. The author highlighted that gametogenesis had been reported in the histological record, but without successful recruitment. It was suggested that this failure is due to biological and environmental features of the habitat, which favor asexual reproduction to maintain the population of *A. haimei* (Fadlallah 1982).

Nevertheless, in the present study *Astrangia haimei* showed a lower density and recruitment rate than other coral species in the Eastern Pacific, (Glynn *et al.* 1994; Medina-Rosas *et al.* 2005; López-Pérez *et al.* 2007; Santiago-Valentín *et al.* 2018; Cabral-Tena *et al.* 2018; López-Pérez and Solís-García 2019); this may be associated with the reproductive strategy of this species: it is a spawning coral with a unique reproductive cycle (Szmant 1986; Ruppert and Fox 1988). Consequently, this coral has a lower fertilization rate, smaller larvae (reduced viability) and a higher mortality of recruits than observed in other species (Fadlallah 1982). Moreover, *A. haimei* is a solitary coral showing a high mortality and lower competitive capacity for the substrate (Fadlallah 1982).

According to the literature, *A. haimei* is a spawning coral that reproduces from November to March (Fadlallah 1982). However, as shown in Figure 2, the recruitment of *A. haimei* peaked during the Spring-Summer season in Llave, not during the Autumn-Winter season as expected. Although studies of species of *Astrangia* have reported a wide range of tolerance to variable environmental conditions (Peters et al. 1988), coral recruits of these species had not been found in previous studies, so the recruitment of larvae of *Astrangia* is considered a rare event (Fadlallah 1982).

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REEF ACTIONS

Invitation to view AIMS historic coral photo transects

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This note is to offer members the opportunity to view some special bits of the Great Barrier Reef that the Australian Institute of Marine Science (AIMS) photographed most years over the last couple of decades of the last century: early 1980s to early 2000s. The near-vertical stereo images were initially taken on film, but are now in digital form. I have been developing tools to extract descriptive and demographic data from these images, using a citizen science portal called 'Zooniverse'. The project is called Coral Baseline GBR, and it will provide both a static baseline for all sites in the early 1980s, and a moving baseline from 1980 to 2000, as sites were variously damaged (or not), and recovered (or not), during that time.

I invite you to visit the website, just for a look at the diversity of coral communities, or later on, if you want, to join Zooniverse volunteers in doing random point sampling and size measurements to document moving baselines. See: https://www.zooniverse.org/projects/pteranodon01/coral-baseline-gbr

You'll get to see the tops, edges and slopes of reefs in all sorts of environments, from muddy nearshore waters, to wave-beaten outer-slope habitats that lie more than 100 km offshore in clear waters at the edge of the Coral Sea, and many more between.

All together, there are 31 photo-transects in two series (Figures 1 and 2): one on the AIMS cross-shelf transect (latitude around 19°S), and one at Lizard Island and Yonge Reef (latitude around 15°S). I described 17 distinctive coral communities that I recognized on the AIMS cross-shelf transect in the first volume of Coral Reefs back in 1982. The paper includes species lists for the 17 communities, and also identifies the need for time-series studies. The photo-transects were established to fill that need. The two other papers mentioned below came from a few of the transects.

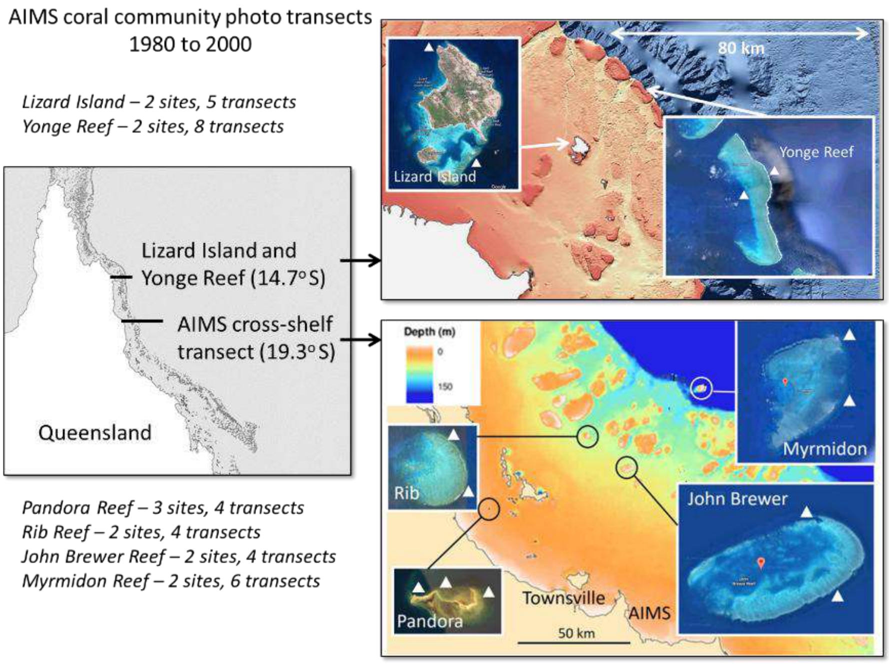

Figure 1. Location of study sites

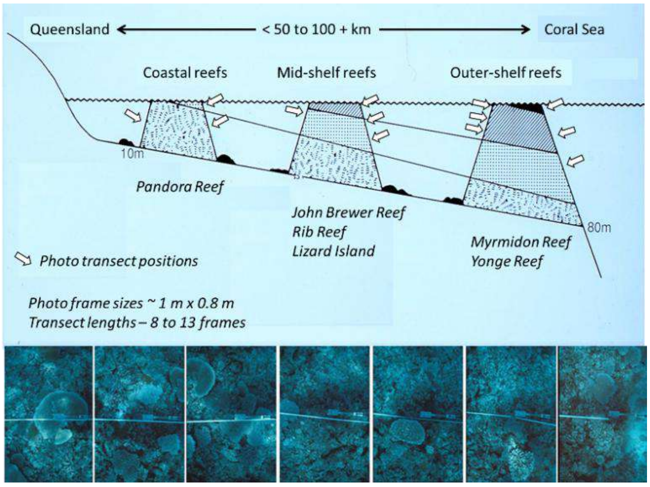

Figure 2. Position of phototransects on stylized cross-shelf profile of the Great Barrier Reef

Zooniverse presents you with the images in a way that makes you swim along all the transects of the one reef, from deep to shallow, before you move onto the next reef. To help you get an appreciation of where each transect is geographically and environmentally, each is preceded by a composite diagram (Figure 3) highlighting its position on a cross-shelf profile, on an aerial photo, and on a diagram representing two major environmental drivers of coral community structure across the GBR: light and wave action.

My AIMS collaborators on this project are Manual Gonzalez-Rivero and Juan Ortiz. We will be including the time-series one reef at a time over coming months, starting with John Brewer Reef and Myrmidon Reef, on the AIMS cross-shelf transect.

Reading

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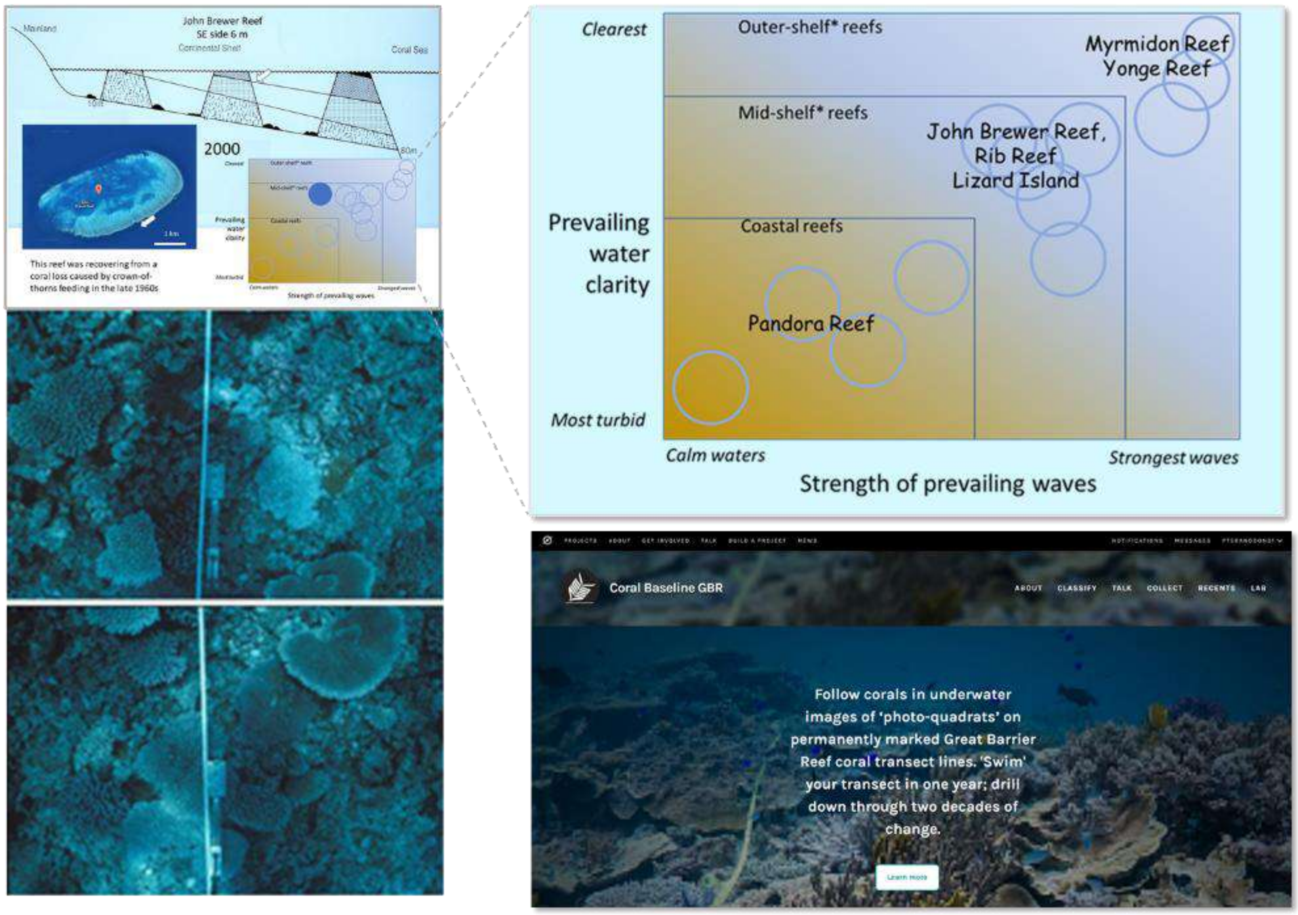

https://www.zooniverse.org/projects/pteranodon01/coral-baseline-gbr

Figure 3. Example of a composite diagram (top left) that precedes each transect (bottom left, typically 8 – 10 images). The subjective environmental space (light v wave action) for the different reefs is shown on the top right. Bottom right is the project's Zooniverse home page.

The great artist (or scientist) is the simplifier: developing Barbados' first Coral Reef Report Card

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"The great artist is the simplifier", said Vincent van Gogh, but so is the great scientist. Barbados has been steadfast in its collection of coral reef data since the 1990s, and is endowed with many published scientific papers on the health of the marine environment. In light of the nation's stated desire to embrace a bluer economy, we concur that regular assessment of the health status of the Barbados' marine environment is of course critical - but only really effective if the information is broadly accessible for stakeholders to take action! What good is it to have scores of datasets meticulously collected and analysed, if the findings are only shared amongst scientists, and moreover, done so in a language that cannot be universally understood? A small but formidable group from the Centre for Resource Management and Environmental Studies (CERMES) at the University of the West Indies, Cave Hill, Barbados took van Gogh's sentiment to heart. Thus, Barbados' first Coral Reef Report Card began development in 2020, in collaboration with the Barbados Coastal Zone Management Unit.

The production of this document was approached as both a scientific and creative endeavour. Its aim is to close the knowledge gap between marine scientists, government officials and the general public, and so inspire the average Barbadian to play their part in the management of Barbados' marine environment. The status and health of the island's coral reefs, mangrove and seagrass ecosystems are illustrated in an output that is colourful, succinct, accurate and uses simple language that the non-scientific public can understand.

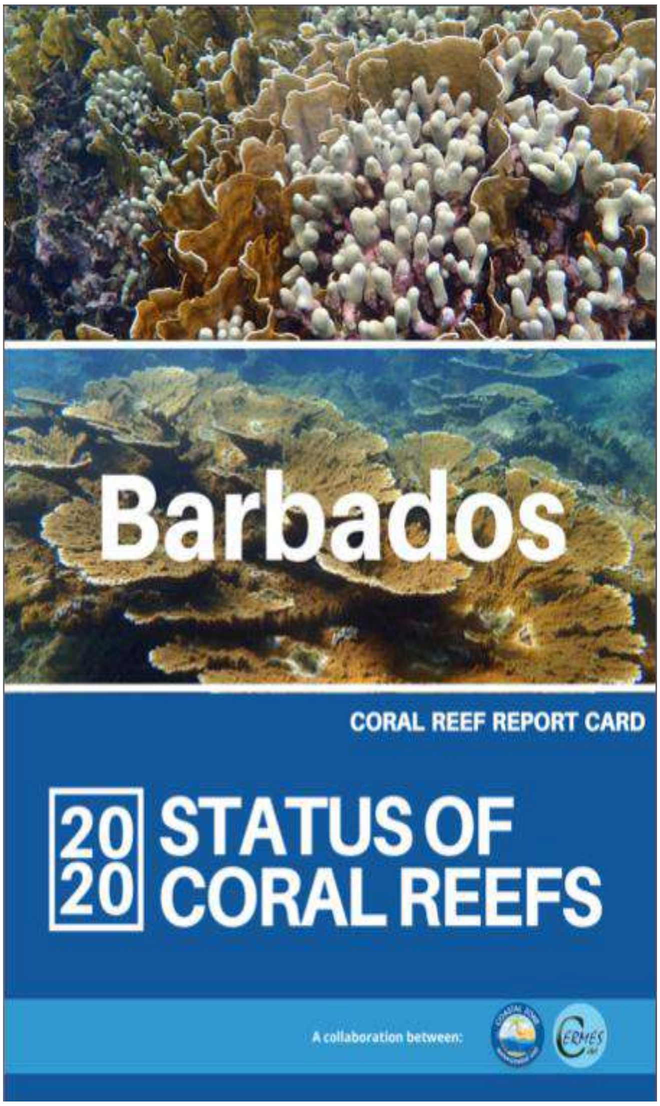


Figure 1. Front page of the 2020 Barbados Coral Reef Report Card

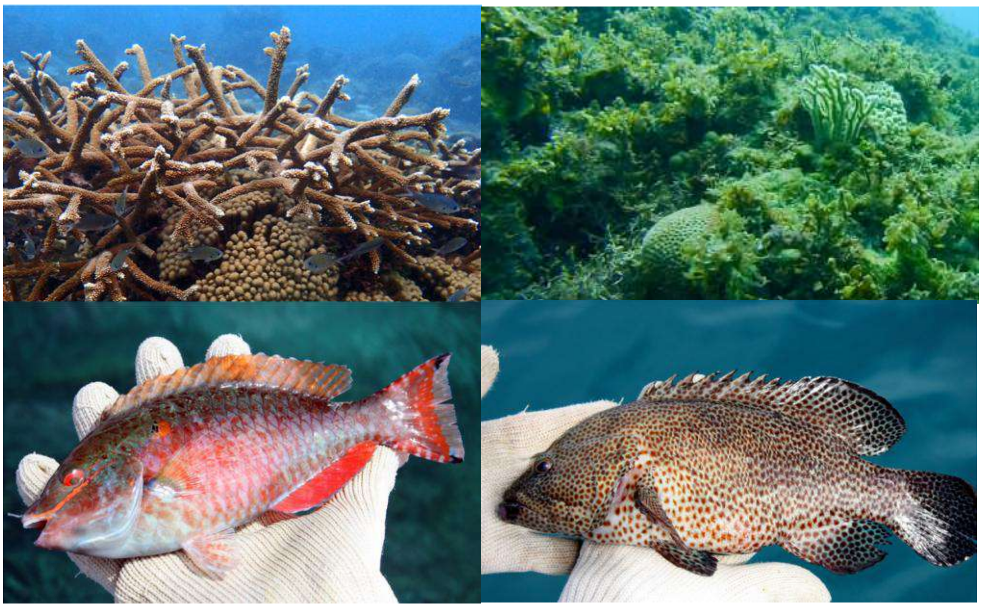


Figure 2. The four indicators used to determine the health of Barbados' reefs – coral cover, macroalgae cover, herbivorous fish abundance and commercial fish abundance. Photo credit: Amy Cox and Hazel Oxenford.

The method of assessing reef health in the Barbados Coral Reef Report Card was informed by other regional report cards, allowing easy comparisons with other Caribbean territories to see how we are all doing relative to each other. The Reef Health Index used is simple and based on coral cover, macroalgae cover, and the abundance of herbivorous fishes (surgeonfishes and parrotfishes) and higher trophic-level fish species of commercial importance (snappers and groupers), with data being collected along 10 x 1 m belt transects. The analysis of the most recent survey in 2017 revealed that the island's reefs are, on average, in 'fair' condition.

Assessment of time-series datasets indicated some decline and some improvement across the different reef health indicators. This included a general decline in coral cover, and slight improvements in fish abundance, although the density of all fishes, especially snappers and groupers remain critically low.

While the success of this output is yet to be determined with regard to influencing public social change, the report's preliminary issue has already attracted the attention of the Minister of Maritime Affairs and Blue Economy, who stated in his address at the opening of Barbados' Bluefest Week 2020 that the time has come to legislate the protection of undersized fishes, and of parrotfishes in particular.

Going forward we look forward to positive changes in the hearts and minds of Barbadians to ensure better protection and a rejuvenation in the health of Barbados' critical ecosystems.

Reef Health Indicators	VERY GOOD	GOOD	FAIR	POOR	VERY POOR
SCORE	5	4	3	2	1
CORAL COVER (%)	≥40.0	20.0 - 39.9	10.0 - 19.9	5.0 - 9.9	<5.0
MACROALGAE COVER (%)	0-0.9	1.0 - 5.0	5.1 - 12.0	12.1 - 25.0	>25.0
HERBIVOROUS FISH (g per 100m²)	≥3480	2880 - 3479	1920 - 2879	960 - 1919	<960
COMMERCIAL FISH (g per 100m²)	≥1680	1260 - 1679	840 - 1259	420 - 839	<420

Figure 3. Reef Health Index used in Barbados Coral Reef Report Card, adopted from other regional outputs. A score is assigned (from 1-5) based on the indicator's actual value, with 1 being very poor and 5 being very good. The overall Reef Health Index (RHI) represents the mean score across the four indicators.

DAMSL: Digital Atlas of Marine Species and Locations

In our December 2019 issue we carried an announcement by the Rosenstiel School of Marine and Atmospheric Sciences (RSMAS) that they had launched a new version of DAMSL, their Digital Atlas of Marine Species and Locations. This atlas (available on-line at www.damsl.org.) DAMSL holds images of over 3,500 marine species captured by world-renowned underwater photographer Myron Wang and donated to the School by Myron and his wife Nicole. This atlas is now being expanded to cover, as the name indicates, locations as well as species, with a collection of images from some of the world's most impressive reef locations being added to the system. The example, reproduced below, and also on our cover, shows a soft coral-dominated area of a reef in Milne Bay, Alotau, Papua New Guinea, photographed in April 1994. Interested researchers may contact Myron at mlw0818@yahoo.com.

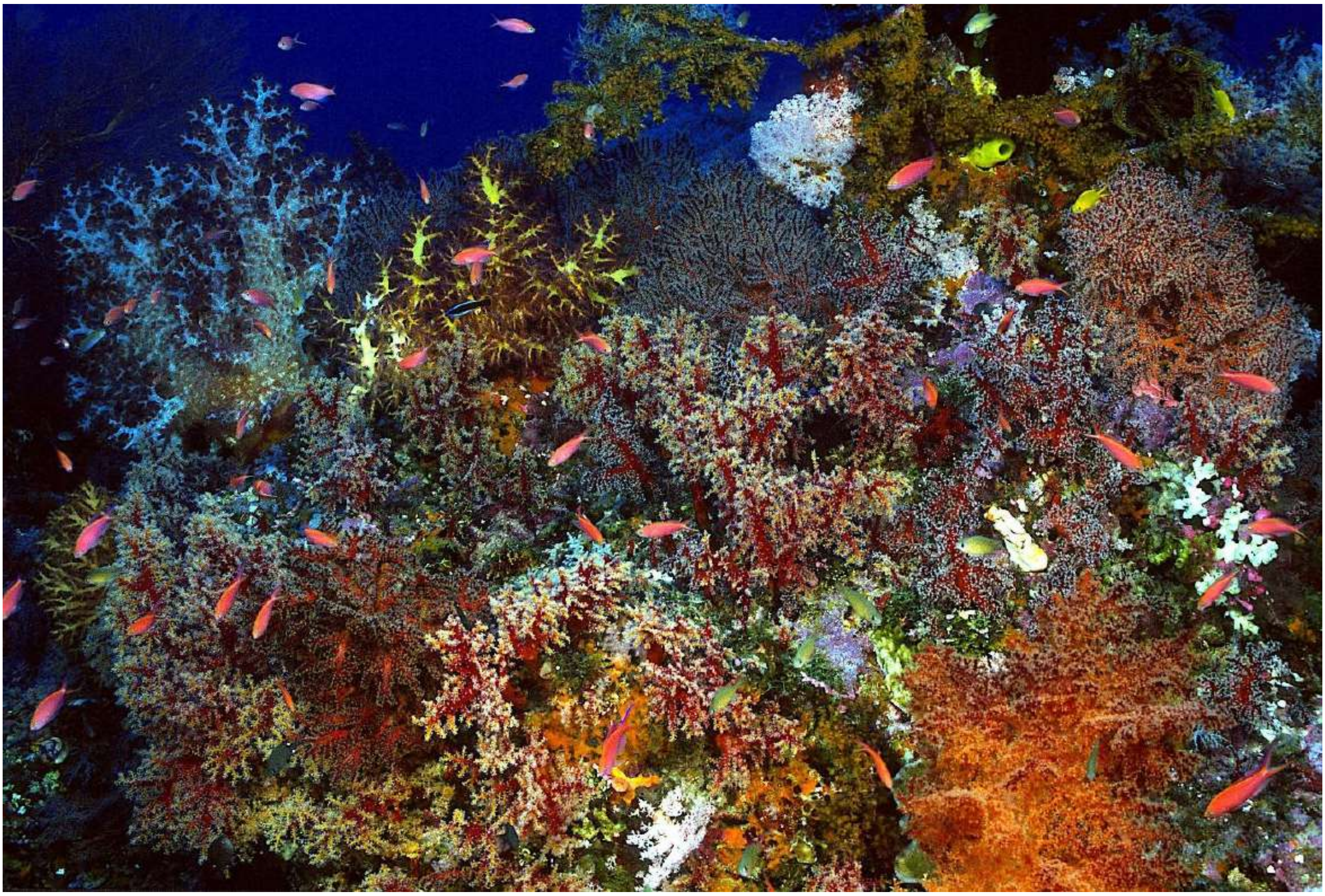
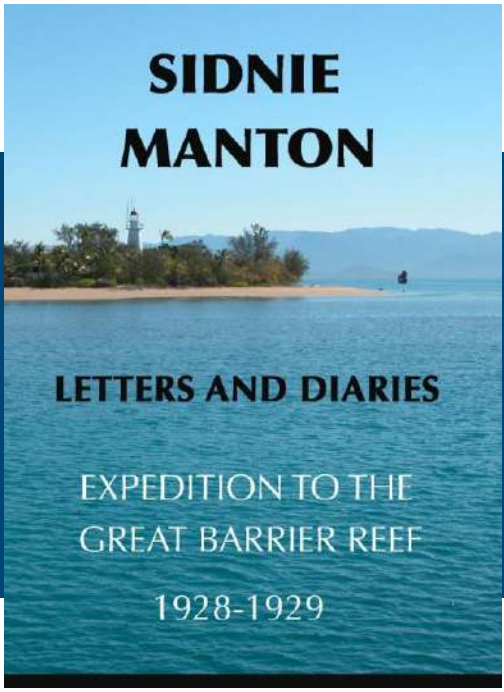


Figure. A reef site in Milne Bay, near Alotau, on the east coast of Papua New Guinea, at about 20 m (photo: Myron Wang)

REEF SHELF



Sidnie Manton: Letter and Diaries

Expedition to the Great Barrier Reef 1928-29

Elizabeth and Jeanie Clifford 2020

Publisher: Amazon (307 pages)

UK	£12.50;
USA	$16.15
Kindle	$9.99

The Great Barrier Reef Expedition of 1928-29, comprising British and Australian scientists, had a profound influence on reef science for at least five decades. It has also provided a scientific legacy right up to the present, almost 100 years after the expeditioners first stepped on to Low Isles on the northern Great Barrier Reef on July 16th, 1928; it was to be home for the main core of scientists for just over 12 months. Significant advances were made in the understanding of nutrition of corals; their responses to elevated temperature; lunar periodicity in coral reproduction and quantitative estimation of coral and algal distribution along reef 'traverses' that were accurately mapped and levelled for height.

Figure 1. Sidnie Manton sorting coral specimens at Low Isles during the 1928-29 Great Barrier Reef Expedition.

Of the 18 official expedition members six were women, three of whom were wives of expedition members, but all the women played important scientific roles to a greater or lesser degree. One of the unmarried women scientists was Sidnie Manton, a Cambridge graduate in Natural Sciences, who joined the expedition on March 25th, 1929 and participated until its conclusion on July 28th, 1929.

Sidnie had come top of her year class at Cambridge and moved in 1926 to Imperial College, London to work on Crustacea. In 1927 she was offered a post as University Demonstrator, specialising in coelenterates, by Professor Stanley Gardiner, Head of the Department of Zoology, Cambridge who had recognised her considerable ability. This was a significant move by Gardiner, not only because appointments up to that point had been exclusively male but also because he had a major role in bringing about the Great Barrier Reef Expedition of 1928-29. For Sidnie the plan was that after receiving her PhD in 1928, aged 26, she would travel to Tasmania to study primitive syncarid crustaceans and from there join the expeditioners on Low Isles, before travelling to Sulawesi, Bali, Java (where she visited reefs in the Bay of Jakarta with Dr. Verwey, a Dutch reef scientist) and Sumatra on her way home.

This book is a remarkable compilation of her diaries and lively letters home throughout this period. Her daughter and grand-daughter have spent 5 years transcribing these documents. The result is a very readable and amusing account of both her travels and her work on Low Isles. One aspect of the book's importance lies in the candid nature of the documents. It is clear that Sidnie was not writing the letters or the diaries with any view to publication, and as a result, there's little self-censorship. This gives us a genuinely unvarnished view through the eyes of a young woman scientist participating in the research trip of a lifetime. Sidnie's diary entries while at Low Isles seem to have mostly served as a memory aid for when she sat down to write letters home to her family. In comparison, apart from brief mentions of her work, Sidnie's letters are peppered with her opinions about everything she sees or experiences. From the spectacular beauty of the natural environment in Australia, the unpredictable weather, the unreliable transport, the locals – who all speak 'the most atrocious cockney', and the often potentially dangerous work or leisure activities she engages in, the reader is left with little doubt as to her tenacity or intelligence.

For modern reef scientists the main interest will be her experiences on the Great Barrier Reef so long ago. These are told in vivid detail, with quite candid comments about her fellow expedition members, the living conditions and the lengthy hours spent underwater quantitatively monitoring corals along selected 'traverses', regularly sampling coral gonads and measuring growth in pocilloporid corals. She accomplished all these tasks in addition to hours spent photographing fauna and flora in the field and processing film as well as drawing detailed maps of the distribution of corals on the reef. These were long, full days of early mornings and very late nights.

On arrival at Low Isles she joined a team that had already been on the island for 8 months and like the other expedition members she had never visited a coral reef before. In the first few days she was allocated to what she called 'donkey jobs' such as cleaning coral aquaria, preserving specimens, and packing equipment for field excursions. However, from day one she was also out on the reef with the leader of the reef party, Dr. T.A. Stephenson, learning the reef organisms and declaring 'distinguishing corals is a fearful game, so many are alike.' Within 3 weeks of her arrival she had already experimented working underwater wearing the diving helmet (developed along the style of that first used by A. Mayor for underwater observations in Samoa) while a colleague pumped down air from a boat above. By the end of May she became a vital member of the coral ecology team quantitatively surveying corals within quadrats single-handed along the 'traverses'. On May 24th after the first day of working underwater with the helmet she said 'I've had the most marvellous day.' The following month she was to describe her work on reefs close to Lizard Island as 'the most wonderful experience all round of my life' with the corals being 'past description.'

Figure 2. A member of the team (possibly Sir Maurice Yonge himself) trying out the diving helmet.

Such excitement and enthusiasm at experiencing this underwater world will be sentiments shared by many reef scientists. Sidnie's work on the traverses was an important part of the considerable scientific legacy of the Great Barrier Reef Expedition, providing an ecological baseline that has allowed scientists to return to the island's reefs to monitor the changes that have taken place over the last 91 years. Sidnie describes this aspect of the early expedition results in her letter to the family on June 23rd 1929 as 'The sections are truly handsome – nobody has ever made a section of the reef edge before let alone examine its fauna with anything but a dredge.'

We would thoroughly recommend this book to every reef scientist – here you will find the highs and lows associated with reef work in an unpredictable environment, and the importance of multidisciplinary team-work, all told in a very engaging and amusing manner by a clearly extraordinarily-talented woman who was to become a zoological legend and Fellow of the Royal Society as a result of her later work on comparative arthropod anatomy and arthropod evolution.

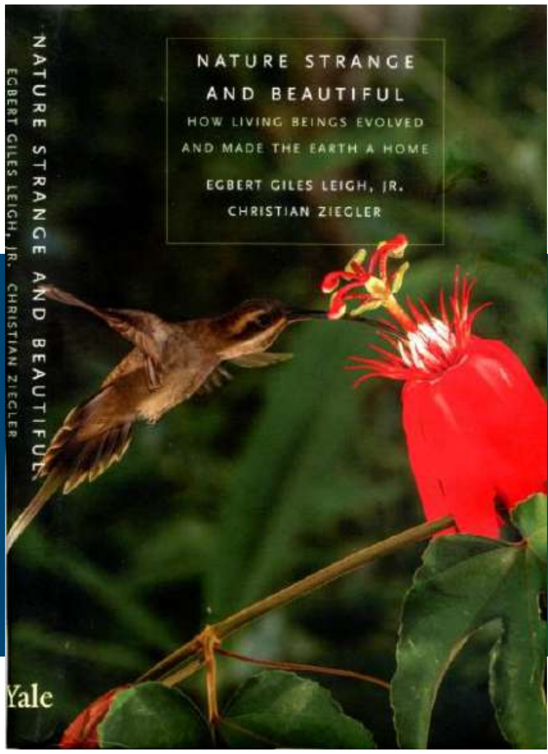
Barbara E. Brown (University of Newcastle, U.K.)
Trisha Fielding (James Cook University Library Special Collections, Australia)

Nature Strange and Beautiful

How living beings evolved and made the Earth a home

Egbert Giles Leigh, Jr., and Christian Ziegler.

Yale University Press, 2019 (304 pages)
Hardback US: $28.00
UK: £17.34



This is a very well written and illustrated book. I like every page. I believe "beauty" in the title refers to the beauty in mathematics or fugues by Bach, i.e., beauty is when complex systems fit together in surprising and elegant ways. The author claims the book is not a thorough review of the mechanisms of evolution and the history of life, but it nevertheless covers many major transitions from the origin of life to the development of consciousness. The theme or focus of this book seems to be cooperation at all levels: between genes, between individuals in social animals including insects, between species, between phyla in mutualisms, and between domains (prokaryotes and eukaryotes). One example at the ecosystem level is the recent (in geological time) origin of grasslands with the coevolution of grasslands and grazers. The removals of "cheaters" that take advantage of the systems are also covered at all levels from genes to societies.

Of course, coral reefs are rich in mutualisms. One cited example I enjoyed was the reference to Janie Wulff's study of three species of coral-reef sponges that grew faster and survived better when intertwined with each other than when alone. Each of the species of sponges had different attributes that provided benefits for the combined group. One species is not easily broken and torn away by storms and is resistant to predation by angelfishes, a second is resistant to effects of sedimentation and predation by starfish, and the third is most able to reattach to substrata if ripped loose. But often, there are "cheaters". A fourth species of sponge takes advantage of the traits of its hosts, but contributes nothing. It grows more rapidly, is less long-lived, and reproduces quickly by fragmentation. Like a disease, it must infect new hosts before killing its present host.

Even if you feel you already know everything about the mechanisms of evolution and the history of life, the clear writing and marvelous examples still make reading delightful. For example, to illustrate flexible phenotypes to accommodate contingencies, the author refers to the ability of embryos of a species of tropical tree frog to "decide" whether to immediately hatch if predation is near. Tadpoles must live in the water, but there are too many predators on eggs and young tadpoles. So the frog comes down from the tree and places eggs on a leaf just above the water. If an egg-eating snake approaches the leaf, the eggs or embryos can recognize the vibrations. If tadpoles are well enough developed (after 5 days of development) to have even a small chance in the water, the eggs hatch immediately. Although, they would have been better off to develop for at least 2 more days in the eggs, they at least have a chance. They jump from the fire to the frying pan. The embryos do not react to vibrations from rainfall, wind, transport by foot, or even an earthquake at 4.7 on the Richter scale, only predatory snakes (Warkentin. 1995. Proc Nat Acad Sci 92: 3507-3510). Every example and every page is delightful and clearly written.

The writing is great and it all reads smoothly because the frank assessment of literature on supporting work and presentation of mathematical support or details of chemical processes are provided in a second part of the book, a sort of large appendix, the Bibliographic Essay. I appreciate this as a reference to have for the chemosynthesis of the earliest times and presently at the mid-Atlantic ridge and other "black smokers" and for the more primitive forms of photosynthesis. All animals have the optimal diameter of arteries, veins and capillaries to minimize the cost of moving blood, and friction within the vessel wall is minimized for all sizes of blood vessels. The mathematics of the cost of moving the blood and the friction with the vessel wall is the same for vessels of all diameters. The mathematics for this and other matters is clearly explained, but it just takes a while to work through. The main body of the book is for a delightful trip through the history of life at all levels from cells to languages and cultures, with the second part for those of us that wish to get the details of the substance of the evidence in the literature.

Chuck Birkeland (University of Hawaii at Manoa)

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REEF DEPARTURES

Tributes to recently departed members and reef scientists

Jon Brodie (1947-2020)

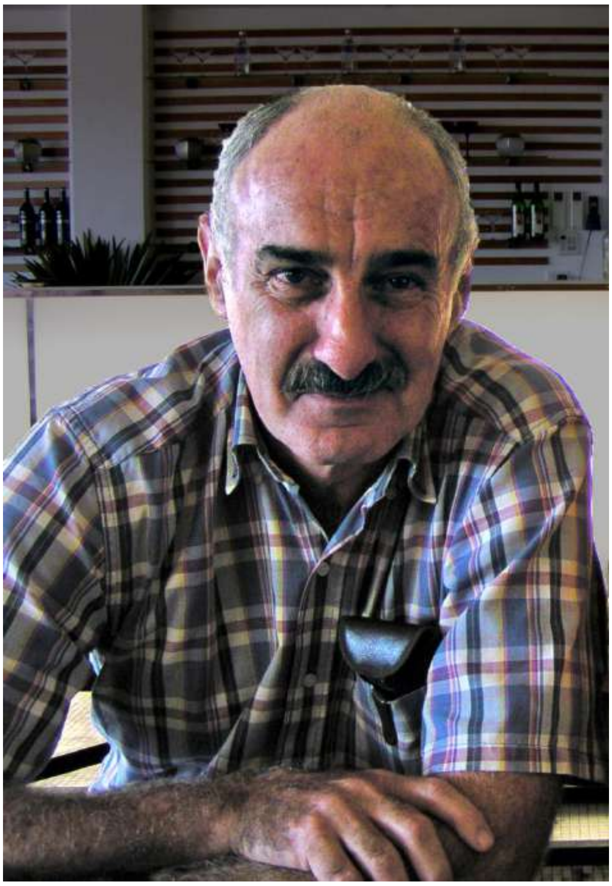
By Gilianne Brodie, Nicola Brodie, Lyndon DeVantier, Emre Turak, Jane Waterhouse, Sue Wells

The reef research and management world lost another outstanding elder recently, with the passing of Dr Jon Brodie in June 2020. Jon had shrugged off several serious health issues in the preceding years, showing remarkable resilience throughout. For over 30 years Jon had driven efforts to stem the impact of pollution on the Great Barrier Reef, and conserve marine systems more generally. Until his passing, Jon remained passionately active in his field, collaborating with many colleagues, writing reports and papers, while working at James Cook University (JCU).

Jon's early career began with undergraduate studies in inorganic chemistry at the University of Sydney. He then worked as an analytical chemist and technical teacher at Newcastle Technical College, before completing a Master's degree at JCU in 1977. Nearly 40 years later, in the twilight of a remarkably diverse and productive career, Jon completed his PhD, on "Terrestrial pollutant runoff to the Great Barrier Reef: effects, causes, sources and management" also at JCU.

During the 1980s, Jon worked as a lecturer and then Senior Research Fellow at the Institute of Natural Resources at the University of the South Pacific in Fiji, becoming INR director in 1987. During that time, Jon developed a keen interest in reef dynamics, particularly the apparent rarity of many species, and the recruitment and 'boom-and-bust' cycles of crown-of-thorns starfish, issues that continued to spark his research focus in subsequent decades. The ongoing effort to address starfish impacts on the GBR and wider south Pacific benefited greatly from his publications, many of which were major collaborative efforts drawing expertise from across several institutions.

From 1988-90, Jon was a Research Fellow at the Australian Centre for Tropical Freshwater Research, JCU, before switching to a managerial role, first as Assistant Director, and from 1994-1998 as Director, for Research and Monitoring at the Great Barrier Marine Park Reef Authority (GBRMPA). He then continued as Director of the Water Quality & Coastal Developmental Group till 2001.



In addition, from 1994 to 1999 Jon consulted as Senior Environmental Impact Assessment and Monitoring Expert for a United Nations Development Program-funded biodiversity project in the Yemen Red Sea. Field work in Yemen, as indeed much of the Middle East, can be challenging (to put it mildly), with incredible heat and basic difficulties accessing transport, accommodation, food and water. On one occasion, the research vessel on which Jon and the team were traveling had warning shots fired across its bow, from a Yemeni military outpost on isolated Red Sea

Islands. Other challenges arose from problems with supply lines, and Jon, ever optimistic and determined to make the best of every situation, used his own finances to keep the project moving forwards. During his time in Yemen, Jon became fascinated by the history, culture and people there, and indeed of the region more generally.

With his grandson Charlie at Agincourt Reef, GBR.

'Retiring' from GBRMPA in 2001, Jon became the Chief Research Officer at the Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), JCU, establishing the "Catchment to Reef Research Group". From 2016, his last work was as a Professorial Research Fellow at the ARC Centre of Excellence for Integrated Coral Reef Studies. He was also a Partner and Senior Scientist with C_2O consulting from 2014. Jon was a world authority on water quality – a research area that is so often under-estimated, and relegated to small seminar rooms at coral reef symposia. Innumerable colleagues and students benefited from his knowledge, guidance and mentorship on this topic. He was a fierce advocate for effective policy, regulation and investment to tackle problems, producing crucial scientific evidence to guide and support government actions to protect the Great Barrier Reef, work that was fundamental in the development of the Reef Water Quality Protection Plans and Reef 2050 Water Quality Improvement Plan. The water quality targets he detailed within these publications still guide today's local land management.

It is difficult to single out key publications (he authored over 100 peer-reviewed articles and over 300 technical reports, books and book chapters) but his leadership on the Scientific Consensus Statements on land use impacts on Great Barrier Reef water quality and ecosystems, published in 2008, 2013 and 2016/17, had a particular legacy, and this initiative continues to influence policy responses to this day. Jon also supported numerous Australian and international conservationists and organisations, providing well researched evidence for their advocacy work.

Jon's research interests and publication record extended well beyond his seminal water quality work. He was particularly fascinated by the interactions of humans with coastal ecosystems, and with their biodiversity more generally, authoring papers with colleagues on corals, echinoderms and molluscs.

From around the turn of the millennium, Jon and his colleagues undertook then novel research into the effects of oil palm plantations on adjacent riparian, mangrove and reef habitats in Papua New Guinea. This work provided detailed recommendations for avoiding and mitigating the impacts. Similarly one of Jon's last papers, in 2020, was on priorities for seagrass habitat protection and management in Tarawa Lagoon, Kiribati. He also served on advisory boards across the Pacific, including the inquiry into the Rena shipwreck in New Zealand.

One of Jon's most memorable and lasting contributions was his dedicated mentoring and encouragement to the next generation of young people.

Around this time, Jon developed a very effective working relationship with trusted colleague and business partner Jane Waterhouse, who he described as his closest friend, and without whom, Jon confessed, he would not have achieved as much as he did.

One of Jon's most memorable and lasting contributions was his dedicated mentoring and encouragement to the next generation of young people, which extended beyond just scientists. Jon was particularly noteworthy for his encouragement and support to professional women; the gender balance and decision making levels in Australian science and beyond would likely be quite different without him. His daughter's grandmother once said that Jon was one of the few males in her long life (>90 years) who had always spoken to her with respect and recognition of her intelligence.

Jon was also deeply interested in history and geography. He loved traveling and always found time to visit the historical sites he earmarked from his readings. After visiting Yemen he developed a keen interest in Near and Middle Eastern history, which he later explored in Turkey, with its millennial-long connections to earlier Roman, Arabian and West European influences. He was like a walking encyclopaedia on world history. In recent years Jon enjoyed traveling with his daughter Nicola and grandson Charlie, discovering new sites, culture and history.

Despite all his achievements, Jon was a little frustrated and disappointed towards the end of his life, as he felt much still needed to be done.

A year before his death he described his feelings [honestly and] movingly[1]: "For the past 45 years I have researched and managed coral reef water quality in Australia and overseas. Now 72, I see that much of my work, and that of my colleagues, has not led to a bright future for coral reefs. … I feel guilty when discussing this situation with young scientists. I worry that my legacy is such that they will spend their professional lives studying and

With his daughter Nicola, student protégé Zoe Bainbridge and close friend and colleague Jane Waterhouse.

documenting the terminal decline of coral reefs. I feel the same sense of guilt towards my 19-year-old grandson [Charlie], who is in his first year of university studying mathematics. The outlook is grim, not just for coral reefs but for society in general."

Jon's realism is well-founded, as the outlook is indeed grim for coral reefs and other marine ecosystems, but without his phenomenal contributions, would be much less understood. Although Jon felt frustrated at times in later years, for most of his life, he maintained a strong positive attitude that inspired others. His influence will continue to be felt for many years hence, as his mentoring of young minds has resulted in many continuing to work for the betterment of the world's natural habitats.

Written in loving memory of Jon

[1] https://theconversation.com/this-situation-brings-me-to-despair-two-reef-scientists-share-their-climate-grief-123520

REEF DEPARTURES

Tributes to recently departed members and reef scientists

Peter Marshall Hope Gayle (1960-2020)

By Bernadette Charpentier and William F. Precht

A Marine Ecologist by training, Peter started his career at the Natural Resources Conservation Department (NRCD) in Jamaica, W.I. where he worked as a Research Assistant in the Aquatic Resources Division. In 1985 he joined the University of the West Indies Discovery Bay Marine Laboratory (DBML) as a Dive Officer, and later assumed the role of Principal Scientific Officer and co-manager of the facility. Peter was a first class BSAC diving instructor and a trained hyperbaric medical assistant. He served as Safety Manager for Hyperbaric Chamber Operations at DBML and was an Advisor to and Co-Chair of the Diving Sub-Group of the Working Group on Fisheries Management and Related Matters of the National Council on Oceans and Coastal Zone Matters (2004 to 2020).

Over the years Peter's research interests focused on various aspects of coral reef ecology ranging from fisheries ecology to the study of deep (mesophotic) fore-reef coral assemblages, the topic of his M. Phil thesis. To help his research efforts Peter became skilled in Open and Closed-Circuit Mixed Gas diving as well as underwater photography and videography. I (WFP) had the pleasure of taking a tri-mix dive class him at DBML in 1988. Following that class, we proceeded to dive off the deep fore-reef to depths of almost 90 meters. It was there that this remarkable place, where humans should not go, lit Peter's fuse to study the reef ecosystem, in hopes of finding that these deep reefs would act as a refugia for many shallower-dwelling reef species.

In recent years, Peter's research shifted to reef restoration/rehabilitation using coral gardening and artificial reef structures (*Acropora* Iron Reef [AIR] modules). His Ph.D. research centered on studying biotic and abiotic factors that could accelerate the production of coral biomass in *ex-situ* micro-fragment cultures for use in the rehabilitation of select reef areas. He knew the topic of reef restoration as well as anyone, and loved to share his knowledge with others at international meetings and symposia.

Peter's contributions to the field of marine biology extended beyond the University of West Indies. He was a leading member of the Association of Marine Laboratories of the Caribbean (AMLC) where he served as the Institutional Representative for DBML for over 20 years, took on the role of President of AMLC from 2012-2013, and co-chaired the Publication committee from 2016 on (see text from http://www.amlc-carib.org/news/Gayle_obit.html).

Along with three colleagues from his early days at the NRCA, Peter was one of the founding members and a Director of the Technological and Environmental Management (TEM) Network, a consulting company encompassing individuals and consulting firms with skills ranging from physical, chemical, and biological sciences to engineering, architecture, oceanography, and project management. Peter led the ecology Team, from

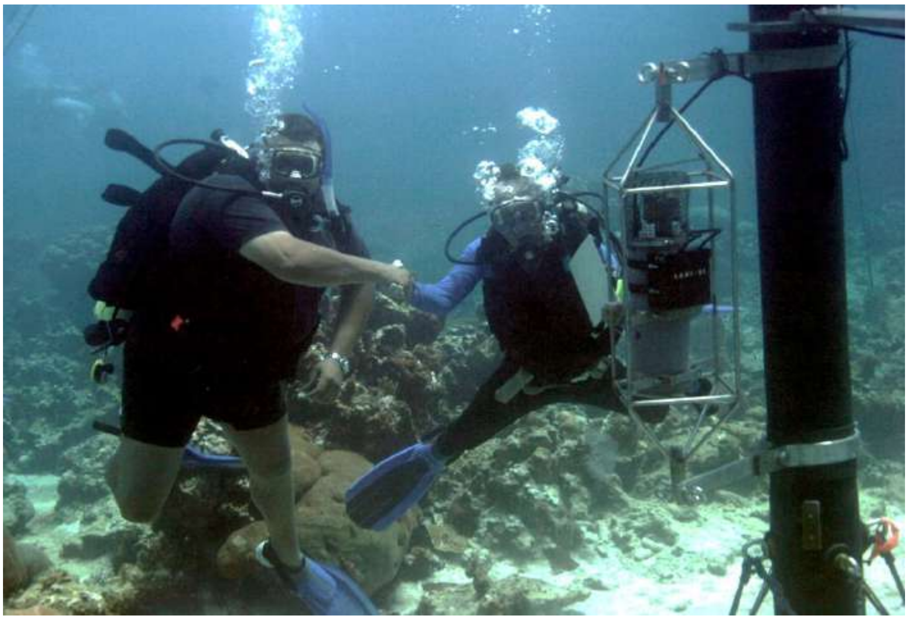
TEM's inception in 1993 to the time of his passing. The level of expertise he brought to the TEM team was noteworthy and included experience conducting environmental and commercial services such as marine (monitoring) surveys, ecosystem management and restoration, remote video scanning and still photography, marine co-ordination, search and recovery missions, light salvage, security inspections and surveys of docks, ships' hulls, cooling systems and propulsion gear. In recent years, he introduced UAV and submersible ROV operations for environmental monitoring, and was among the first scientists to use photogrammetry and 3D imaging as an everyday tool.

As a respected marine ecologist, Peter played a pivotal role on the TEM Network team in assessing environmental impacts and developing practical mitigation plans which influenced numerous coastal development projects, including the Kingston Transshipment Port, Kingston Wharves, Falmouth Cruise Ship Port, and Ocho Rios Cruise Ship Port, to name a few. Not only was Peter recognized for his invaluable contribution to the TEM projects, but also for building strategic relationships with fellow professionals to strengthen the capability of the TEM Network, and to promote environmental conservation and stewardship in Jamaica at large.

Ever so proud of his homeland, Peter served as Lieutenant (s.g.)/Captain in the Jamaican Defense Force Coast Guard (National Reserve) as Diving and Weapons Officer for 12 years. He was also a member of the Jamaica Institute of Environmental Professionals and an Honorary Game Warden for NEPA (National Environmental Protection Agency).

Beyond his many achievements Peter was known for his kindness and generosity. To foreign scientists, graduate students, and visitors at DBML, Peter was the welcoming face and a great source of knowledge, be it regarding Jamaican reefs or the Jamaican way of life. His never-ending smile, even under the toughest circumstances, could light up a room. While everyone knew of Peter's deep and bellowing voice, which could be heard from one end of the DBML campus to the other, few people knew that in his spare time he sang bass with the St. Ann's Bay Singers, including as a soloist. In his early days he was also an avid cricket player, a sport he loved dearly and followed closely.

Peter was always eager to discuss and exchange ideas, or to lend a helping hand with logistics in the field, or even drive you around the island to get that one piece of equipment for your next experiment. To those who had the opportunity to dive with Peter he was known as Poseidon or Neptune. DBML will not be the same place without him. He was a scientist, diver, colleague, a mentor, and a dear friend who will be sorely missed by all that had the great fortune to meet him – gone too soon but never forgotten!



Peter assisting colleagues from NOAA-AOML installing their ICON/CREWS station at Discovery Bay. Peter is shaking hands with James Hendee at the completion of that installation. Photo taken by Bernadette Charpentier.

REEF DEPARTURES

Tributes to recently departed members and reef scientists

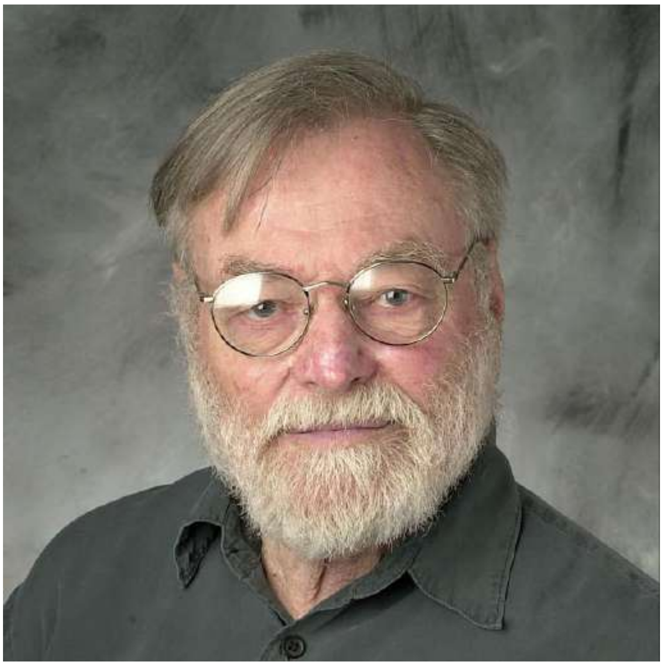
Joseph ("Joe") Connell (1923-2020)

By Rupert Ormond

Joe Connell was not primarily a coral reef researcher, but he was a highly respected general ecologist, who published some highly influential papers concerning coral reefs and other high diversity ecosystems. He was also an Honorary Member of ISRS / ICRS. In fact, the editors believe he was the last surviving of the old-style Honorary Members surviving, from when the honor was principally awarded to scientists approaching retirement age, in respect of a lifetime's contribution to relevant fields.

Joe was born in Indiana, USA, went to school in Pennsylvania, and began his first degree at the University of Chicago. His studies were interrupted by the Second World Word, during the latter part of which he served as a meteorologist with the US Army Air Corps, based in the Azores. Hostilities ended, he returned to Chicago to complete his first degree, followed by an MA in Zoology at the University of California, Berkeley, where he was supervised by the influential ecologist Aldo Leopold. Influenced by a paper on barnacles by Edward Deevey, that he had reviewed during his Masters, he then travelled to the UK where he undertook research for a PhD at the Marine Biological Station at Millport on the Isle of Cumbrae, in the Firth of Clyde (south-west of Glasgow); this was under the supervision of Sir Maurice Yonge (who had already undertaken important research on corals[1]) at the University of Glasgow.

His PhD work focussed on the zonation patterns of two well-known species of barnacle (*Balanus balanoides* and *Chthamalus stellatus*) on the rocky intertidal near the Marine Station, where, as through much of the west coast of Europe, they form discreet bands, with *Chthamalus* above, and *Balanus* below. His experiments led him to argue that the observed segregation of the two species



was the result not only of differences in tolerance to desiccation during low tide, but to interspecific competition, whereby the faster growing *Balanus* was able to exclude the slower growing *Chthamalus* from the lower zone. On selected lower zone plots he removed the *Balanus* and found that if this was done, not only did *Chthamalus* spat settle, but that they would grow and survive, provided the *Balanus* were absent. This work, when published[2], soon found its way into the majority of early ecology and marine biology text books.

Post UK, Joe took up a post-doctoral post at Woods Hole Oceanographic Institution, at Falmouth, Massachusetts, and then obtained an assistant professorship at the University of California, Santa Barbara, where he was to remain for the rest of his career. His earliest work there was also a study of two species of intertidal barnacle, conducted at Friday Harbor Marine Laboratories, on San Juan Island, in Washington State. There he found that

[1] See articles pages 25 and 63

[2] Connell JH (1961) The influence of interspecific competition and other factors on the distribution of the barnacle Chthamalus stellatus. Ecology 42: 710-723

rather than inter-specific competition controlling the distribution of barnacles, it was predation by three gastropods that restricted the abundance of the most common species, *Balanus glandula*, enabling all three to co-exist.

These early studies were influential both as being amongst the earliest examples of field experimental ecology, and for revealing the likely roles of both competition and predation in structuring natural ecosystems. This led him to investigate the application of these ideas to much more complex ecosystems - rain forests and coral reefs, which he undertook to study in Queensland, Australia, establishing multiple permanent plots which he monitored for many decades. In making a start, on the reef he was assisted in coral identification by Carden Wallace, and in the forest by Geoff Tracy and Leonard Webb of the CSIRO rain forest ecology unit. This work resulted in his most widely cited coral reef paper entitled "Diversity in tropical rain forests and coral reefs", publish in 1978[3]. He was nothing if not patient and persistent; his transects on Heron Island were photographed 36 times between 1962 and 2000. His observations led him to emphasise two further ecological mechanisms, the role of habitat disturbance (e.g. cyclone / hurricane damage felling trees or clearing corals) in promoting diversity, and the significance of predation and disease in frequently targeting common rather than uncommon species[4]. In particular Joe's name has become linked with his oft-cited "Intermediate Disturbance Hypothesis", and with the "Janzen-Connell hypothesis", which attributes a key role to density-dependent predation and infection.

Aside from this seminal work, Joe published a series of review papers that widely influenced ecological thinking, about not only the mechanisms underlying species diversity, but also such questions as the nature of successional change in natural communities. In recognition of the role he had played in developing modern ecological theory he was the recipient of honors including the Guggenheim Fellowship, the Ecological Society of America's George Mercer and Eminent Ecologist awards, an American Academy Fellowship, membership of the Australian Academy of Science, and, as mentioned, Life Membership of ICRS (then ISRS).

I got to know Joe a little only late on, when in about 2004 he stayed for a few days with my wife and I on a return visit to the University Marine Biological Station at Millport, of which I was then Director. It turned out that every ten years he had been revisiting and re-recording the experimental barnacle plots established during his PhD. He had an engaging personality and a curious mind, forever keen to "figure out" (as he phrased it) this observation or that. We accompanied him down the shore to give him a hand. There we were struck both by the meticulous detail with which he recorded his observations, but also by the very small number of replicates that his classic study had involved. I wondered whether his PhD data would have met the high standards for replication that he himself subsequently set; but it is not every PhD student who gets his ideas into so many textbooks. He is widely credited with influencing hundreds if not thousands of students and researchers, in consequence of which several much fuller appreciations of his contribution have already been published elsewhere[5].

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[3] Connell JH (1978) Diversity in tropical rain forests and coral reefs. Science 199: 1302-1310

[4] Connell JH, Hughes TP, Wallace CC, Tanner JE, Harms KE, Kerr AM (2004) A long-term study of competition and diversity of corals. Ecol Monogr 74: 179-210

[5] Sousa S et al. (2021) Resolution of Respect: Joseph Hurd Connell; Lubchenko J, Sousa WP (2020) Joseph H Connell – ecologist who transformed the study of natural communities, Nature 586: 670; Murdoch WM, Sousa WP (2020) Joseph H Connell – innovative experimental ecologist Science 370: 410

Joe Connell in 2003 amid rain forest near Cairns, Northern Queensland (photo P Green, La Trobe University, Victoria, Australia)

Note re photographic images: where no photographer is credited with an image, this normally indicates that the photograph was taken by the author(s).

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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 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 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).

Green turtle, *Chelonia mydas*, in Virgin Islands National Park, US Virgin Islands; photo by Caroline Rogers

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