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Number 47

REEF ENCOUNTER

REEF LIVES –Ruth Gates, Ed Gomez, Alan White, Callum Roberts
ARTICLES – Coral Reef Myths, Marine Ornamental Fish Trade
GRANTS & AWARDS – ICRS Honors, Graduate Fellowships, Travel Grants
GRADUATE FELLOWSHIPS – Coral Skeletons, Thermal Adaptation, Historical Shark Communities, Heat Shock Proteins
UPCOMING CONFERENCES – ICRS2020, ITMEMS 6, Singapore

ICRS
International
Coral Reef Society

The News Magazine of the
International Coral Reef Society

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EDITORS, OFFICERS & COUNCIL MEMBERS

REEF ENCOUNTER

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.

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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.

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CORAL REEFS - THE JOURNAL

The International Coral Reef Society also publishes through Springer's 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 (see http://www.springer.com/life+sciences/ecology/journal/338).

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COVER PICTURE: A Maldives coral reef – illustration from the book "A Reef Life" by Callum Roberts (see book review in REEF SHELF section) – photo by Alex Mustard.

CONTENTS

EDITORAL

Welcome to the 2019 edition of REEF ENCOUNTER. A number of things have changed since our last issue. We have changed the Society's name. We have a new logo. We have a new website. But most striking, and upsetting, has been the loss of a much loved President – Ruth Gates – who oversaw those modernising changes, and whose unexpected illness and death (see REEF DEPARTURES section) stunned all of us involved with the Society.

But we have a new President and Vice President, in Andréa Grottoli and Joanie Kleypas, to both of whom a big welcome. We have a clutch of new Council members (see inside front cover), whose support and enthusiasm is much needed. And we have a number of new chapters, including the dynamic Coral Reef Consortium, which held a very well-attended REEF FUTURES conference in Key largo since our last edition, a European Chapter, which will ensure the continuation of the series of European Coral Reef Symposia, following the success of the Oxford ECRS in 2017, and a Mid-East Chapter which held a successful conference more recently in Abu Dhabi.

We retain the ambition to publish REEF ENCOUNTER twice yearly. Earlier this year there was a dearth of authors offering articles, but now more than enough to produce a bumper issue. So, please remember that general articles and short research reports and book reviews will always be welcome. Please remember that REEF ENCOUNTER offers a medium through which thought-provoking ideas and small but significant observations or studies can be put on record.

Rupert Ormond
Coordinating Editor, Reef Encounter

RECORDING SECRETARY

2019 has been a busy year for ICRS! We convened quarterly council and monthly officer meetings, the most recent of which were held during the 2nd week in December. We approved the formation of new regional Chapters and adopted Vision, Mission, Code of Conduct and Diversity StatementS. With ICRS2020 less than a year away, we have been discussing meeting preparations and soliciting bids to host the 2024 Symposium. The Society also launched its new name, logo, website and membership-handling system, and we are currently brainstorming 'Big Ideas' for raising our visibility and engagement in coral reef issues.

Liz Drenkard
ICRS Recording Secretary

PRESIDENT'S MESSAGE

Dear 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. The team of Officers and Councilors serving the Society is an exceptionally talented and dedicated group of individuals and it is a privilege to be working with them. Over the past year we have been very busy. In addition to officially changing our name and launching a new website, we have developed mission and vision statements that clearly showcase the strengths of ICRS.

Mission

ICRS promotes the acquisition and dissemination of scientific knowledge to secure coral reefs for future generations.

Vision

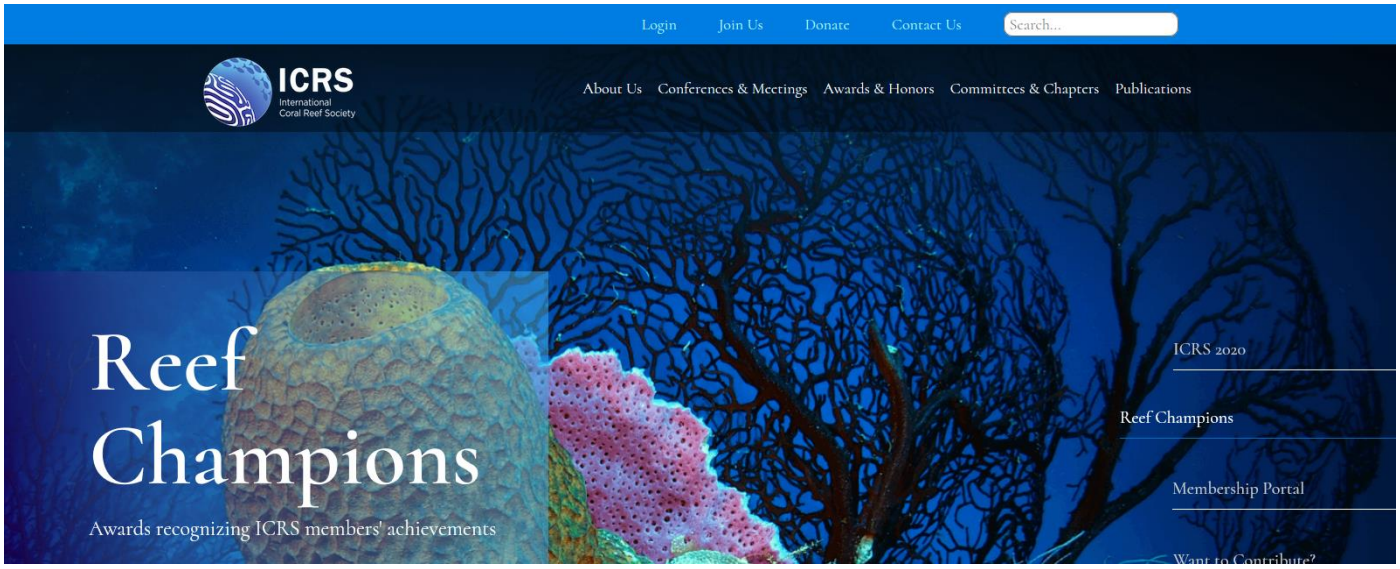
To be a leader in coral reef scientific discovery, to contribute to the education of future coral reef scientists, and to be a strong voice for science informing policies that protect coral reefs.

Visit our website at www.coralreefs.org/about-icrs/ to learn more about how we are implementing each element of our vision statement. But we wanted to take this further and develop a Plan of Action. How can we do more as a Society to make a difference for coral reefs? While the plan is in the final stages of approval, I can give you a sneak peek at a couple of things we are already implementing. First, part of that plan includes building alliances and bridges between ICRS and other coral reef societies and organization in the world to strengthen our collective voice. To that end, we have approved the new European Chapter and the Mid-East Chapter. Discussions are underway with several other organizations to further broaden these ties. Another element of the Plan of Action is for ICRS to be a more active participant in bringing coral reef science and policy together on the international

stage. As a first step toward that goal, I traveled to Australia and participated in the International Coral Reef Initiative's (ICRI) 34th General Meeting (https://www.icriforum.org/). ICRS is actively engaged in three ICRI ad hoc committees charged with developing policies and position statements that will be incorporated into United Nations documents leading up to the COP15 UN Convention on Biodiversity in 2020. The plan also includes initiatives for reducing ICRS' carbon footprint, increasing education and outreach, and engaging all members and citizens in actions to protect coral reefs. We are hoping to launch the Plan of Action ahead of the ICRS2020 and to actively share the plan during the meeting.

The ICRS is uniquely positioned to effect change, inform minds, and work to better understand and protect coral reefs. While we still mourn the loss of the past ICRS president late Dr. Ruth Gates, the Society is moving forward in a positive and purposeful direction. We are always eager to hear from ICRS members. Please share your thought and ideas with me or any of the Officers. Together we can make the society stronger and our impact greater.

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



visit our relaunched website at: www.coralreefs.org

TREASURER'S REPORT

The financial status of the International Coral Reef Society (ICRS) continued to gain solid standing during 2019 with a balance of $320,005.17 USD as of November 30, 2019 (Figure 1). The majority of the income to cover general expenses associated with ICRS operations was provided by membership dues (Figure 2). However, ICRS also received an $11,116 USD award from Springer to recognize the Journal Coral Reefs as ranked 6th among all Marine and Freshwater Journals. The Society also received a total of $10,185 USD in donations during 2019 specifically earmarked to support the Ruth Gates Memorial Fellowship, which is matched by the Society for up to $15,000 USD. Finally, ICRS helped to secure an initial $44,000 USD from a NOAA Coral Reef Conservation Program Grant to support the International Coral Reef Symposium (ICRS) 2020 meeting at Bremen, Germany. Approximately $36,500 of the grant has been transferred into our account and this is being used to assist with the initial meeting expenses (Figure 2). We hope to secure a secondary NOAA grant of $40,000 USD in 2020 to provide additional support for the ICRS 2020 meeting.

Expenditures for 2019 include over $27,000 in student fellowships and awards as well as our monthly management fees (and other routine costs) of $16,665 USD. We also provided $5,000 USD sponsorship for the Mexican Coral Reef Symposium out of our totaled annual budget of $15,000 for meeting sponsorships. The additional expenses, which are forecasted for December 2019, still leaves the Society with well over $300,000 USD at the end of the calendar year. Officers and council members are currently discussing ways to spend Society funds to maximize benefits to people and reefs around the world. Ideas to date include increasing the number of awards for excellence and innovation, funding opportunities for travel and research, annual support for the operations of ICRS Chapters, investment into a stable market to perpetuate long-term financial stability of the Society, and sponsorship for local and regional Societies wishing to host workshops and conferences.

Erinn Muller

ICRS Treasurer

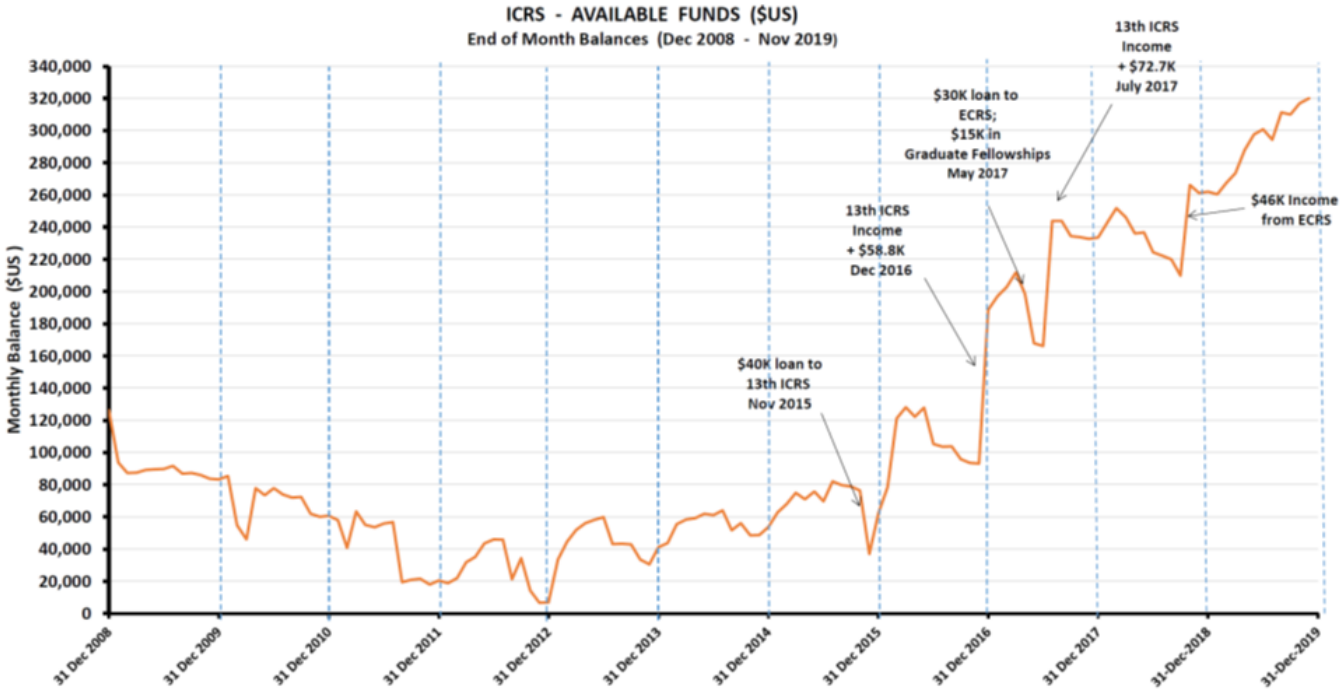
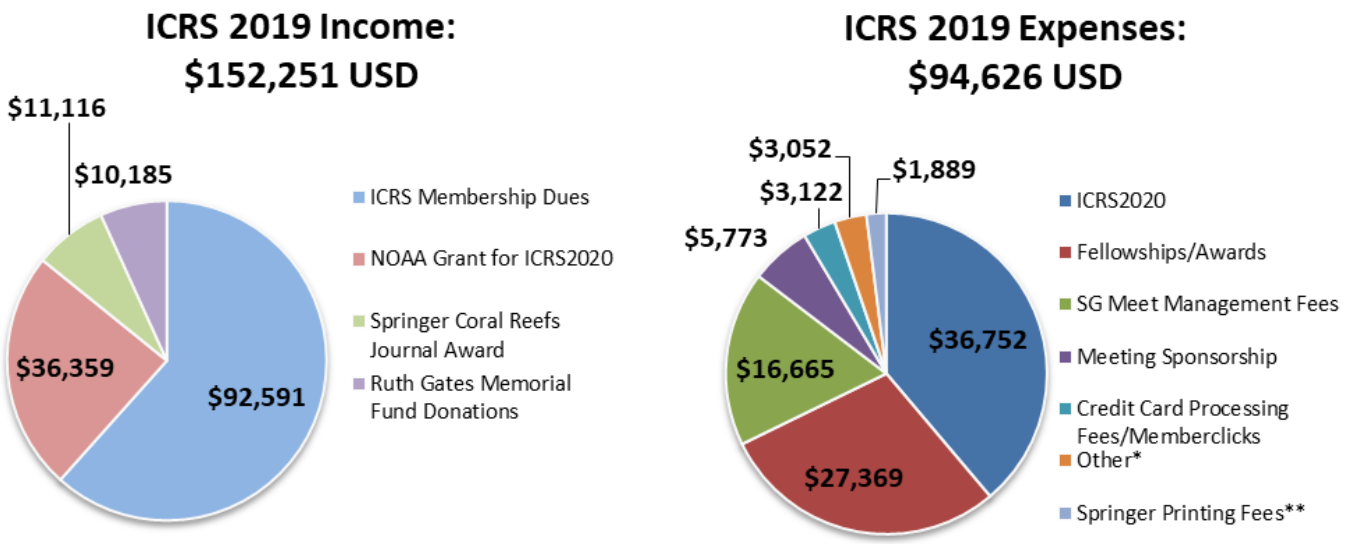


Figure 1. Monthly uncommitted funds held by ICRS from January 1, 2009 until November 30, 2019. 13th ICRS: 13th International Coral Reef Symposium; ECRS: European Coral Reef Symposium.



* Officer's Insurance, Website updates, CPA fees for taxes
** For ICRS members that choose print copies of Coral Reefs

Figure 2. Identified income and expenditures for the International Coral Reef Society from January 1, 2019 until November 30, 2019.

CORAL RESTORATION CONSORTIUM

The Year in Review

The Coral Restoration Consortium (CRC) started in 2017. In 2018, ICRS adopted it as its first Topic Chapter and the Steering Committee is one and the same as that of the ICRS Restoration Topic Chapter. At its inception the Coral Restoration Consortium was focused on the Caribbean, and most of the leadership was drawn from that region. Within the past year, as reefs have struggled and a growing number of locations engaged in reef restoration, the CRC has expanded globally. In December 2018 CRC hosted the first ever international conference on coral reef restoration (see Conference Reports). In June 2019 the CRC voted in several new Steering Committee Members from various tropical regions, and in September we adopted three Regional Groups (Eastern Tropical Pacific, Latin America, and Australia).

The CRC coordinates coral reef restoration science and practice, primarily via the Working Groups. I'd like to highlight products from two Working Groups in particular. In July, the Monitoring Working Group, in coordination with the Reef Resilience Network, put together an excellent webinar on Photomosaics,. The webinar presents the state of the science, the benefits of monitoring reefs with this technology, low-budget as well as high-resolution options for implementation, and resources for adoption. Photo-mosaics are an ideal method for documenting the successes and challenges of reef restoration. The large area images can illustrate the ultimate metric of reef health at an appropriate ecological scale. They document species composition, coral cover, and growth of corals, and allow a re-examination of past data. The webinar relied on expertise from several academics and featured case studies by two reef restoration practitioners. It is archived on the Reef Resilience Network website (https://reefresilience.org/.

Meanwhile, the Genetics Working Group published two papers this year. Considerations for maximizing the adaptive potential of restored coral populations in the western Atlantic, and Molecular tools for coral reef restoration: beyond biomarker discovery (in press). This group has taken on the critical and difficult task of providing genetics guidance on restoration for practitioners and managers, even when the science is incomplete. They provide clear and simple guidance on obtaining restoration material, recommending using at least six genets. Although the results focus on the relatively species-poor Caribbean, since the Caribbean has been at the forefront of restoration, these recommendations should serve the global coral reef community as a starting point for consideration.

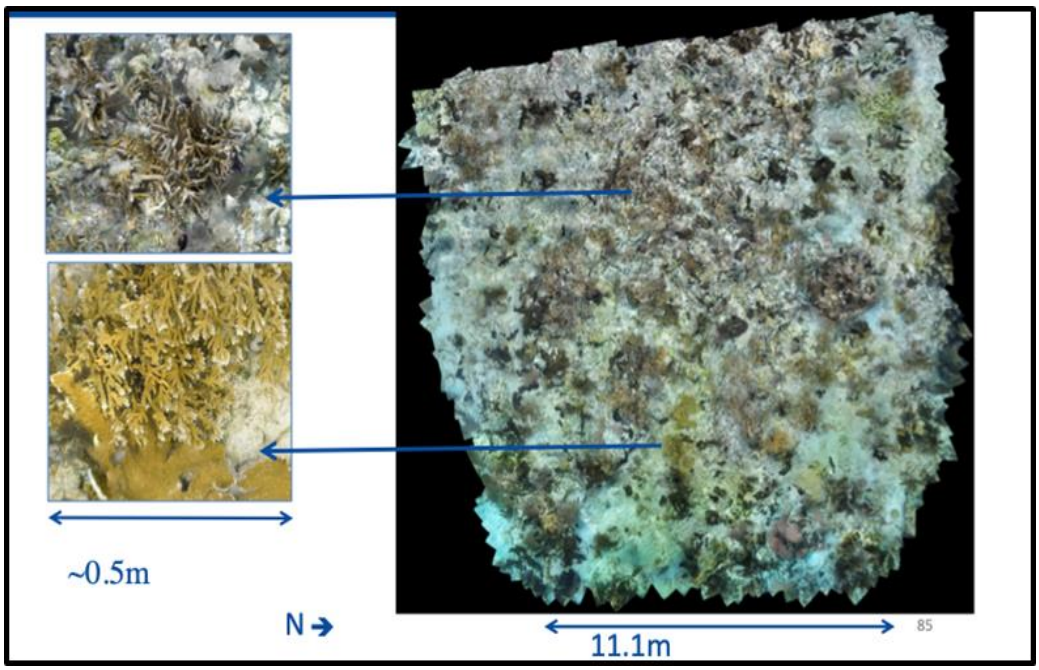


Figure 1. *Photomosaic from Belize. Image credit: Fragments of Hope.*

In addition to these stellar accomplishments, the Larval Propagation Working Group has coordinated observations on spawning times and research on post-settlement survival and created multiple species fact sheets. The Land-based Propagation Working Group has prepared a health-check protocol and the Monitoring Group has prepared Coral Restoration Monitoring Guidelines as well as a new Restoration Database. All of these documents will be reviewed by CRC Leadership in the coming months, after which they will be made available to the community. Lastly the coral restoration community can look forward to another Reef Futures conference in May 2021.

Tali Vardi, Chapter Coordinator

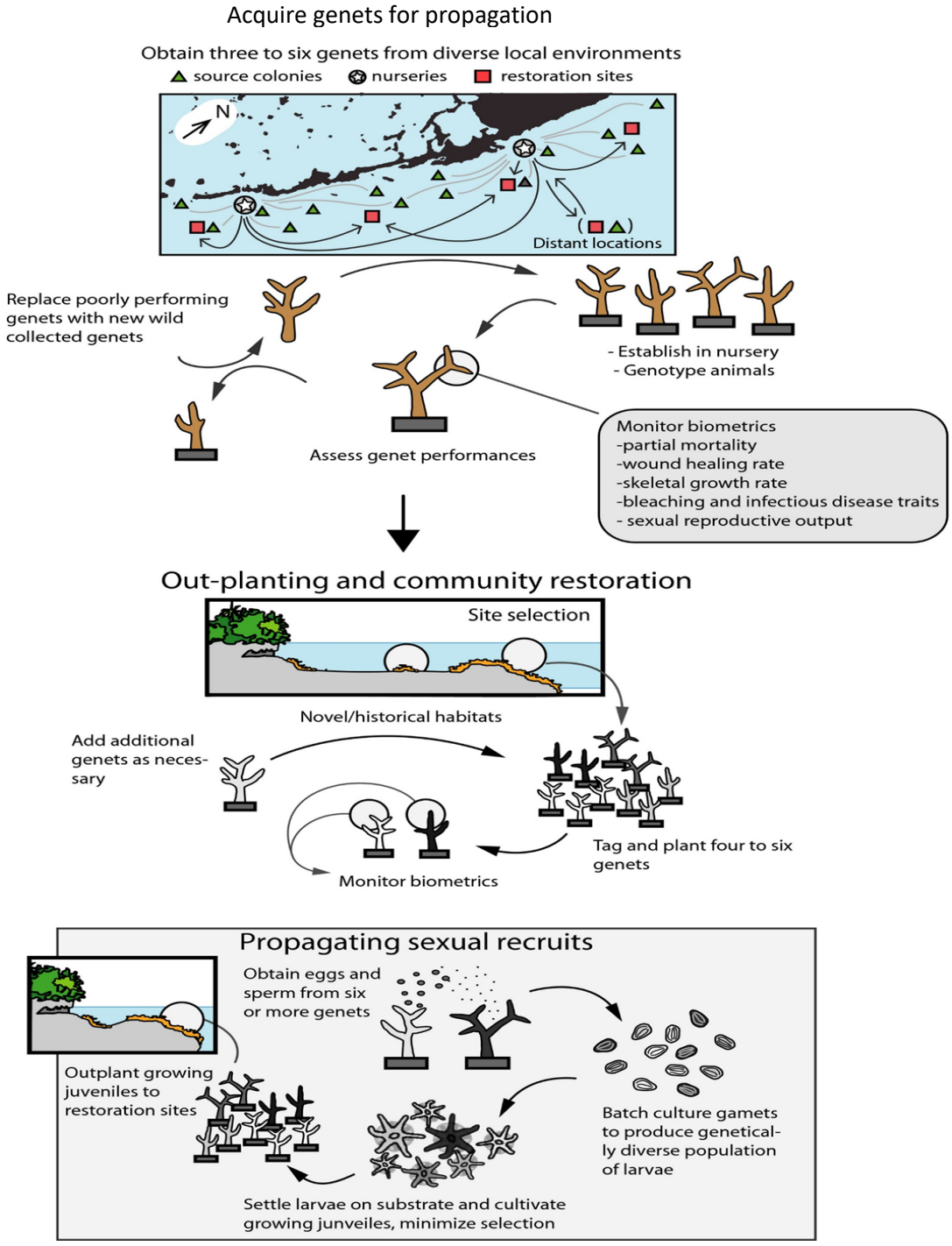


Figure 2. *Overview of basic restoration guidelines to maximize the adaptive potential of reef-building corals facing a rapidly changing environment. A genet is defined as one or more genetically distinct individuals originating by asexual reproduction from of a single ancestor.* *Reproduced from Baums et al. 2019.*

FORMATION OF EUROPEAN CHAPTER

Call to Europe-based Members & Reef Enthusiasts

It is a great pleasure to announce that a European Chapter of the ICRS has been formed with the approval of the ICRS President and Council.

Mission: The broad purpose of the Chapter is to pursue within Europe, and among reef scientists based in or visiting Europe, the Missions and Aims of the International Coral Reef Society. A particular aim will be to hold and promote at four-year intervals further European Coral Reef Symposia. European Meetings of ICRS have been held frequently since the formation of the Society, but have occasionally lapsed due to the lack of any organisation tasked with organising it. The most recent ECRS was held in Oxford, UK in 2018; **the next ECRS is being planned for Brussels, Belgium in 2022**. In addition, the Chapter will prioritize networking and collaboration among reef scientists based in Europe, and among students studying at European Institutions.

Management: A provisional ad hoc committee was formed to establish and manage the chapter. Among these it has been agreed that the following serve as a steering group:

Chair: Gert Wörheide (Ludwig-Maximilians-Universität München, Germany)
Treasurer: Marc Kochius (Vrije Universiteit Brussel, Belgium)
Secretary: Rupert Ormond (Marine Conservation International & Heriot-Watt University, Scotland)

Other members of the committee are:
Dominic Andradi-Brown, University of Oxford, Oxford, UK; Francesa Benzoni, University of Milani-Bicocca, Milan, Italy; Maggy Nugues, University of Perpignan, Perpignan, France; Chris Perry, University of Exeter, Exeter, UK; Serge Planes, University of Perpignan, Perpignan, France; Christian Wild, University of Bremen, Bremen, Germany.

In addition, we are currently calling for three Europe-based volunteers to supplement the committee:

- two early career researchers (PhD or PostDoc level)
- one member willing to act as a communications officer

We aim to ensure the full representation of female members and therefore would like to encourage the (self-) nomination of female colleagues. Anyone willing to volunteer for one of these positions should please get in touch as soon as practicable, sending a short letter of motivation and a short CV.

We would like to assume that all Europe-based members of ICRS (i.e. those with European addresses recorded in their membership details) would wish to be affiliated to the European Chapter. However, if any Europe-based member does NOT wish to be a member of the chapter, please let us know as soon as convenient.

Conversely, anyone interested in coral reef science or conservation is welcome to become affiliated with the chapter as an associate member, even if they are NOT a paid-up member of ICRS. It is hoped this arrangement will in particular be attractive to students. We look forward to serving the coral reef science community in Europe and beyond.

Gert Wörheide, Chapter Chair
woerheide@lmu.de

ANNOUNCEMENTS

STUDENT TRAVEL AWARDS TO ICRS2020

The Society is pleased to announce the availability of 10 Student Travel Awards for student members to attend the 14th International Coral Reef Symposium (ICRS2020) in Bremen, Germany. The application deadline is January 15, 2020. More details can be found online at: http://coralreefs.org/student-travel-award/

To be considered for a travel award, you must be a presenter of an accepted abstract for a poster or oral presentation. These awards are only available to ICRS student members, but if necessary you can still join us today at: https://icrs.memberclicks.net/membership-application#/. Completed applications or questions about the awards should be submitted to Dr. Lisa Rodrigues, Chair of the ICRS Honors and Awards Committee, email: lisa.rodrigues@villanova.edu

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RUTH GATES MEMORIAL AWARD

The Society announced earlier this year the award of the first Ruth Gates Memorial Award to Till Roethig of the University of Derby, Derby, UK, for a project entitled "An overlooked threat - low salinity and its effect on coral thermotolerance".

The award is made in memory of the Society's immediate past present, Dr. Ruth Gates, who died unexpectedly in 2018 while in office (see REEF LIVES section). The award, open to any post-graduate student, includes a $5,000 grant to develop solutions to restore and conserve coral reefs endangered by climate change, the field in which Ruth herself was active. It is intended that the reward will be available annually (see: http://coralreefs.org/student-grants-and-awards/ruth-gates-memorial-award/)

CALL FOR ICRS 2024 BIDS

The Society is now calling for bids from local groups willing to host the 15th ICRS (ICRS15), to be held in the summer of 2024. The hosting group should include members of ICRS willing to form the nucleus of a Local Organizing Committee. Ideally, the successful bid and host location for ICRS15 will be announced at the end of the 14th ICRS, July 2020 in Bremen. For more information on bid requirements please see http://coralreefs.org/conferences-and-meetings/future-icrs-bid-info/. Bids should be submitted to **ICRS President, Dr. Andréa Grottoli**, by 1st June 2020.

REGISTRATION OPENS

As surely members will know, ICRS 2020, the 14th International Coral Reef Symposium, is being held, for the first time in its history, in Europe - in the cosmopolitan and historic city of Bremen, Northern Germany, from 5th – 10th July 2020. This will also be the first ICRS planned so as to be fully carbon-neutral (see: https://www.icrs2020.de/green-strategy/).

All authors whose abstracts have been accepted for presentation as a talk or poster should by now have been notified. And early-bird registration now opens in less than a month's time.

Many details of the event are now available on the website at: https://www.icrs2020.de/. These include full details of conference themes, of plenary speakers and of workshop sessions. Plenary speakers include: Johan Rockstrom, Sangeeta Mangubhai, Natalie Ban, Jody Webster, Iliana Baums, Nick Graham and Katharina Fabricius.

Also available are full details of the ICRS2020 Photographic Competition. There are three themes: **1. BEAUTY, 2. THREATS and 3. SCIENCE.** Each participant can submit a maximum of three pictures. Image size should be at least 3000 x 4000 pixels and images sent (as JPEGs) (maximum 10 MB per e-mail) to: photocompetition@icrs2020.de.

Key Dates

30 November 2019 — **Notification of presenters**
Communication of presentation assignments to ICRS 2020 participants

15 January 2020 — **Early bird registration opens**
Registration opens to book at reduced participant fees.

31 March 2020 — **Early bird registration closes**
Closing of registration for ICRS 2020 at reduced participation fees

31 March 2020 — **Registration for exhibition space closes**
Exhibitors can book their exhibition space at ICRS 2020 up to this date.

30 April 2020 — **Oral presenters registration deadline**
Participants with oral presentation assignment are required to register now.

05 July 2020 — **ICRS 2020 commences**
The 14th International Coral Reef Symposium opens its doors in Bremen.

The ICRS 2020 scientific program is structured around 15 overarching themes (see below). Each of the themes will include both a series of specialised sessions and an associated open session. Open sessions will cover all aspects of a particular theme that are not addressed by its specialised sessions. Theme 14 is an exception, in that it will only include an open session, without any specialised sessions.

Details of the venue and of the available accommodations are summarised on extra web-pages. There are 10,000 hotel beds available across all categories, varying from cozy family-run hostels to luxury five-star hotels, with 3,200 of these located within walking distance of the conference hall.

More information about the city and sites worth seeing are given on further pages at: https://www.icrs2020.de/services/bremen/ Highlights include the magnificent town hall (built 1405 - 1410) and distinct Roland statue, which have held UNESCO world heritage status since 2004.

ICRS 2020 - Themes

01: Reef environments and climate of the past
02: Species and their populations
03: Ecosystem functions and services
04: Microbial ecology, holobionts and model organisms
05: Cold-water and temperate reefs
06: Unexplored and unexpected reefs
07: Scalable observations and technologies
08: Human relations to reefs
09: Global and local impacts
10: Organismal physiology, adaptation and acclimation
11: Resilience, phase shifts and novel ecosystems
12: Conservation and management
13: Interventions and restoration
14: Outreach and education
15: New theories and future projections

Bremen also boasts an outstanding scientific reputation. Bremen University campus, with its strong marine science focus, includes two marine science clusters: the Center for Marine Environmental Sciences (MARUM) and the Bremen Marine Ecology (BreMarE). This is supplemented by several world-class marine research institutions such as the Max Planck Institute for Marine Microbiology and the Alfred Wegener Institute for Polar and Marine Research, creating a multi-dimensional research hub. Many scientists from these institutions are actively involved in coral-reef related work and are members of the ICRS 2020 organising committee.



Photo-credits: centre Holger Anlauf; right and left BTZ.

AKIDEMIC LIFE

Coral Reefs, Conferences & Kids

Many of you are planning your trip to Bremen for ICRS 2020, excited about catching up with old friends and meeting new collaborators. But, if you have caring responsibilities, conference travel can be challenging and often a bit stressful: Should you take the kids? If you leave them at home, who is going to do school pick up? And if you take them, how are you going to juggle caring and conference demands?

aKIDemic Life is an online information hub developed by academics for academics that aims to make your preparations for ICRS 2020 that little bit easier. We provide a curated selection of resources relevant to your trip to Bremen. For more information check out our website's 'travel with kids' page. Topics include:

Leaving the kids at home. This might be the first time you have left your child(ren) overnight. This article provides some great tips on how to prepare them for your departure and keep them happy while you are away.

Choosing your airline. Do you know which airlines allow you to keep your baby in the bassinet during turbulence? Or that Lufthansa's bassinets take babies up to 14kg in weight, whereas on Turkish airlines the maximum allowable weight is 8kg? These can be very important details to know when you are faced with a long-haul flight to a conference where you need to be on the ball rather than an exhausted zombie. Check out www.flyingwithababy.com for all these details and more.

Packing and travelling. Dr Anna Cohen Miller, one of our advisory board members, has become an expert on travelling with kids to conferences. Check out her essential guide to flying with kids to help work out what to pack, how to negotiate the airport with your children in tow and how to keep them entertained!!!

Bremen & ICRS. Bremen has lots of great resources for families, whether you need to change your baby at the airport, want to do some kid-friendly excursions while you are in town, or are looking for a hotel that will welcome your brood. Bremen also has an online magazine for families that provides a calendar of events and a kid-focused searchable map that gives you the location of playgrounds, sports fields, museums and more (although this might require you to use a bit of google translate!) Further child care information for ICRS2020 will be made available at: https://www.icrs2020.de/services/child-care/

Funding for childcare at home or at the conference. So now we get to the sticky bit, how are you going to fund extra childcare at home or babysitters in Bremen? Clearly, there is much more to be done in this space to ensure academics with caring responsibilities do not miss out on presenting at national and international conferences. However, an increasing number of universities are providing support schemes for parents travelling to conferences, but in our experience, many of these schemes are very poorly advertised. So, your first stop should be your department or university – even if they have nothing available for this trip, it is important that management is aware of the massive demand for this sort of support. There are also a range of external organisations that provide this type of funding e.g. Capstone Editing or general conference travel funding that could help cover your costs e.g. FSBI, so it is worth doing a search online to find local opportunities. We hope you have a great trip to Bremen, either with or without your family. For more help balancing life and academia check out www.aKIDemicLife.com, and if you have ideas for new content or have burning questions please get in touch (info@akidemiclife.com).

Kirsty Nash, Institute for Marine and Antarctic Studies,
Hobart, Tasmania, Australia (nashkirsty@gmail.com)

SOCIETY AWARDS AND HONORS 2020

CALL FOR NOMINATIONS
FOR DARWIN MEDAL & OTHER SOCIETY AWARDS

There's still time to 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. In particular, this coming year, 2020, we will present the Darwin Medal, our Society's most prestigious award, to a senior ICRS member who is recognized worldwide for major scientific contributions throughout their career. The most recent winners have been Jack Randall, Jeremy Jackson, Terry Hughes, Charlie Veron and Yossi Loya. Complete nomination criteria and information can be found online. The Medal will be presented at ICRS2020 in Bremen, Germany and the recipient will give a plenary address. Nominations for the Darwin Medal close on January 15, 2020.

In addition, please nominate colleagues at all career levels for the following annual awards. New this year, we have removed age limits from Society Awards and look forward to receiving a diverse array of qualified candidates. Nominations for all awards listed below close on February 15, 2020.

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

Full descriptions of each award including nomination criteria and details of the documents that should be submitted can be found on the Society's website at: http://coralreefs.org/awards-and-honors/nominations/

The recipients of the 2019 awards were:
Mid-Career Award: Nicholas A. J. Graham (Lancaster University, Lancaster, England, UK)
Early-Career Award: Lauren T. Toth (US Geological Survey, Florida, USA)
Coral Reef Conservation Award: Alan T White (Sustainable Ecosystems Advanced (SEA) Project, Jakarta, Indonesia)
Elected to ICRS Fellows Status: Ruth Gates
Previous recipients of these awards can be found at: http://coralreefs.org/awards-and-honors/recipients/

Please submit complete nomination applications (and related enquiries) to ICRS Honors and Awards Committee Chair, Dr. Lisa Rodrigues (lisa.rodrigues@villanova.edu).

CALL FOR GRADUATE FELLOWSHIP APPLICATIONS

SMALL GRANTS FOR GRADUATE RESEARCH

The International Coral Reef Society (ICRS) is committed to encouraging and supporting students interested in coral reefs, and typically offers six Graduate Fellowships per year for research on Coral Reef Ecosystems. Applications for the 2020 Fellowships should be submitted by February 15th 2020. The fellowships provide funding (currently up to US $2,500 per award) which may be used to cover the costs of fieldwork, or of visiting another institution, in order to obtain results that are to be included within a thesis submitted for a research degree (e.g. PhD, MPhil, or MSc by research).

Developing Countries. At least two of the Fellowships are reserved for students coming from Developing Countries in different parts of the world.

Eligibility. The fellowships are available to students who are either student or full members of ICRS, and are already admitted to a Research Masters or PhD program at an accredited University or College. The funding is not available for use after a student has submitted their thesis, nor to cover the costs of attendance at a Conference.

The 2019 Awardees were:

Jessica Bellworthy, Bar-Ilan University, Ramat Gan, Israel (Parental effect of chronic copper exposure during brooding on the thermal tolerance of planulae).
Naomi Huntley, University of the Virgin Islands, St. Thomas, Virgin Islands (Shifts in the coral associated microbial community following stony coral tissue loss disease infection).
Igor Pessoa, Rio de Janeiro State University, Rio de Janeiro, Brazil (Accurate trace metal analysis of coral skeletons: anthropogenic influences in corals at Ilha Grande Bay, Rio De Janeiro, Brazil).
Krishnaveny Saranadha, Central Marine Fisheries Research Institute, Kochi, Kerala, India (Coral disease distribution at Lakshadweep atolls).
Sterling Tebbett, James Cook University, Townsville, Queensland, Australia (Functioning of climate-transformed coral reefs).
Diana Ugalde, Universidad Nacional Autónoma de México, Sisal Hunucmá, Yucatán México (Scales of spatial variation of marine sponges (Porifera: Demospongiae) diversity of southern Gulf of Mexico and Mexican Caribbean coral reefs).

Application requirements and instructions can be downloaded from http://coralreefs.org/student-grants-and-awards/graduate-fellowships/. Applications should be sent by email to ICRS Corresponding Secretary, Dr. Michael Sweet (m.sweet@derby.ac.uk)

Winner of the "Best Paper Award" for *Coral Reefs* volume 37 (2018)

Members of the Coral Reefs editorial team nominated 22 papers for consideration for 2018's Best Paper. The clear winner was a paper in which author Ross Cunning and his team explored the mechanisms underlying symbiont shuffling in three species of reef coral, showing a strong empirical relationship between shuffling outcomes and the relative photochemical efficiencies of symbiont clades D1a, B and C. The broader significance of this work is captured in the authors' own words, which state it 'will help refine predictions of coral responses to environmental change and inform interventions to manipulate symbiont communities to enhance coral resilience'.

Ross was also the recipient of this award in 2015, making him the first multiple winner since this award was first made in 1987. Congratulations Ross! The lead authors and titles of seven other papers that received multiple nominations for this year's award are listed below. Congratulations to you all!

The Winner

Symbiont shuffling linked to differential photochemical dynamics of *Symbiodinium* in three Caribbean reef corals by Ross Cunning, Rachel N. Silverstein and Andrew C. Baker

Abstract

Dynamic symbioses with functionally diverse dinoflagellate algae in the genus *Symbiodinium* may allow some reef corals to alter their phenotypes through 'symbiont shuffling', or changes in symbiont community composition. In particular, corals may become more bleaching resistant by increasing the relative abundance of thermally tolerant *Symbiodinium* in clade D after bleaching. Despite the immediate relevance of this phenomenon to corals living in warming oceans—and to interventions aimed at boosting coral resilience—the mechanisms governing how, why, and when symbiont shuffling occurs are still poorly understood. Here, we performed controlled thermal bleaching and recovery experiments on three species of Caribbean corals hosting mixtures of D1a (*S. trenchii*) and other symbionts in clades B or C. We show that the degree of symbiont shuffling is related to (1) the duration of stress exposure and (2) the difference in photochemical efficiency (Fv/Fm) of co-occurring symbionts under stress (i.e., the 'photochemical advantage' of one symbiont over the other). The advantage of D1a under stress was greatest in *Montastraea cavernosa*, intermediate in *Siderastrea siderea*, and lowest in *Orbicella faveolata* and correlated positively with the magnitude of shuffling toward D1a. In holobionts where D1a had less of an advantage over co-occurring symbionts (i.e., only slightly higher Fv/Fm under stress), a longer stress duration was required to elicit commensurate increases in D1a abundance. In fact, across these three coral species, 92.9% of variation in the degree of symbiont shuffling could be explained by the time-integrated photochemical advantage of D1a under heat stress. Although Fv/Fm is governed by numerous factors that this study is unable to resolve mechanistically, its strong empirical relationship with symbiont shuffling helps elucidate general features that govern this process in reef corals, which will help refine predictions of coral responses to environmental change and inform interventions to manipulate symbiont communities to enhance coral resilience.

Keywords
Coral bleaching; Symbiont shuffling; qPCR; Photochemical efficiency; Mutualism; Photophysiology

Honorable Mentions

Congratulations also to all authors of the following papers, which also received multiple nominations:

S Tebbett et al. Sediment addition drives declines in algal turf yield to herbivorous coral reef fishes: implications for reefs and reef fisheries

Z Pratte et al. Contact with turf algae alters the coral microbiome: contact versus systemic impacts

B Gintert et al. Marked annual coral bleaching resilience of an inshore patch reef in the Florida Keys: A nugget of hope, aberrance, or last man standing?

J Turner et al. Depth-related patterns in coral recruitment across a shallow to mesophotic gradient

V Schoepf et al. Impacts of coral bleaching on pH and oxygen gradients across the coral concentration boundary layer: a microsensor study

J Robinson et al. Environmental conditions and herbivore biomass determine coral reef benthic community composition: implications for quantitative baselines

B Taylor et al. The world's largest parrotfish has slow growth and a complex reproductive ecology

Terry Done (Convener of *Coral Reefs* Best Paper Award)

ITMEMS 6

The International Tropical Marine Ecosystems Management Symposium

The International Tropical Marine Ecosystems Marine Symposium (ITMEMS) is a flagship activity of the International Coral Reef Initiative (ICRI). To date five ITMEMS have been convened around the world. The first was held in Australia (1998), the second took place in the Philippines (2003), the third was in Mexico (2006), the fourth in Guadeloupe (2011), and the fifth was once again held in the Philippines (2016).

The sixth ITMEMS will be held in Manado, Indonesia from the 14th-17th of April 2020 under the theme "Healthy Reef, Wealthy Ocean", at the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) building. Participants of the 6th ITMEMS will also be invited to visit the Bunaken National Marine Park on a field trip.

The aim of ITMEMS is and has always been to develop and strengthen the capacities of coastal and marine managers and their partners to conserve and promote the sustainable use of coral reefs and their related ecosystems. Participants at the sixth ITMEMS will comprise MPA managers and stakeholders, including NGOs, fishing communities and tourism businesses.

Thematic experts and experienced practitioners will lead sessions on a range of topics including (but not limited to) Innovative Finance, Sustainable Tourism,

Reef Resilience, Strategic Communication and the Live Reef Food Fish Trade (for a full list of the topics please see the ITMEMS 6 website). The format of ITMEMS allows participants the freedom to choose the learning sessions they attend, therefore, ensuring they gain the most from the symposium.

For more information please see the ITMEMS 6 website, or contact Claire Rumsey.

The Asia-Pacific Coral Reef Symposium 2022

The National University of Singapore and National Parks Board Singapore invite coral reef researchers to the 5th Asia-Pacific Coral Reef Symposium to be held in Singapore from June 20th to 24th, 2022.

With the theme 'Coral reef science and management in a rapidly changing world', we aim to establish this Symposium as a forum for reef scientists and managers to present, discuss and integrate the science and conservation of coral reef ecosystems and biodiversity. Ultimately, we hope the Asia-Pacific scientific community can come together to create new paradigms to take on the key challenges to our region's reefs in the future.

The programme will comprise four days of formal scientific proceedings with plenary talks, oral and poster presentations, as well as a half-day of workshops organised by conference participants and a half-day of mid-symposium tours.

The call for abstracts will open towards the end of 2021. For more information, please follow us on Facebook, Instagram and Twitter @apcrs2022.

Singapore Corals

REEF CURRENTS

General articles and overviews of reef science and management

Reefs: Catalyst for a Life of Learning, Tough Love and Fun Work

Alan T. White[1]

Chief of Party, USAID SEA Project, Jakarta, Indonesia
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Given my years young, most people assume I am well into a retirement phase of life. It is not that I don't contemplate 'retirement', but the reality is that I am much happier being fully engaged in activities with a sense of direction and contributing to the needs of marine conservation and all that entails. Presently I am 4 years into guiding a large 5-year U.S. Government supported marine conservation project in Indonesia. And while I would like to say that the job gets easier with experience, the USAID Sustainable Ecosystems Advanced (SEA) Project (www.sea-indonesia.org) is probably the most challenging of my career, and yet also tremendously rewarding. "Challenging" in the sense of scale of Indonesian marine conservation issues, and in the complexities of working in Indonesia and trying to comprehend what will make a real difference, and when our efforts are simply blowing in the wind. But, rewarding because of the amazing dedication and fortitude of a young generation of Indonesians who are working to figure out how to protect reefs, set up effective marine protected areas, improve policies, develop innovative law enforcement approaches, do useful marine science, and raise awareness across thousands of small communities in coastal areas of the country. So, while my wife Vangie and I have adapted to life in Indonesia, and like the country and the people, and are probably learning as much professionally and personally as at any time in our lives, we still miss our home in Hawaii where we will return in several years.

Being in Indonesia is a great way to culminate a career of working on coral reef conservation and coastal zone management issues. The Indonesian archipelago has it all, in terms of tropical marine resources and conservation issues; with 17% of all the coral reefs in the world mostly scattered around remote islands and along an 88,000 km coastline, it is often difficult to know where to start. The plus side is that many of the coral reefs and coastal habitats in Indonesia are still in relatively good condition due to their remoteness and to a seeming lack of impact from warming ocean temperatures. Most of the qualitative differences in reef, other habitat and water quality status, is proportional to the distance from human population centers. Thus, the marine life surrounding Java Island that supports about 140 million people is by no means pristine and barely surviving in many areas. In contrast, the areas in eastern Indonesian, where our USAID SEA project works, are still blessed with relatively healthy reefs boasting healthy old coral heads, large and abundant fish populations and a noticeable presence of charismatic marine life,

[1] Alan White was the winner of the 2019 ISRS Coral Reef Conservation Award and was invited to write about his career, reflecting on the challenges of tropical marine conservation. The picture is of Alan and his wife Vangie in Cebu Island on a recent Saving Philippines Reefs expedition.

such as Dugong, whale sharks, manta rays etc. that have great potential to attract an increasing number of marine enthusiasts—both Indonesian and foreign. But, in our connected world, the abundance of fish, valuable species for export, is quickly becoming too well known by seemingly remote fishing communities and these populations need urgent protection. Yet, the needed shift in environmental awareness is coming about through a revolution of education, rapidly evolving local government abilities, and a growing tourism industry. So, while optimism is needed to keep us motivated, it is not just a dream, since I see changes in Indonesia that should be long lasting and serve to protect its marine heritage, provided, that is, that increases in ocean temperature do not roll over all the healthy reefs!

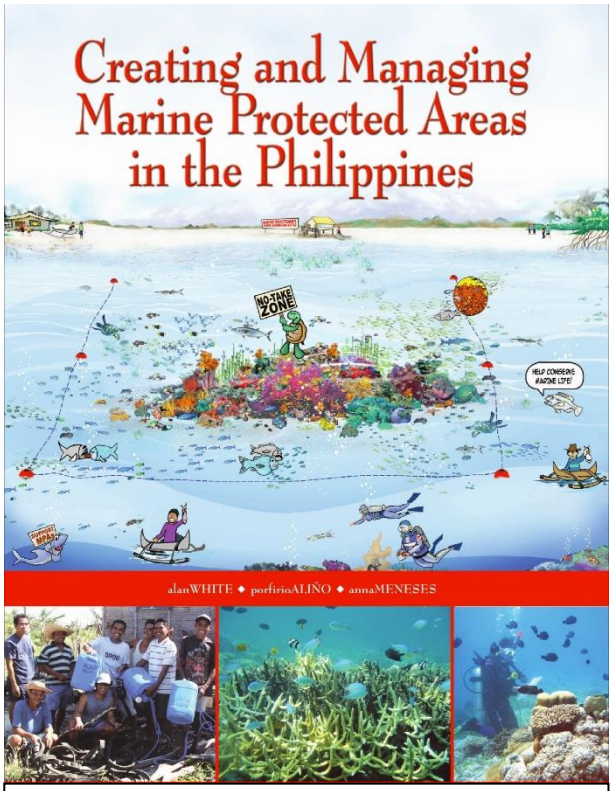
1972, Alan on boat dock of Charles Darwin Research Station, Academy Bay, Santa Cruz Island, Galapagos where afternoon breaks from writing the Galapagos Guide included a swim in the bay

You might wonder how I got to this place, having a career that I sometimes feel has surpassed my youthful dreams of adventure and conquering the world. Not that our marine conservation world is conquered by any means; but to make a difference, I believe, we need, in some degree, to have that attitude, because the challenges are indeed great. At the end of my undergraduate years in U.C. Berkeley, which opened my eyes to global problems in the 1960s, I decided to join the U.S. Peace Corps and ended up working for the next 5 years in the Galapagos Islands, Ecuador. This wonderful experience was enabled by an open-minded Peace Corps Director, John Arango, who upon being asked his permission to travel to Galapagos to work with the Charles Darwin Station under the direction of Dr. Peter Kramer, responded, "when are you leaving". I wasn't sure I had heard him correctly, but within several weeks I was on a bi-weekly flight to Galapagos with my friend, Bruce Epler. We had no idea what we were getting into, except that the adventure attracted us. Two years later we had completed the first tourist guidebook to the Galapagos Islands (Epler and White 1972) and our minds were firmly focused on the need for biodiversity and marine conservation as a lifelong path. The Galapagos at that time was just beginning to be exploited by foreign fishing boats, and during our years there the Galapagos Marine Reserve was designed and legalized based on the early surveys of Jerry Wellington and colleagues. In those years the Galapagos National Park was looking to the potential of high-end tourism to generate the financial incentives needed to gain the support of both the island communities and the national government for adequate protection. Many of us know the events that have emerged since in Galapagos, but at least protection has prevailed.

One thing I learned while in the Galapagos was that marine conservation was not all about being a marine biologist or ecologist. The issues threatening the marine environment there had little to do with marine life biology, and all to do with people and their lack of understanding of the limits of marine resources, with the ability of government and non-government organizations to have an influence on the fate of our environment, and with politics and human greed. Thus, my next step back to the real world was to work on a master's degree in international administration, which complemented my undergrad work in economics and business. The master's program required an internship that sent me to the Philippines under the auspices of the Smithsonian Environmental Peace Corps Program to work with the then National Environmental Protection Council under Dr. Celso Roque, a nuclear physicist turned environmentalist. With good fortune, I ended up working with the National Marine Parks Task Force for the Philippines, and with a group of young Filipinos, all newly trained scuba divers (we learned to dive together). With

their task leader, Dr. Gavino Trono of the University of the Philippines, we travelled to many of the rumored good sites for marine parks scattered around the 7000 island archipelago. We did rapid surveys to determine the status and feasibility of the sites for protection under national law, but were mostly oblivious to forces that might actually protect some of the wonderful sites that we explored and recommended. These trips were great adventures, with some misadventures, but quickly alerted me to the reality that Philippine coral reefs were not long for the world under conditions we observed of rampant destructive fishing, overfishing, uncontrolled coastal development and an almost total lack of appreciation of the benefits to be derived by most stakeholders from coral reefs in their natural and healthy state. This realization in 1978 was a turning point in my career, leading me to focus on saving the reefs by doing whatever that required. In my early foray in the Philippines I was lucky to have great peer support through the kindred spirits of Prof. Edgardo Gomez, John and Liana McManus, Kent Carpenter, Dr. Angel Alcala and others.

After a year with the national survey team, followed by a year based in Dumaguete, Negros Oriental, at Silliman University, working with Angel Alcala and gaining insights into the difficulty of protecting several small island reefs in the Visayan Sea (e.g. Sumilon and Apo Islands), I planned my dissertation research. I wanted to determine what would be the necessary ingredients to effectively conserve Philippine coral reefs within marine protected areas, marine reserves or local government declared marine "sanctuaries" from an ecological, governance and socio-economic perspective. With this direction I landed at the University of Hawaii and the East West Center for a Ph.D. in geography and marine resource management and conservation (White 1986). At the same time, the hundreds of underwater surveys conducted on Philippine reefs in those years had turned me into an amateur coral reef ecologist which led to my compiling "Philippine Coral Reefs, A Natural History Guide" (White, 1984, 2001).



2004, Cover to Creating and Managing MPAs in the Philippines was a popular guide for managers, planners and local officials to support their MPA work that was disseminated to all 800 plus coastal municipalities/cities in the Philippines

The timing of my research on marine conservation fitted well with the aims of the East West Center Environment and Policy Institute which in 1982 provided me with a 2-year study grant for field work in the Philippines, Malaysia and Indonesia to analyze the status of MPAs (12 in all) from an ecological, institutional and social perspective. The study highlighted that the engagement of local coastal communities was essential for any effective management to occur, regardless of the best intentions of national governments. This was certainly true in the 1980s in any case, and only started to change in the 1990s and beyond, when the Philippine government enabled several well-managed National Marine Protected Areas. But, until the present time, most of the effectively protected sites in the Philippines are under local government control and managed in collaboration with stakeholder communities. This realization has tailored my focus on conservation with a "bottom-up" approach (White et al. 1994). At the same time my intern job in the East West Center led to the development of a section in a marine policy atlas for Southeast Asia (White 1983). This experience ingrained me with the urgent need to "scale-up" marine conservation work, but little did I know how difficult that was to do in reality!

As I traveled in Southeast Asian countries with an eye for the need to move beyond community-based approaches, I realized that marine conservation in the region could only work given a more holistic approach than simply establishing small, or even large, "marine protected areas". This insight came from the reality that the coastal areas are multiple use, support relatively large populations of the resource dependent people, and that the governments (local and national) had many issues to deal with and were thus more attracted to integrated solutions. Thus "ICM" or integrated coastal management was born in the region and evolved in the Philippines to be supported by national policies. ICM fitted well with a local government mandate to manage coastal and marine resources including fisheries to 15 km offshore. Thus, while MPAs and reef conservation were often a center piece of an ICM program, ICM allowed government bodies to formulate more comprehensive plans for the management and protection of their resources and to implement such plans with a budget allocation quite separate from that of the national agencies. It is interesting to note that ICM evolved to be the "ecosystem-based management" (EBM) approach of later years, one that has many similarities.

The 1990s gave me a chance to test these ideas through my first "real" job as a technical advisor for the ASEAN-US Coastal Resource Management Project through which, from 1986 to 1992, we initiated coastal resource management in each of the six (at that time) ASEAN countries. This project, led by Dr. Chua Thia-Eng at ICLARM (International Center for Living and Aquatic Resources Management - now the World Fish Center) in Manila, was a monumental deep dive into the governmental mechanisms and cultures of the six countries concerned, attempting to understand why so little gets accomplished despite national government commitments. Nevertheless, in each of the six countries we initiated viable coastal zone management and reef protection pilot sites, and, due to the insistence of our project implementation policy, the governments were obligated to contribute substantial counterparts to the process. Viable long-term management efforts were initiated in Lingayen Gulf, Philippines; Johor State, Malaysia; Segara Anakan Lagoon, Indonesia; Ban Don and Phangnga Bays, Thailand, and in Singapore and Brunei, though come project completion I was weary of the constant travel and spending so much time in training and planning workshops!

2006, Alan in Colombo Sri Lanka with Coast Conservation Department Officials planning modifications to the CZM Plan after the 2004 tsunami

Shortly after this project, I moved with Vangie, from 1992 to 1996, to Sri Lanka where our son Ian was born. Work there focused on a narrowly defined coastal zone and the implementation of a CZM Plan that controlled building setbacks and maintained the integrity of the physical coastal zone of beaches and fringing reefs in the face of ongoing coral mining and coastal erosion (Rajasuriya and White 1995). These goals were being achieved quite well until the 2004 tsunami surged across these coastal habitats on the southeast facing side of the country. Working with the Sri Lankan Coast Conservation Department and the National Aquatic Resources Agency gave me more insights into how bureaucracy and personalities can make or break a well-designed system. The stories from 4 years in Sri Lanka could

fill a tome on CZM planning processes, the impact of people's varying character and political turmoil—but that's for another time!

A key finding from these programs was that in order to convince governments to act, they needed to understand the reality of "shifting baselines" as described by Jeremy Jackson and others. The tremendous losses of reefs and fisheries that had occurred by the 1990s were barely appreciated by policy makers, a fact which highlighted the need for good baseline data on both environmental status (e.g. of coral reefs and other habitats) and economic value. In 1998 Abbie Trinidad and I compiled a booklet entitled "The Values of Philippine Coastal Resources: Why Protection and Management are Critical" (White and Trinidad 1998), which helped set the stage for government budget allocations to better manage coastal resources. This prompted local governments to allocate budgets for conservation, because the municipal mayors often understood the economics involved better than ecological considerations. Fisheries, being the primary economically valuable resource of concern at the time, got the attention of both local and national leaders. This little booklet encouraged some mayors to launch their own coastal programs that proved just the beginning of a national movement to establish small MPAs in each of the 800 plus coastal jurisdictions.

2007 Saving Philippine Reefs (SPR) survey team in Bohol, Philippines. The SPR surveys started in 1992 and have been conducted every year since then, covering more than 50 large and small MPAs and accumulating a dataset on the status and trends of reefs in all survey sites for which analysis and publication continues

After Sri Lanka, my choice of assignment was to join the USAID Philippine Coastal Resource Management Project (CRMP), given my earlier work there and my familiarity with the country. The CRMP moved the needle on marine conservation and systematic planning in the country from 1996 to 2004. It set the stage for two follow-on projects that focused on reefs, fish and viable governance mechanisms. These projects largely succeeded due to a 1991 law that shifted many coastal management responsibilities to local governments and fostered increased local participation in the management of coastal areas. For countries with long and dispersed coastlines and limited resources, the devolution of authority to local governments is an essential catalyst in addressing coastal conservation issues. The unique feature of the CRMP was the involvement of municipal and city governments in the planning and implementation of ICM plans that included a range of interventions designed to address management of marine resources and areas to 15 km offshore. This heralded ICM as a "basic service of local governments" and required that each local government participate in baseline assessments to establish the extent and status of resources, and their patterns of use, as well related management issues. One criterion of a complete CRM/ICM plan was that it should include one or more MPAs that contained no-take zones for fisheries improvement, provided protection of critical habitats, and could provide other benefits such as sustainable tourism.

2013 Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security Regional Exchange for MPAs; the six-country body formulated and approved the Coral Triangle MPA System Framework and Action Plan launched in 2014 across the region

The lessons learned from the CRMP served to assist subsequent projects and are now proving of value in Indonesia, where one of the key issues of effective coral reef conservation is the relative authority and capacity of local government units to do their jobs. Challenges identified through the CRMP were issues of financial sustainability, inadequate capacities, weak law enforcement, and lack of integrated government oversight. A development for addressing these weaknesses was a "CRM certification system" that provided an incentive for local government. The benchmarks for a local government to achieve initial certification were: budget allocated, CRM related organizations formed and active, CRM plan developed and adopted, shoreline management initiated and best practices (e.g. reef and mangrove conservation, MPAs, etc.) implemented. Unfortunately, so-called "certification" systems require adequate institutional understanding and support which are not readily found, and thus the system withered. But a simpler and easier to implement MPA management effectiveness system was adopted in the Philippines and Indonesia, where they were informed by research supported by a Pew Fellowship grant in 2001 and by "How is your MPA Doing" (Pomeroy et al. 2002); the result was an MPA "management effectiveness" system that was adopted in 2010 in the Philippines and now operates along with a similar system in Indonesia. The experience of the MPA evaluation system indicates the need for baselines that can be measured and against which progress can be measured in a practical and transparent manner. Without measurable progress, the institutions and people involved give up or move on to another focus. One initiative that sustained attention was the giving of awards for best managed MPAs following criteria set out in the Philippine national MPA evaluation system. Such awards are now given each year and publicized through television and social media.

2014 Reef gleaning is a common practice on many reefs in Southeast Asia and is often a symptom of the relative dependence of coastal residents on food from the reef and in many areas contributes to overfishing of reef organisms

During our years in the Philippines, living in Cebu City and employed through the CRM Project, Vangie and our colleagues realized that short term "aid" projects were not on their own sufficient for building the necessary local capacity for conservation; thus we launched the "Coastal Conservation and Education Foundation (CCEF) in 1998 (www.coast.ph/oneocean.org). It was launched with motivated persons who came initially from donor projects and wanted to continue their work. Now CCEF, with 22 years of operation, has been able, in the southern Philippines, to support numerous and diverse activities promoting reef conservation and rehabilitation and institutional development

Large sweetlips is indicative of the many mature fish in the Tubbataha Reefs where fishing has not been allowed for 15 years and now provides fish larvae for the Sulu Sea fisheries and beyond

to achieve those ends. A benefit of long-lived focused organizations such as CCEF is that with a consistent vision it can monitor change over time. Thus CCEF's "Saving Philippine Reefs" annual coral reef survey expedition has gathered data on numerous reefs in MPAs over 20 plus years, the data documenting the status of reefs in relation to management interventions and the impacts of coral bleaching among other influences. The legacy of collecting, managing and analyzing data within the Coral Triangle countries is not great, but there are bright spots, and our 20 plus year data-set tells a story of successes and failures and helps illuminate major cause-effect relationships between management and conservation, as well as promoting awareness of the shifting baseline syndrome.

In the intervening years between work in the Philippines and Indonesia, I was fortunate to work with The Nature Conservancy (TNC) and support the development of the Coral Triangle Initiative for Coral Reefs, Fisheries and Food Security through the Coral Triangle Support Partnership consortium of the World Wildlife Fund, Conservation

2018 Massive schools of Jackfish roam parts of the Tubbataha Reefs and are great attractions for divers and photographers; the Park collects user fees that now cover a large portion of the management costs and compensate traditional fishers for not fishing in the area

International and TNC (supported by USAID). In addition to assisting with the institutional development of the CTI-CFF and its Regional Plan of Action, my focus was mostly on the MPA Technical Working Group and the formulation of the Coral Triangle MPA System Framework and Action Plan comprised of almost 2000 MPAs across the six countries (White et al. 2014; Green et al. 2014). A key aspect of the MPA system was the development of a monitoring and evaluation system for tracking progress in MPA health and across the other goals for seascapes, fisheries, climate change and threatened species. The indicators for monitoring progress in the CTI-CFF now feature prominently in the newly revised Regional Plan of Action for 2020-2025 and serve the critical need to be able to show measurable change in terms that senior regional policy makers can understand. Again, the indicators are not only biophysical and governance related, but they also designed to illustrate the economic benefits of marine conservation (www.coraltriangleinitiative.org).

To end, I must recognize the incredibly important role of my wife Vangie in our travel and work given her energy and enthusiasm for reef conservation endeavours. Vangie has guided the Coastal Conservation and Education Foundation through her financial and organizational skills without which CCEF would never have been able to generate the positive impact it has on Philippine capacity for reef conservation. Of course, CCEF, like any small NGO, requires constant mentoring and funding to continue its mission. But the strength of small NGOs in the business of marine conservation is that they can connect directly with those very stakeholders who directly affect the plight of reefs and thus can benefit coastal habitats through positive behaviour change.

2018 Alan counting fish over the large expanses of branching Acropora coral in Tubbataha south reef that has fully recovered from blast fishing in the 1980s and the severe bleaching in 1998

The lessons for aspiring reef scientists, managers and enthusiasts that I can convey mostly pertain to the need for multidisciplinary collaboration. The longer I live and work in the countries where tropical marine resources lie, the more I realize that all the best science in the world will not save coral reefs without effective communication, capacity building, education, social-economic development and probably most important, the buy-in and understanding of stakeholders at all levels of the conservation puzzle. Good science is always needed to add valuable guidance to the planning and design of reef conservation programs, but we as researchers must try to see the larger picture of how it will be used, and we must fully understand the barriers to changing behaviour and putting successful action programs into effect. Integrated, well-planned and long-term programs are essential. Despite the many barriers, I can say that

the needle has moved dramatically towards a much higher level of public awareness of the key issues and what needs to be done to address them, since I worked in the Galapagos or started diving on Philippine coral reefs. Moving that awareness and knowledge yet further, to secure meaningful action, is our collective challenge. The more creative young (and older) minds we can apply to the problem as well as leadership in and out of government, the better, because in the end it is mostly risk-taking individuals that catalyse progress in our world. We must all support young interns and students from a variety of disciplines in developing careers in coastal and reef conservation and continue to provide guidance and encouragement to all aspiring researchers and practitioners. And, in our ever-evolving careers and lives, we must take every opportunity to build the relationships among people and institutions that will build their capacity to secure effective conservation. It is not easy, but the learning, tough love and fun that results is well worth the effort!

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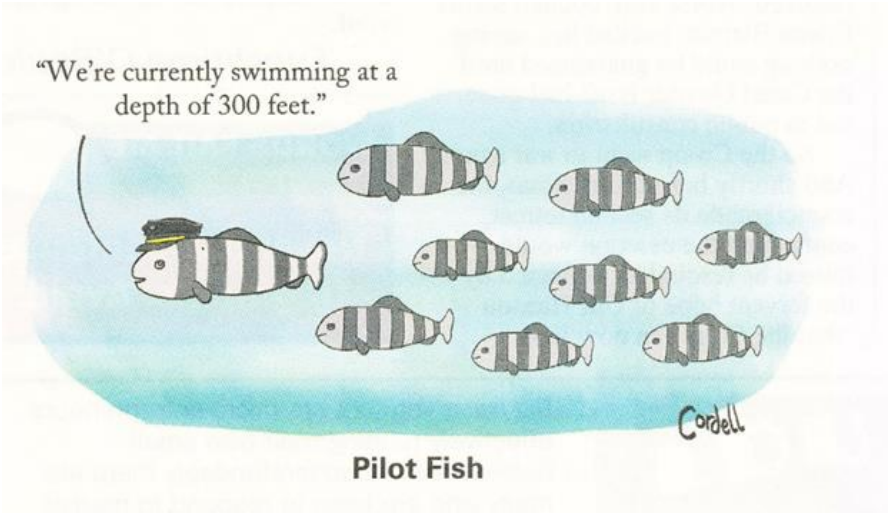

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Coral Reef Myths and Misconceptions

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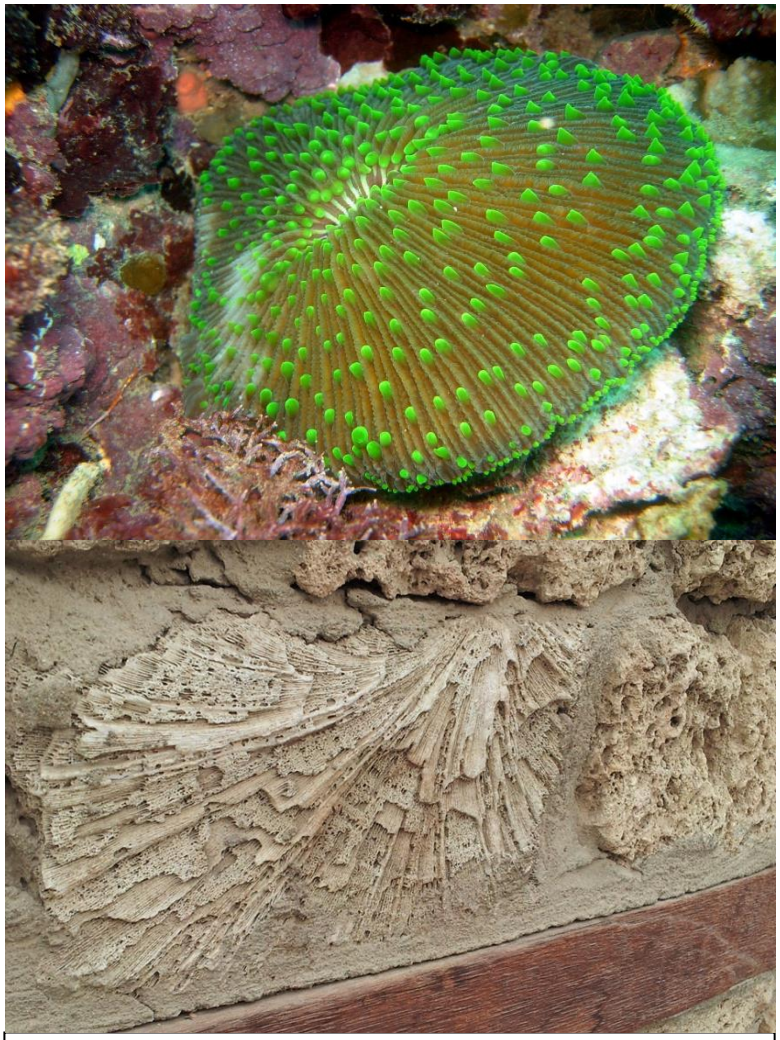
There are a number of things that are sometimes said about coral reefs that appear to be, if not myths, then misconceptions. These are most often stated in the popular press. Scientists in contrast are typically careful to not state more than the evidence supports, though they, like anyone else, sometimes want to wake the public up with dramatic statements, warning about the present-day threat to coral reefs. Some of the press does a relatively good job of presenting the scientific findings. But often ideas and details are distorted, passing along the food chain, and even the more informed members of the public can easily misconstrue the situation. Here is my personal take on the myths and "mythconceptions" I have most frequently encountered.

Myth No. 1: 'Polyps in corals are individuals and new individuals (polyps) are produced by asexual reproduction.' Polyps in coral colonies do divide in a process similar to asexual reproduction in species that have solitary polyps, but in coral colonies the division is not completed, they remain attached to each other. While typically one can think of polyps as either modules of a larger individual (the colony) or as individuals themselves, as long as they are connected by living tissue to other polyps, they are physiologically part of a single larger individual. All polyps in a colony are connected not only by their surface layer, but also by their digestive cavity and by their nervous system. Further, sexual maturity is reached when a colony reaches a certain size, not when a polyp reaches a certain size. All polyps in a colony are genetically identical (except for somatic mutations), and all are the same sex. If you touch one spot on a colony of a species with tall polyps, like most *Goniopora*, a wave of polyp contraction will move across the colony, thus they behave as a single individual. Other at least partly modular organisms include bryozoans, colonial ascidians, segmented worms (annelids) and arthropods. Asexual reproduction certainly occurs in corals, when colonies are broken into fragments. But a colony adding polyps is just adding modules.



Above: A Fungia *hard coral, a species in which the colony consists only of a single very large individual polyp, and the polyp structure is easily seen (photo by the author). Below: A fossil massive coral showing the growth pattern of a colony, embedded in the old city wall of Jeddah (photo by R Ormond).*

Myth No. 2: 'Polyps in a coral grow on top of older polyps and kill them, so building up the colony.' No, corals secrete skeleton externally, especially underneath their polyps. There are also water-filled spaces in that skeleton. The basal tissue lifts and then starts a new layer of skeleton to form such spaces, while additional polyps are formed to cover any extension in surface area. Polyps don't smother each other. Just very occasionally in a few corals, such as some massive *Porites*, corallites and polyps appear to get crushed between growing lumps of skeleton (Darke and Barnes 1993). The cells are probably shed since in the related hydroid, *Hydra*, all body cells are replaced every 20 days. Stem cells produce new cells, pushing older cells towards the extremities, from which they are shed (Siebert et al. 2019).

Myth No. 3: 'All of the world's reefs are now dying.' Perhaps this depends on what you mean by "dying"? Coral declines are well documented and widespread, with declines in the Caribbean (Gardner et al. 2003), Pacific (Bruno and Selig 2007), and Indian Ocean (Ateweberhan et al. 2013) well documented. However, a study of more areas in the Caribbean found that areas that had not been included in previous studies had not declined as much as the ones that were included (Jackson et al. 2014). Further, the first study to look at the Pacific as a whole (Bruno and Selig 2007) found that the South Pacific had not declined, though early records were sparse or absent, and a new summary of trends for the Pacific has found that downward coral trends there have not been as large as reported before (Moritz et al. 2019). A study of the Indian Ocean showed that coral cover was relatively steady up to 1998, when a massive El Nino hot spell reduced coral cover there drastically. Coral cover then increased for several years as reefs recovered, and then levelled off, though well below the original coral cover (Ateweberhan et al. 2013). Looking at the latest graphs for the Great Barrier Reef (https://www.aims.gov.au/reef-monitoring/gbr-condition-summary-2018-2019), it is tempting to say that reports of the complete death of that reef system are an exaggeration (see also myth 12). So, while the decline of corals is widespread around the world and undeniable, the picture is a bit more complicated. There are reefs that have recovered from massive damage, other reefs that have not been massively damaged, as well as reefs that have been massively damaged and have not recovered. All the indicators, though, are that things are going to get much, much worse before they get better.

Extensive coral bleaching of the branching coral, Acropora muricata. *The upper surfaces of the corals have lost their coloration, but color is still evident in the lower parts around the bases of branches. If unfavorable*

Myth No. 4: 'Before humans started destroying reefs, most coral reefs had almost 100% coral cover.' By coral cover we mean the percentage of the reef's surface covered by live coral. In fact, few if any near-pristine reefs have nearly 100% coral cover, whether they are high-latitude reefs or low-latitude reefs, except very locally (McManus pers com; Vroom 2011). A survey by John McManus of the available literature on near-pristine reefs produced an average of about 40% coral cover (McManus pers com), while the Coral Reef Ecosystem Division of NOAA produced an average of 35% cover for the many near-pristine reefs of the U.S. Pacific (Vroom 2011). A survey of reef researchers found that reefs were most often estimated to have originally had about 65% coral cover (Eddy et al. 2018). There is no reason that reef ecosystems have to have near 100% hard coral cover. It is very easy to be deceived looking at a reef from an angle nearly horizontal to its surface, for example while diving. From such an angle, almost all you see is the tops of living corals that project upward. But If you look down on a reef from some way above, suddenly you see lots of patches of sand, bare rock, sponges, soft corals and algae in between the living hard corals. Small areas can indeed reach 100% coral cover, but coral reefs are naturally highly patchy in character. Disturbances such as hurricanes or crown-of-thorns starfish outbreaks periodically damage reefs, often killing many corals, though usually coral cover returns. For this and other reasons, coral cover goes up and down over time naturally and the average over time is well below 100%.

Myth No. 5: 'Bleached corals die of starvation.' Coral bleaching, where corals lose their zooxanthellae (symbiotic algal cells) and color, happens in response to various environmental impacts, notably to well above normal water temperatures. However, some people (even some scientists?) seem to assume that all bleached corals die. That is not the case. If temperatures return to normal in time, corals can survive and regain both their zooxanthellae and color. When bleaching kills corals, the thing that kills the coral isn't necessarily the loss of zooxanthellae and subsequent starvation. It is true that If they lose zooxanthellae, they lose a major source of nutrition (Houlbrèque and Ferrer-Pagès 2009), and those that do not catch much zooplankton lose the most (Grottoli et al. 2006). But they can also die very quickly if the water gets hot enough. "These widespread losses were not due to the attrition of corals that slowly starved because they failed to regain their symbionts. Rather, temperature-sensitive species of corals began to die almost immediately in locations that were exposed to heat stress" (Hughes et al. 2018). In such cases they are dying too fast to be dying from starvation. Every organism has an upper limit to the temperatures they can survive in. Above that, their proteins start to denature. This happens to the coral animal as well as the zooxanthellae, though the temperature is not necessarily the same. Nevertheless, mortality can easily happen long before the coral starves to death, if the temperature is high enough. In summary, it is likely that there can be two causes of mortality in bleaching events, cooking and starvation, and which causes the actual mortality depends on the extent and duration of raised temperature as well as the species concerned.

Myth No. 6: 'Coral skeletons are made of $CaCO_3$, so they include carbon, and thus corals absorb CO_2, and thus corals help reduce CO_2 in the atmosphere and hence climate change'. Unfortunately, the process by which corals metabolise carbonate into their skeletons actually releases CO_2 into the water. This is counter-intuitive, but it's the way the chemistry works (Ware et al. 1992). However, over geological time, coral reefs do sequester carbon and have played a role in allowing life ("as we know it") to exist (Hallock 2015).

Myth No. 7: 'The loss of corals in the Caribbean was caused by global warming.' Most of the loss of corals in the Caribbean happened before the documentation of much coral bleaching, which is the main way in which global warming has killed corals in most other parts of the world. The factor that caused most of the decline in the Caribbean was coral disease, and the primary coral disease that kicked off that decline was white-band disease (Aronson and Precht 2001). It kills *Acropora* and caused massive declines in two of the three most abundant coral species in the

Caribbean, *Acropora palmata* and *Acropora cervicornis*, which, it is now hard to credit, once formed dense stands in shallow water along most Caribbean reefs. Other factors, including loss of grazing sea-urchins (especially of *Diadema antillarum*) followed by algal overgrowth, increased sediment and nutrient loads and other coral diseases have continued to cause further loss, besides which mass coral bleaching has now killed large amounts of corals as well. Humans may have helped coral diseases kill corals. One disease (not white-band) is caused by a bacterium that is common in vertebrate (including humans) digestive systems, and might have been spread in sewage. Other coral diseases flourish in higher water temperatures or in corals weakened by higher temperatures, and so may have been intensified the impact of global warming (Gintert et al. 2019). A new disease (Stony Coral Tissue Loss Disease) is now ravaging the corals of Florida and the Caribbean, killing at least 13 different species of coral, arguably the most lethal coral disease ever yet reported (Precht et al, 2016; Gintert et al, 2019).

Myth No. 8: 'Sea level rise will damage or kill coral reefs.' Some people assume that all the effects of climate change have to be bad. Not true, although most effects are bad and the net effect of all of them is a gigantic threat to coral reefs and humans both. But the effects of sea level rise *per se* on reefs depends on various other factors. in some cases it will indeed damage reefs, but in others, it will either be neutral or even beneficial. In areas where there are high sediment levels due to sediment runoff from land, rising sea levels will allow waves to sweep across reef flats, stirring up mud and damaging corals. It will also erode soft sediment along shorelines. This effect is well documented, for example, on the south side of Molokai Is., Hawaii (Field et al. 2011). But in areas with little or no terrestrial sediment, that won't happen. The world has thousands of atolls, with no terrestrial sediments to cause this problem. And areas like the Red Sea and the west coast of Australia, both well-endowed with fringing reefs, the land is a desert, and there is little sediment runoff from land.

Above: A typical Indo-West Pacific reef flat at low tide, with numerous live colonies exposed to air. Below: More extensive coral thickets partially exposed at low tide. (Both images taken in American Samoa by the author).

Conversely sea-level rise may benefit some corals. On reef flats where sediment is not a problem many corals grow in such shallow water that they are exposed to air at low tide. If they are exposed to air too long it kills them; that's why reef flats are so flat. Corals that grow too high are killed by exposure to hot air,

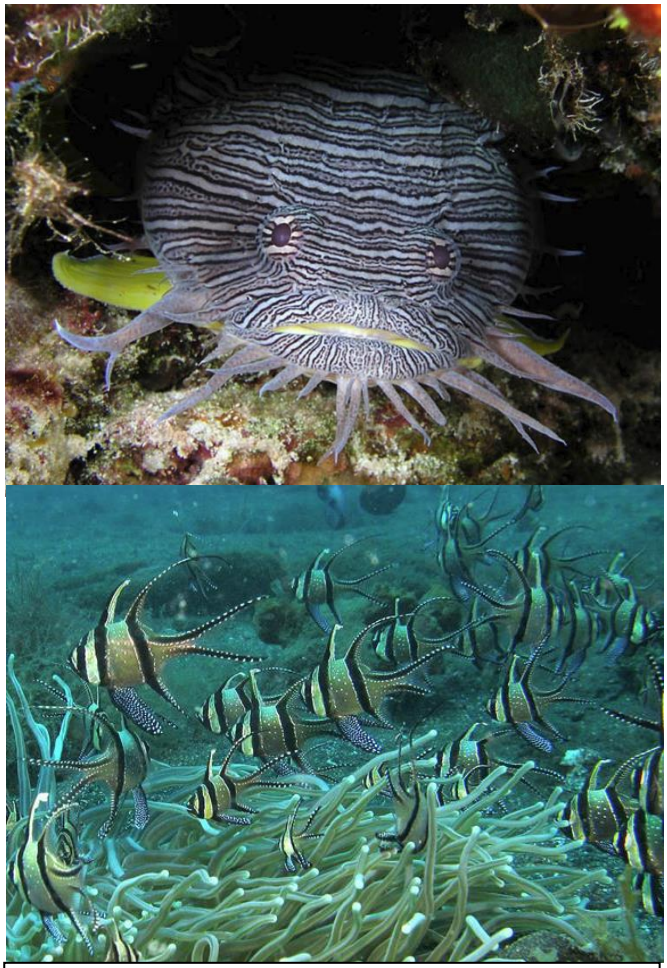
but corals that are lower down are not exposed, so survive and grow, filling in the gaps. In short, the lowest tides act like a lawn mower, and as a result reef flats typically have low coral cover (Fenner 2012). But during periods when low tides become less extreme coral cover can increase, as predicted some time ago ("In a 50–100 year Greenhouse scenario of rising sea level, we predict that recolonisation of present day reef flats will be extensive and prolific." Kinsey & Hopley, 1991) and documented in at least two subsequent studies (Brown et al. 2011; Scopélitis et al. 2011). Some corals grow upward much faster than sea level rise, Staghorn (*Acropora*) for example at least 10 cm a year, while sea level rise currently averages only about 3 mm a year. Thus corals can easily outgrow sea level rise. But reefs themselves (the carbonate structure) grow more slowly. Geological studies find that in the past reefs have averaged about 3-6 mm a year (Montaggioni, 2005), which is as fast or faster than present sea level rise. So, reefs are not about to be drowned by sea level rise. Not to mention that reefs can continue to grow until they are at least 30 m deep, and sea level rise at 6 mm a year would take 5,000 years to submerge a reef flat 30 m deep, even if it didn't grow. Further, the farther down the reef slope you go, the smaller proportion of the depth that is added to by a small annual rise. The irony is that sea level rise is not rapid enough to be very helpful to corals before almost all will have been killed by the higher temperatures of a warming planet. Thus it is considered that reefs that can keep up with present sea level rise will not be able to keep up with sea level rise predicted from the higher IPCC (Intergovernmental Panel on Climate Change) warming scenarios (Perry et al, 2018), but this primarily because of the mass bleaching and mortality caused by high-temperatures (Fenner 2012).

Myth No. 9: Many articles say that coral reefs are the most diverse of marine ecosystems. Some imply they are the most diverse ecosystem on the planet, terrestrial or marine. Assuming we are talking about species diversity, the latter claim is not true. Tropical rainforests are more species diverse than coral reefs because of insects, which are the most diverse group of animals and plants by far, and abundant and diverse in tropical rain forests, but absent from coral reefs. However, coral reefs do have higher diversity than tropical rainforests at the animal phylum level, i.e. in terms of the number of biological phyla present (Ormond et al. 1997; Paulay 1997). Otherwise coral reefs may or may not be the most species diverse of marine ecosystems, depending on the areas under consideration. First, coral reefs vary widely in their diversity, those in the Coral Triangle (the Philippines, eastern Indonesia, northern New Guinea, and the Solomon Islands) in particular being highly species diverse. But coral reefs in Brazil and the Eastern Pacific have very low diversity, and reefs in between the high and low areas have an intermediate diversity. Besides this, the diversity of deep sea sediments is not really well enough known to be sure exactly how diverse they are compared to reefs. It also depends on how the comparison is made. Do we want to compare equal areas? If so, reefs may be more diverse. Or should we compare the entire ecosystem? If so, deep sea sediments whose extent is vastly greater may be considered more diverse.

Myth No. 10: 'Zooxanthellae provide the bright colors of corals.' Although most corals are a shade of brown, some, especially in shallower areas are bright pink, blue, purple, green, yellow, or other colors. Whatever their color, when corals get too hot, they "bleach" and turn white. Some people assume that since following bleaching the zooanthellae (single cell algae) are no longer present inside their cells, it must mean that all of the bright colors characteristic of corals are present in the zooxanthellae. But those biologists who separate out zooxanthellae from the host coral cells report that zooxanthellae are always brown. Thus, any colors other than brown in living healthy corals are probably due to separate pigments in the animal cells of the coral, not to those in the zooxanthellae. It has been proposed that these other pigments play a role in protecting the corals from bright sunlight, in particular the UV radiation that is part of it. So why exactly the corals should lose these pigments, just when they might be most needed, remains unclear. Some corals however, especially if bleaching is only mild, retain some pale yellow, pink, blue, or purple

(because the pigments are in the coral cells), and in some cases fluoresce. This is thought to be a mechanism for re-emitting the excess energy absorbed by corals in bright sunlight.

Myth No. 11: 'All coral reef fish have a larval dispersal stage.' Not so much a myth as forgetting something of importance. Many of the papers that address fish larval dispersal begin with something like 'Most coral reef fish species have a larval dispersal stage.' True. However, not all species do. Notably, Elasmobranchs, which are important on reefs, with sharks dominating in many near-pristine areas (Fenner 2014), do not have a larval dispersal stage. Instead some sharks and rays have live birth, while others lay relatively large eggs, usually in protective cases. The resulting pups often remain in protected waters until they are larger, when they can disperse, which it seems at least some individuals must do, since they have significant biogeographic ranges, and adults of some species can migrate across whole oceans. But this isn't dispersal by larvae; they don't have any. In addition, there are a selected few bony (teleost) reef fish that don't have a larval dispersal stage. Often they have very restricted ranges, toadfish in the Caribbean being an example. The splendid toadfish (*Sanopus splendidus*) was known from only Cozumel, Mexico, but has been found in Belize as well, as are a couple of other species with quite a restricted range. What happens is that both eggs and young are relatively large with the young post hatching remaining in crevices with the adults. A larger number of reef fish lay eggs on the reef (rather than spawning directly into the plankton) and guard them until they hatch. Damselfish (Pomacentridae) are the most speciose group showing such behaviour, among which various Clown fishes are perhaps best known for it. However, normally the larvae then disperse. But in the Indo-Pacific, the spiny chromis (*Acanthochromis polyacanthus*) has young that stay with the adults and feed off of their surface mucus. Some mouthbrooders, such as cardinalfish and jawfish, take such larval care one stage further, with typically the male taking the larvae in to his mouth, whenever danger threatens. The Bangaii Cardinalfish (*Pterapogon kauderni*), found naturally only in the Bangaii Islands off the eastern side of Sulawesi, Indonesia, is probably best known for this.



The splendid toadfish (Sanopus splendidus) (above) and Bangaii Cardinalfish (Pterapogon kauderni) (below). Photos Christina Koukkos (above) and NOAA Fisheries (below).

Myth No. 12: 'Many coral reefs are now dead.' This is an oversimplification more than a myth. Many reefs are certainly degraded, no question. One problem is what is being referred to by "a coral reef"? The difficulty is that the term could refer to two very different things, one of which can be killed, the other which can not. One is the geological structure of the reef, a build-up of calcium carbonate. That structure has never been alive, and it isn't destroyed by the death of the corals growing upon it, although there is biological, chemical, and physical erosion of reefs, it is tiny compared to the size of reefs thousands of feet thick and many miles wide, at least over human life spans. The other thing, that is surely what people intended when reporting that a reef is dead, is the coral reef community, including

especially the corals. The organisms which constitute the ecosystem and its ecological communities are of course living and certainly can die. Even then, there remains a problem. In fact, when someone says that a coral reef is dead, what they likely mean is that the coral-dominated habitat has been shifted to another ecosystem, such as an algae bed. All hard substrates in shallow tropical ocean water get covered with some kind of life very quickly. If favourable conditions are restored, the coral ecosystem, unlike a dead individual, has at least the potential to recover (as long as none of the species have gone extinct). In either case, saying that certain coral reefs are "dead" is a dramatic statement that makes good press, but is clearly an oversimplification that can generate misunderstanding.

Myth No. 13: 'You can restore any reef area by replanting corals.' This may be an exaggeration more than a myth, probably no one is saying "any" reef can be restored, but many people, especially developers, do not realize that reef restoration is not that simple. The problem is that whatever threat damaged the coral reef ecosystem may still be active. Yes, the major elements of the coral assemblage and community can always be put in place, but for how long will they survive? Or will the factors that originally damaged the corals, be they high temperatures, sediment loads, pollution or disease, simply damage them over again, and all the time, effort, expertise, and money spent go for nothing?? There have been a number of high-profile examples (for example in the Arabian Gulf) of those overseeing huge coastal development projects assuming that the corals destroyed in the process can simply be put back in place afterwards, like so many palm trees. This is in part a replay of the old debate about artificial reefs and reef structures, many of which were put down on the seabed in the hope of establishing flourishing coral reef habitats, but constructed of inappropriate materials in inappropriate locations (see Edwards and Clark 1999; Edwards and Gomez 2007). But even if a suitable substrate has been chosen and an appropriate design selected, corals will not grow if conditions are not suitable for them in the first place. Of course, new emphasis is now being placed on selecting or breeding super-corals, which may be able to "grow boldly where no coral has grown before". And there is also the issue: how long will the restored coral community likely last? If only a few years, it is probably not worth doing. If even a few decades, it may help to see us through to a brighter, cooler, future!

Perhaps thirteen is an unlucky number to stop on, not boding well for the future. So proposed additions or deletions would be welcome, as well as more kindly comment![1]

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[1] *The article is intended to be thought-provoking; the editors welcome comment for inclusion in the next issue!*

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Spread of the new coral disease "SCTLD" into the Caribbean: implications for Puerto Rico

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The ongoing deterioration and significant decline in live coral cover and diversity in coral reef communities worldwide is strongly associated with increasing water temperatures linked to Global Climate Change, aided by anthropogenic activities (Harvell et al. 2004, 2007, 2009; Weil and Rogers 2011; Maynard et al. 2016; Woodley et al. 2016). In the Wider Caribbean, major community structure and function decline was marked by two region-wide, concurrent, highly virulent disease epizootics in the early 1980's. These events almost wiped out two foundational scleractinian species (*Acropora palmata* and *A. cervicornis*), and the keystone sea urchin *Diadema antillarum*. White band disease (WBD) affected the acroporids and was caused by a complex of vibrio bacteria (Gil-Agudelo et al. 2006). The *Diadema* mass mortality had all the trademark characteristics of a virulent, transmissible, bacterial or viral infection, but the putative pathogen (pathogens) was never identified (Lessios 2016). Populations of both acroporids and sea urchins suffered over 95% mortalities throughout the wider Caribbean (Gladfelter 1982; Lessios et al. 1984a,b; Aronson and Precht 2001; Lessios 2016), followed by a cascade of ecological consequences (significant loss of live coral cover, primary productivity, spatial complexity, biodiversity and fecundity; loss of ecological functions, increase in algal cover and biomass, etc.), ending in a shift from coral- to algal-dominated communities and the loss of ecological services to other tropical marine communities and to human beings (Aronson and Precht 2001; Weil and Rogers 2011). Several other disease-induced mass mortalities of other cnidarians, as well as of massive, plate and nodular reef-building genera, have in the last 30 years resulted in additional loss of biomass, diversity and live coral cover on many Caribbean reefs (Miller et al. 2009; Weil et al. 2009a; Weil and Rogers 2011; Bastidas et al. 2011; Weil et al. 2017).

More recently, a presumed new "white-plague type" disease, killing large numbers of corals in a short time, was reported from southeastern Florida in 2014 (Precht et al. 2016; Walton et al. 2018). It followed dredging operations (2013-2015) in the Port of Miami channel, that resulted in high sedimentation and turbidity near "ground zero" (Miller et al. 2016), and came after Summer-Fall high thermal anomalies that led to extensive bleaching across the Florida Reef Tract (Manzello 2015; Walton et al. 2018). Therefore, it is possible that the pathogen(s) could have been released from sediment disturbance, or that pathogen virulence and/or host susceptibility were affected by the high temperatures, or both. Often new disease outbreaks occur following a change in host-parasite biological or ecological relationship, the introduction of a novel pathogen(s) in susceptible host populations, the emergence of newly evolved pathogens and/or changes in environmental conditions that alter the microbiome/host physiological equilibrium, fostering increased pathogen virulence, transmissibility and coral mortality (Daszak et al. 2000, 2001; Harvell et al. 2007, 2009; Weil and Rogers 2011; Woodley et al. 2016; Aeby et al. 2019).

This apparently new disease has been called "Stony Coral Tissue Loss Disease" (SCTLD). It is waterborne, highly transmissible and highly virulent (rapidly kills coral tissues at a rate of 3-4 cm/day), affecting at least 22 foundational, scleractinian species (generalist), both usually characteristic traits of a novel pathogen (Weil and Rogers 2011). Furthermore, in Florida and St. Thomas, most diseased coral lesions treated with an antibiotic (*amoxicillin*) showed

Table 1. Chronological dispersion of SCTLD in Florida and the northern Caribbean, and appearance of localized disease outbreak in Puerto Rico

2014 - First reported off the coast of Miami-Dade County, Florida
2015 - Expanded to Biscayne National Park and north to Broward County in Florida
2016 - Continued spreading in Florida, south to the Upper Keys and north to Palm Beach County
2017 - Moved south into the Middle Keys and to the northern latitudinal edge of the Florida Reef Tract
2017 - First reports from the north coast of Jamaica in July 2017
2018 - Reached the Lower Keys in Florida, more reports made from Jamaica, new reports from Mexico, Belize and St. Maarten

- Spring 2018: New observations from the northwest coast of Jamaica
- July 2018: First reports from Quintana Roo, Mexico
- October 2018: First report in the eastern Caribbean, St. Maarten

2019 - Moved to the southwest end of the Lower Keys, not into the Dry Tortugas National Park. AGRRA created a map to report and track SCTLD throughout the Caribbean:

- January 2019: First reports at Flat Cay, St. Thomas, U.S. Virgin Islands
- March 2019: Reported at more locations in St. Maarten; First report in northwest coast of the Dominican Republic
- June 2019: First report from Belize
- August 2019: First report from Saint Eustatius

2019 - First reports of a localized disease outbreak off the eastern coast of Puerto Rico

- November 2019: Reports of highly virulent tissue loss disease affecting several corals in Tamarindo Chico reef, Culebra, Puerto Rico. Many colonies with signs similar to those reported for SCTLD.

https://floridakeys.noaa.gov/coral-disease/disease.html; https://www.agrra.org/coral-disease-outbreak/

signs that disease progression had slowed or even stopped (SCTLD, Florida Keys National Marine Sanctuary 2018; M. Brandt pers. comm.). These characteristics indicate that a bacterium or a complex of bacteria might be responsible, although the putative agent(s) have yet to be identified (Meyer et al. 2018; Aeby et al. 2019). Similarities of SCTLD signs with those of white plague disease type II (WPD-II) (Richardson et al. 1998; Weil and Rogers 2011; Woodley et al. 2006; SCTLD-Report-Florida Keys National Marine Sanctuary) has produced uncertainty when attempting to identify the disease in the field. Some differences with WPD include: acute multifocal infections on single colonies, tissue and mucus sloughing, and more rapid tissue mortality. These symptoms may not, however, be observed in all colonies, or in a single survey, but only in repetitive surveys of the same colonies.

Both of the above diseases are “generalists”, affecting multiple species, although species susceptibility seems to vary. Of the 22 species reported with SCTLD signs, most of them are important reef-building species in the Caribbean. Six species seem to be highly susceptible in Florida (prevalence > 85%) and other localities: *Meandrina meandrites, Colpophyllia natans, Dichocoenia stokesii, Pseudodiploria strigosa, P. clivosa* and *Dendrogyra cylindrus*. Five species showed prevalence values higher than 45% in Florida (*Eusmilia fastigiata, Diploria labyrinthiformis, Montastraea cavernosa, Stephanocoenia intersepta and Orbicella faveolata*) (Meyer et al. 2018; Aeby et al 2019; SCTLD-Report-Florida Keys National Marine Sanctuary-2018). Four susceptible species (*D. cylindrus, O. faveolata, O. franksi* and *O. annularis*) are listed as threatened under the United States Endangered Species Act. The *Orbicella* spp. complex, *Montastraea cavernosa* and *Siderastrea siderea* are listed under intermediately susceptible to SCTLD, however, species susceptibility could vary geographically and temporally as the disease moves through the Caribbean. Corals, like many other modular cnidarians, do not show many different visible structural/ physiological responses to diseases, specially, within the white band-white plague syndromes. These syndromes produce a white, clean skeletal band after the die-off of the tissue, between the normal-looking tissue and the colonizing turf algae. The band width

is determined by the balance between how fast the tissue is dying (virulence) and how fast algal turf is colonizing. Although similar signs have been observed across sites, we cannot assume that the observed signs represent the same disease produced by the same pathogen (s), as this may not be the case all across the local and/or geographic distribution of the disease (Sunagawa et al. 2009). Once the pathogen(s) of SCTLD has been determined, diseased colonies in all the reported localities will have to be tested to confirm whether all cases represent the same disease.

In Florida in 2015-2017 SCTLD spread quickly (at a rate of 7–10 km/month) along the Florida Reef Tract both south and north of "ground zero". Since then it has expanded to several northern Caribbean localities (Table 1 - https://www.agrra.org/coral-disease-outbreak/; https://floridakeys.noaa.gov/coral-disease/disease.html) producing significant mortalities in populations of the susceptible species in all localities where it has been observed, raising concerns about the overall impact it could have on the already declining coral reef communities across the region (Lunz et al. 2017; Florida Keys National Marine Sanctuary 2018; Meyer et al. 2019; Aeby et al. 2019). The dispersion pattern of SCTLD does not seem to follow directly the direction of local and regional currents from "ground zero", since it has shown up in localities in directions against the normal current, and/or at sites thousands of km apart. Since the disease is waterborne and highly infectious, it would be expected to follow the direction and speed of ocean currents, however it was reported from Jamaica in July 2017 with no reports from Cuba or the Cayman Islands. It was reported in Quintana Roo, Mexico in July 2018 and in Belize in June 2019.

The disease was first observed in St. Thomas, USVI, in January 2019, before it was observed in the Dominican Republic and then in the Turks and Caicos Islands. It quickly spread along the southwest coast of St. Thomas, producing highly localized mortality of the susceptible species, and has been documented as spreading northeastward as well. There are no reports of outbreaks of SCTLD from the Bahamas, Cuba or other localities intermediate to the southernmost areas where it has been reported, leading some researchers to postulate that cruise/cargo ships or "contaminated" dive equipment might be involved in SCTLD dispersion. There might be other biological/oceanographic explanations for this discontinuous dispersion pattern. For example, the pathogen (s) might be part of the normal microbiome of the holobiont, as mutualistic components, or the sediment and substrate, and become virulent given certain changes in environmental conditions, host susceptibility or both.

Oceanographic current models projected that as a waterborne pathogen SCTLD would reach Puerto Rican waters, close to Vieques or Culebra, by May-June 2019. It was not however until October 2019 that a few, isolated colonies of some of the susceptible species were observed with the described SCTLD signs in Culebra. Between March and August 2019 several colonies of *S. siderea* were observed with signs of what looked like acute WPD or SCTLD on many reefs in the east (Ceiba, Humacao, Culebra and Vieques) and west (Cabo Rojo, Guanica and Mona) of Puerto Rico. Some colonies showed mucus and tissue sloughing, and fast, multifocal, acute rapid loss of live tissue, similar to SCTLD signs. In what seems a systemic immune response, several colonies became dark purple or just dark (Fig. 2). However, there were no other diseased species and no signs of an outbreak, which could indicate that this is a different disease affecting only *S. siderea*, possibly induced by the thermal anomaly hitting the area this year (Miller et al. 2009; Weil and Rogers 2011). By November 2019, a minor, localized outbreak of what looked like SCTLD also affected many colonies of several species at Punta Tamarindo Chico reef (18°18.578'N - 65°19.040'W) on Culebra Island, off the eastern coast of Puerto Rico (Fig. 1.). Curiously, colonies with typical multifocal signs of SCTLD were not observed in November 2019 at any of the 29 random sites surveyed in Culebra for NOAA's National Coral Reef Monitoring Program (NCRMP). So far, Tamarindo Chico reef is the only locality reported to have characteristic signs of SCTLD in Puerto Rico.

Water temperatures have been above average this year for the northeastern Caribbean, reaching seven Degree Heating Weeks (DHW) (local measurements and NOAA) by November 2019. In September 2019, this thermal anomaly induced yet another extensive bleaching event that expanded all over Puerto Rico's shallow and upper-mesophotic coral communities by November. Bleached corals make it difficult to distinguish the signs of SCTLD or WPD. Bleaching prevalence measured around Culebra during the NCRMP surveys in November 2019 varied between 50-62% (partially to totally bleached), with the most susceptible species in this area being *O. annularis, O. faveolata, P. strigosa, D. labyrinthiformis* and *S. siderea*. During this period hard corals in Culebra were possibly more susceptible to disease

due to thermal stress. Per anecdotal evidence, SCTLD lesion progression rates appeared to slow down or even stop during periods of higher water temperatures and/or coral bleaching in Florida and the USVI; however the relationship between these factors is still uncertain (Aeby et al. 2019).

Consecutive surveys in Tamarindo Chico reef showed a significant increase in disease prevalence in SCTLD susceptible species, from 4% in October, to 50% in November, and 74% in December (Hernández-Delgado and Suleimán-Ramos, unpublished data). Similar to the initial stages of SCTLD in St. Thomas, acute impacts have remained highly localized across a single reef site, affecting mostly meandroid species. Disease prevalence varied across species: >50% in *D. cylindrus*, 80% in *P. strigosa, P. clivosa,* and *D. labyrinthiformis*, and >90% in *M. meandrites* and *S. siderea*, which, as mentioned above, have shown signs of disease well before this localized outbreak. The disease indiscriminately affected wild and nursery-restored colonies of *D. cylindrus, Pseudodiploria* spp., *D. labyrinthiformis, C. natans, M. meandrites* and *S. siderea*. It has also affected colonies of *D. cylindrus* and *E. fastigiata* on adjacent coral farms, but with a significantly lower prevalence (<5%). With the collaboration of Nova Southeastern University, the NGO Sociedad Ambiente Marino and a provisional permit provided by the Puerto Rico Department of Natural and Environmental Resources (DNER), preliminary testing with an experimental treatment of amoxicillin antibiotic in CoreRX Base2B yielded promising results, halting disease progression in 90% of treated colonies of *Pseudodiploria spp.*, *D. labyrinthiformis, Colpophyllia natans, D. cylindrus, M. cavernosa* and *S. siderea* (N = 50 colonies).

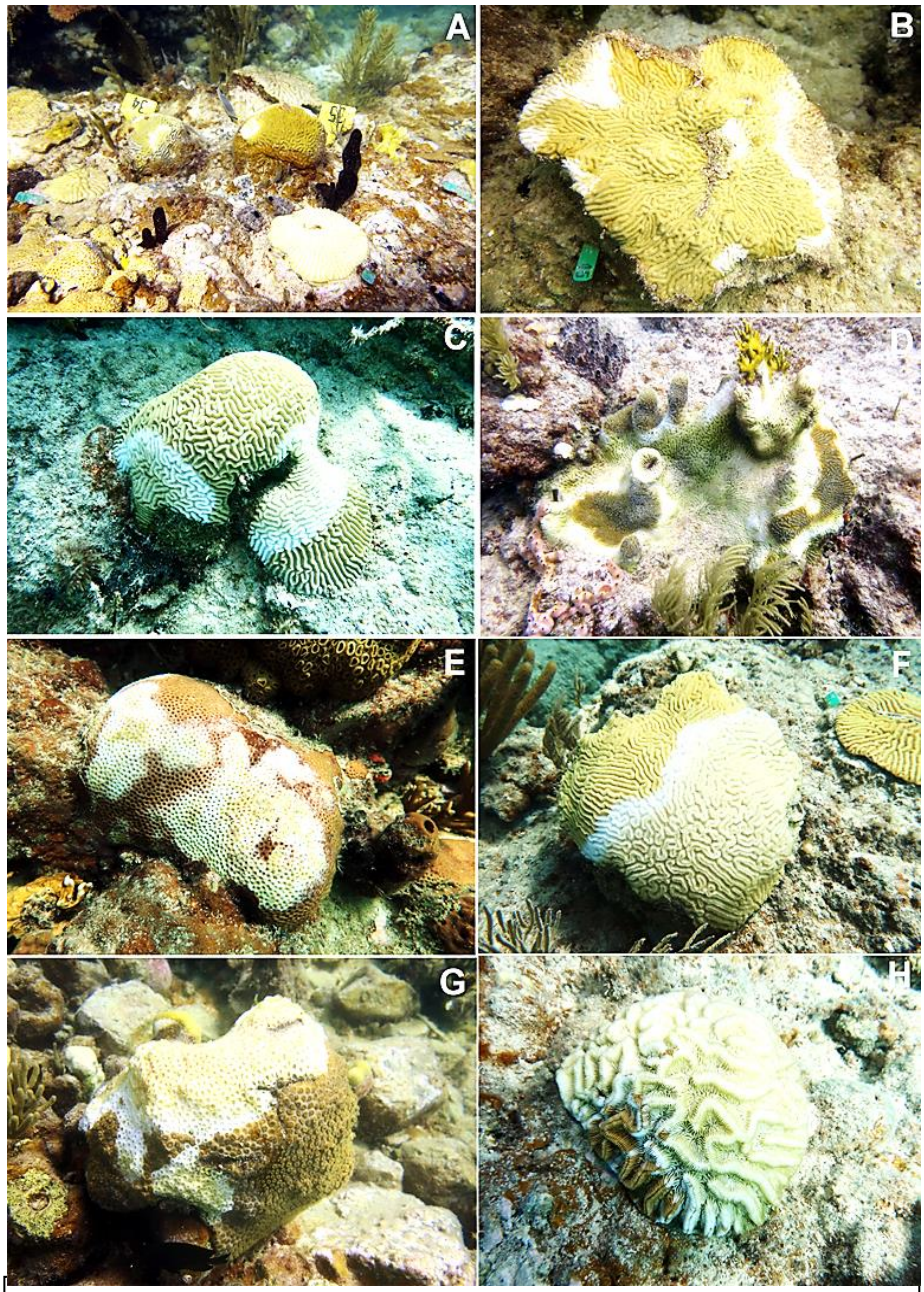

Figure 1. Photographs of diseased colonies of species susceptible to SCTLD in Tamarindo Chico, Culebra. Several small colonies of *P. strigosa* with multi-focal infected areas (A). Colony of *P. clivosa* with fast advancing, multi-focal infections (B). Medium sized *P. strigosa* with two rapidly advancing diseased areas (C). Almost 100% mortality in small *D. cylindrus* (D). Mucus and tissue sloughing in *S. siderea* (E). Rapidly advancing white band area in *D. labyrinthiformis* (F) and *M. cavernosa* (G). Small colony of *C. natans* that is almost 100% dead in a short time (H).

One of the most effective responses documented thus far, from Florida and St. Thomas, has been the use of amoxicillin; but given the characteristics of SCTLD, there is a pressing need to increase significantly the number of colonies treated per locality (and to text other antibiotics) in order to minimize the risk of infection spreading to other

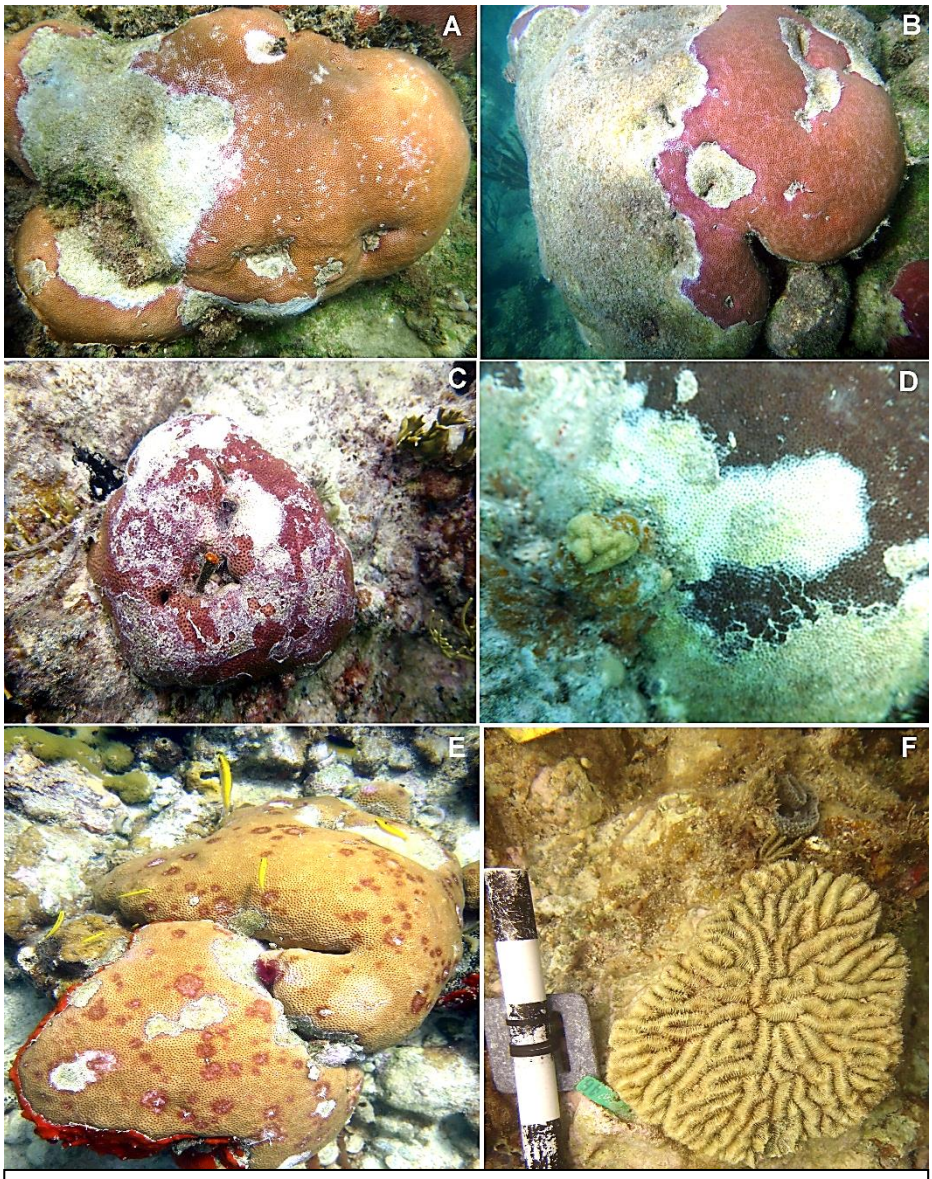

Figure 2. Diseased colonies *of S. siderea* around Puerto Rico, some before the outbreak of the possible SCTLD outbreak was reported in Tamarindo Chico, Culebra. Two large diseased colonies with multifocal infected areas and evidence of fast mortality in Guaniquilla, west coast of Puerto Rico (A, B). Mucus and tissue sloughing in diseased *S. siderea* (C, D). Colony of *S. siderea* with multiple signs of dark spots disease and multi-focal infections of a white-plague type that could be SCTLD (E). A recently fast killed colony of *M. meandrites,* with skeletal structure covered by sediment and signs of some turf colonization (F).

reefs. There is also a need to reduce, if possible, the numbers of recreational visits (i.e., SCUBA diving, snorkeling, kayaking) to the affected sites and to implement strict equipment disinfection protocols and also initiate outreach activities to inform and educate the stakeholders and any visitors. The DNER has been participating in the USVI-SCTLD status monthly calls even before suspicious colonies were identified in Puerto Rico. With the support of the DNER, SCTLD education and outreach materials generated by other jurisdictions have been translated into Spanish and shared with relevant audiences to increase awareness and promote SCTLD prevention. In addition, theoretical and practical training on SCTLD was held by Sea Grant FL, Sea Grant PR and the DNER for coral reef experts, dive shops, fishermen and other stakeholders. Direct communication was also established with tourist operators in Vieques, where SCTLD was expected to show-up first, following UVI projections.

Several other Federal and local government agencies, Institutions and NGOs [the National Oceanic and Atmospheric Administration (NOAA), the University of Puerto Rico in San Juan, Sociedad Ambiente Marino (SAM), HJR Reefscaping, Coastal Survey Solutions, and the Department of Marine Sciences (DMS) of University of Puerto Rico, Mayaguez] have also collaborated to educate, prevent, prepare, and respond to the threat of SCTLD on Puerto Rico's coral reefs. By staying in contact with key stakeholders in both Florida and the USVI, these institutions have had the benefit of learning from other jurisdictions' experiences to develop response plans, protocols and "rapid response teams" (RRT) for Puerto Rico. The RRT are trained on how to identify the disease and differentiate it from other coral diseases and bleaching, how to treat diseased colonies, and how to decontaminate diving equipment after dives in disease-impacted areas, among other response activities. Such training and preparedness is crucial given the threat of SCTLD to coral reefs in Puerto Rico. Researchers are exploring other ways to control the disease.

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The Impact to Reefs of The Trade in Marine Ornamental Fishes

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Marine ornamental fishes, primarily fishes from coral reefs, are caught for private and public aquaria. The business has grown strongly over the last two decades and is now worth 1.5 billion US$ (Wabnitz et al. 2003; Smith et al. 2008; Monticini 2010; Rhyne et al. 2012, 2017; Dee et al. 2014; Leal et al. 2015; Biondo 2017), so that despite past measures taken to regulate the industry the fishery represents a real threat to reef communities, albeit less significant than that posed by climate change. Currently around 2,300 species and annually about 40 million specimens are estimated to be traded worldwide (Rhyne et al. 2017; Stevens et al. 2017).This figure does not include mortality in the supply chain, which represents a major concern (Wabnitz et al. 2003; Vagelli 2011; Stevens et al. 2017). In some places the trade directly threatens the species concerned, due to poor handling during capture and transportation, or to damage to the ecosystem resulting from unsustainable capture practices, such as the illegal use of cyanide in Southeast Asia (Vagelli 2011; Cohen et al. 2013;). Most ornamental fishes seem to be sold to the USA, Europe and Japan (Wabnitz et al. 2013). For Asia, Africa, Central and South America, however, there are hardly any data available.

Since few coral reef fishes are bred in captivity, the majority come from the wild (Wabnitz et al. 2003; Rhyne et al. 2012, 2017; Biondo 2017, 2018; Biondo and Burki 2019). The Food and Agriculture Organization of the United Nations (FAO) and the World Association of Zoos and Aquariums (WAZA) state that only 25 marine ornamental fish species are being captive bred in commercial numbers (Bartley 2005; Penning et al. 2009). A 2013 list of captive bred marine ornamental fishes published by the Marine Breeders Association (MBA) lists 15 species, while 29 species of captive bred species were readily available in the US in 2015 and 27 in 2016 (Sweet 2014, 2016b). However, there are reports of between 100 and 330 species of marine ornamental fish having been bred in captivity, largely on a hobbyist or research scale. Of these, approximately 30–35 species are currently in commercial production, albeit still on a relatively small scale (Fotedar and Phillips 2011; Sweet 2016b).

Tangible trade data are only collected for species that are listed on the Appendices of the Convention on International Trade of Endangered Species of Fauna and Flora (CITES; www.cites.org). Thus, there is no monitoring of the trade for virtually any coral fishes, except seahorses (*Hippocampus* spp.), the clarion angel fish (*Holacanthus clarionensis*) and the napoleon wrasse (*Cheilinus undulatus*) (see illustration on p 48), for which trade is regulated by CITES. Historically, scientists have pointed out the importance of accurate trade statistics , but so far only a handful of studies have attempted to quantify this global trade (Wabnitz et al. 2003; Rhyne et al. 2012, 2017; Biondo 2017, 2018; Biondo and Burki 2019). Europe is a major importer of coral reef fishes and uses the Trade Control and Expert System (TRACES) to monitor trade in live animals for disease prevention purposes. Similarly, the US monitor this trade using the Law Enforcement Management Information System (LEMIS), (LEMIS 2009; Rhyne et al. 2017). Neither data collection systems are intended to record species-specific information on marine ornamental fishes, but rather they record numbers of traded specimens. However, TRACES collects information on species to at least family level. Consequently, it is possible to estimate the volume of trade, and to some extent also families and species traded, into Europe. Studies done for Switzerland from 2014 to 2017 showed that about 50,000 specimens were traded to Switzerland annually and that the species came from 19 countries and were also trans-shipped to 11 EU countries (Biondo 2018) (Fig. 1).

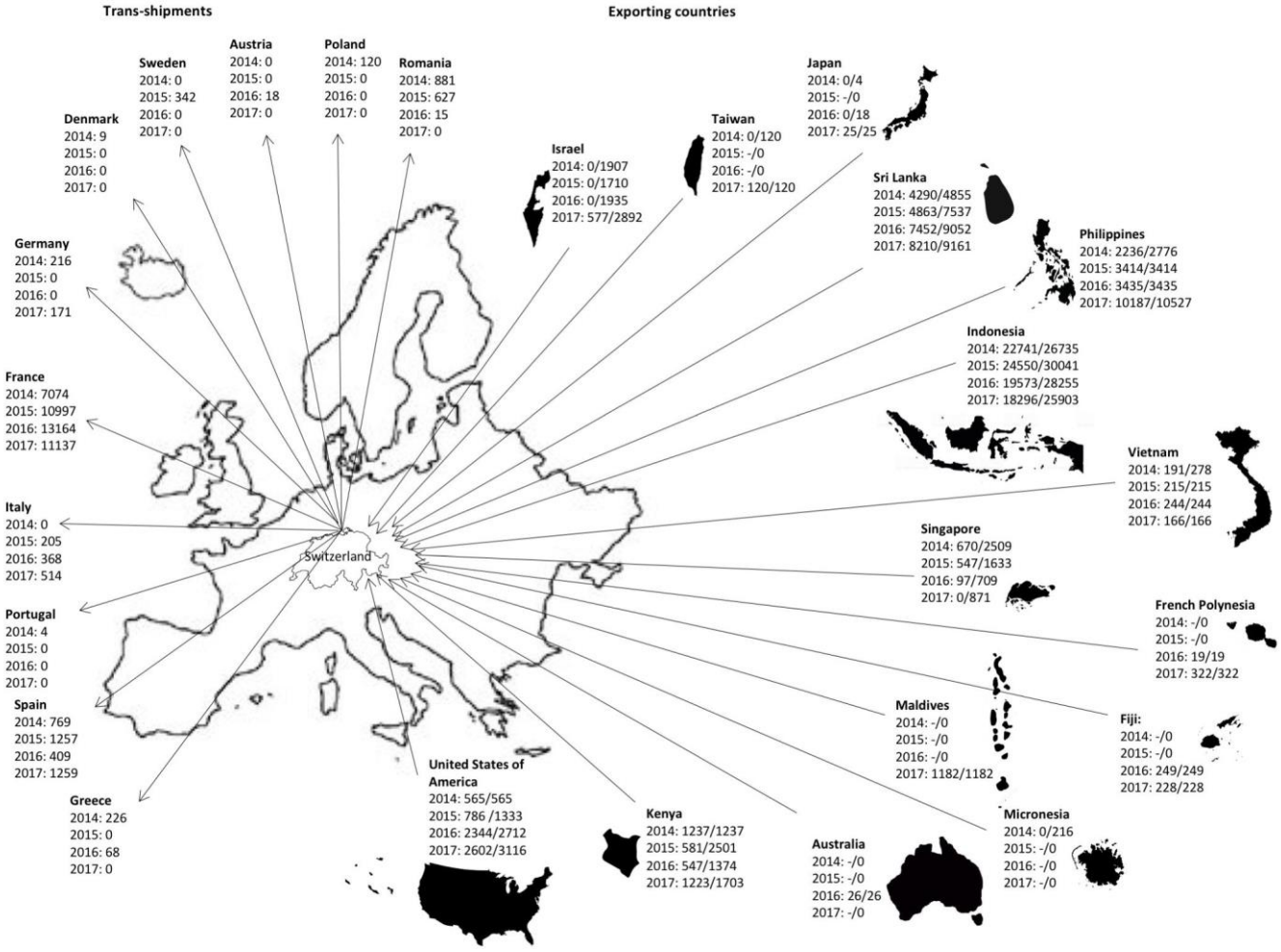

Fig. 1. Pathways of marine ornamental fishes imported to and trans-shipped from Switzerland from 2014 to 2017. Exporting countries = Number of specimens remaining in Switzerland/number of overall specimens. 0 = shipment without detailed data for specimen or species, - = no data discernible. Trans shipping countries = Number of specimens trans-shipped (Biondo, 2018).

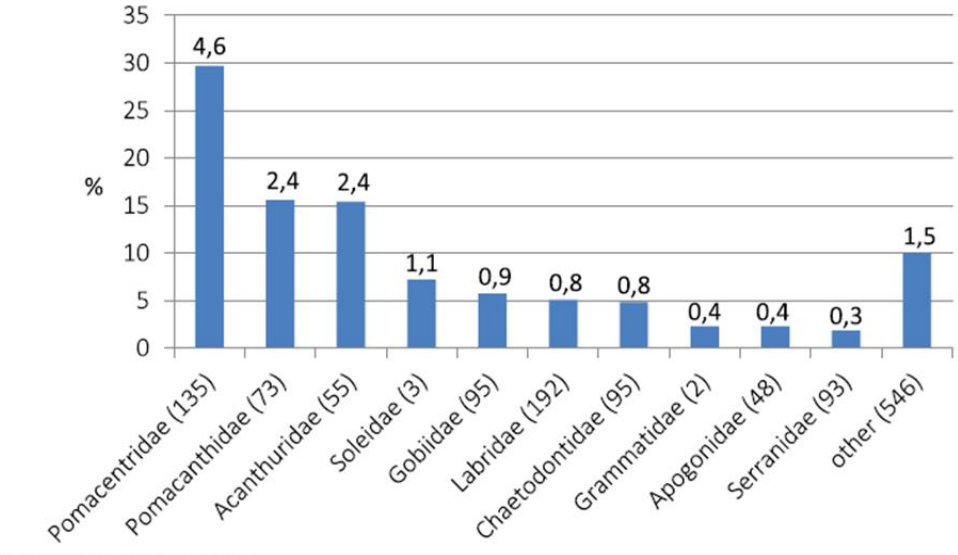

Fig. 2. *The trade volume (as % of the total) of the top ten families traded into Europe between 2014 and 2017. The number of imported species in the family are in parentheses; the numbers on top of each bar represents the numbers of specimens imported in millions (Biondo and Burki, 2019).*

The trade for the whole of Europe was found to amount to approximately 4 million marine ornamental fishes per year during the period 2014 and 2017 (Biondo and Burki, 2019). Between 2014 and 2017, fish species from 86 families were imported to Europe. The top 10 families made up 90% of the fish in terms of number of specimens (Fig. 2).

For data from Europe, especially susceptible species were identified using the number of traded specimens, trends in the trade volume, and IUCN Red List conservation status, as well as vulnerability according to FishBase. After normalization of data a score was created to generate a watchlist that indicates overall susceptibility to overexploitation of the species concerned (Biondo and Burki 2019). Unfortunately, however, almost a third of species listed were found to be data deficient or not evaluated by the IUCN Red List and so could not be included in these calculations (Biondo 2018; Biondo and Burki 2019) (Table 1).

	Switzerland								Worldwide	
Red List Evaluation	**# Spp**	**%**	**# Spp**	**%**	**# Spp**	**%**	**# Spp**	**%**	**# Spp**	**%**
YEAR	**2014**		**2015**		**2016**		**2017**		**2018**	
Not listed	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Not evaluated NE	86	30.2	95	29.6	46	26.7	63	29.7	1505	39.5
Data deficient DD	10	3.5	10	3.1	7	4.1	10	4.7	201	5.3
Least concern LC	182	63.9	209	65.1	117	68.0	134	63.2	1957	51.3
Near threatened NT	4	1.4	3	0.9	1	0.6	2	0.9	42	1.1
Vulnerable VU	2	0.7	3	0.9	1	0.6	2	0.9	88	2.3
Endangered EN	1	0.4	1	0.3	0	0.0	1	0.5	19	0.5
Critically endangered CR	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0

Table 1. IUCN Red List evaluation of marine ornamental fish species imported to Switzerland from 2014 to 2017 showing variation in the numbers of species imported and their significance (as % of the numbers traded) per year in relation to the global IUCN Red List evaluation of the species concerned, as listed in FishBase (accessed 23.05.2018).

In previous decades, various initiatives were introduced with a view to regulating the international ornamental fish trade, but these efforts have had only limited success. The Marine Aquarium Council (MAC) label was established in 1998 to ensure traceability, good practices, and sustainable schemes of ecologically and socially responsible fishing, but has been inactive since 2008 (UNEP 2009). The Global Marine Aquarium Database (GMAD) launched in 2002 was intended to collect accurate trade data, but voluntary data entry ceased after one year due to lack of funding (Townsend 2011; Murray et al. 2012). Also, the EU commissioned consultancy study on improving trade statistics for EU imports of tropical marine fishes (UNEP-WCMC 2008) has not resulted in any action since the report's submission.

As a result of the available research in August 2019 Switzerland, the European Union and the USA submitted to CITES CoP18, (in Geneva, Switzerland) a proposal to investigate the international trade in marine ornamental fishes in preparation for the next conference in 2022 (https://cites.org/sites/default/files/eng/cop/18/doc/E-CoP18-094.pdf). The over 180 member states represented recognised the urgency of the situation and approved the proposal by consensus. From now until the next Animals Committee meeting, which will take place in the summer of 2020, the

first steps in this investigation need to be agreed and acted upon. The principal aim of the work will be to determine which species need to be listed in the Appendices of CITES, under the terms of which their trade can be monitored and research conducted to determine if this is having detrimental effects on the species. Subsequently it may well be necessary to restrict or ban the trade in certain species, but it is a concern that this will likely take 8 years or more to achieve.

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The napoleon wrasse (*Cheilinus undulatus*), one of the few reef fish species for which monitoring of trade is required under CITES. Illustration from the book "A Reef Life" by Callum Roberts (see book review in REEF SHELF section) – photo by Alex Mustard.

GRADUATE FELLOWSHIP REPORTS

Spatial and temporal modulation of the expression of Heat Shock Proteins in the coral *Acropora muricata* before and during the 2016 El Niño

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Anthropogenic activities including climate change-driven disturbances such as elevated sea surface temperature and ocean acidification are escalating the frequency and severity of coral bleaching events. The vulnerability of corals to bleaching tends to be highly variable within geographical locations and between and even within cnidarian genera (Kleypas et al. 2008), suggesting the occurrence of differential bleaching patterns. Variable bleaching patterns could be due to patchy distribution of stress or development of mechanisms by corals to withstand thermal stress. The mechanisms behind increased tolerance to thermal stress remain debatable. The main drivers of differential response of corals are the existence of more thermally tolerant coral taxa (Marshall and Baird 2000) and symbiont genotypes (Baker et al. 2004). Other biological traits including antioxidant capacity, energy reserve recovery, photoprotection and modulation of expression of genes involved in heat stress response have been reported as being involved in the process.

However, one vital acclamatory response of coral to thermal stress, namely the modulation of the expression of a group of molecular chaperones called heat shock proteins (Hsps) (Olsen et al. 2013), still remains to be thoroughly studied. There is evidence that corals have an enhanced thermotolerance capacity linked to cellular protective mechanisms such as the induction of the Hsps (Chow et al. 2012; Seveso et al. 2014). Hsps have vital cytoprotective functions. As molecular chaperones, they are involved in protein folding, unfolding, sorting, transport and assembly of complexes. They also protect cells from apoptosis and stress. During a stress event, such as exposure to thermal stress, protein misfolding, aggregation or disruption of regulation and disassembly of multiprotein complexes may occur, leading to subsequent activation of signaling pathways. Through their cytoprotective functions, Hsps are thought to restore proteolitic homeostasis. Heat shock proteins are categorized into several families that are based on their approximate molecular mass and specific functions: small Hsps e.g. Hsp 16, 40-kDa Hsp, 60-kDa Hsp, 70-kDa Hsp, 90-kDa Hsp and 110-kDa Hsp. The expression of heat shock protein genes following heat stress and their potential use as biomarkers have been well studied in corals, but their regulation at the protein level still needs to be investigated. Hsps are important components of the folding system in different organelles and play essential roles in cellular physiology and stress response. In particular, Hsp70 and Hsp60 are vital molecular chaperones that preserve protein homeostasis and Hsp32, a heme oxygenase-1 protein involved in response to cytosolic oxidative stress. Following environmental stresses, protein expression of these Hsps are up-regulated in order to activate cellular repair processes and increase tolerance to adverse conditions by conserving metabolic functions.

In Mauritius, in the lagoon of Belle Mare, bleaching of one of the most abundant reef-building corals, *Acropora muricate* (Fig. 1), was found to occur on the outer back reef, but not in colonies situated near the shore, during the 2009 bleaching event (Fig. 2). Similarly, during the 2016 El Nino the extent of bleaching was greater on the outer reef. These observations suggested that coastal colonies of *A. muricata* have developed capabilities to withstand light and

Figure 1. *Bleaching of back reef* A. muricata *colonies observed in summer 2016*

thermal stresses. The two sites are known to experience comparable maximum temperatures, but daily temperature variation is 2-fold greater at the coast site than at the reef site (Louis *et al.,* 2016). The two sites also had different thermal histories as bleaching of *A. muricata* colonies occurred only at the reef site during the 2009 bleaching event (Bhagooli and Taleb-Hossenkhan, 2012).

We hypothesize that near coast colonies possess better acclimatization features and that the coral colonies at these two distinct habitats would thus differ in terms of modulation of the expression of the vital proteins Hsp70 and Hsp60. In this study, we hence aimed to examine and compare the protein expression profiles of these Hsps in *A. muricata* from these two locations, during the summer and winter months of a non-bleaching year (2014) and a bleaching year (2016).

Material and Methods

Coral sampling. Upright tips of *A. muricata* nubbins (5 cm long) were collected in Belle Mare lagoon (Fig. 2). Six different colonies (n=6) were sampled each from the near-coast station and from the back reef station in summer and winter during the non-bleaching year 2014 and bleaching year 2016. The two stations were approximately 700–800 m apart. All coral nubbins were immediately flash-frozen in liquid nitrogen and shipped on dry-ice to the University of Milan-Bicocca (Italy).

Protein extraction and quantification. Coral nubbins were homogenized in SDS-buffer (Seveso et al., 2014). Protein concentration was determined with the Bio-Rad Protein Assay Kit II (Bio-Rad Laboratories) according to the manufacturer's protocol. Proteins were then separated by SDS- polyacrylamide gel electrophoresis (SDS-PAGE). The anti-Hsp60 monoclonal antibody (IgGI1 mouse clone LK-2, immunogen: recombinant human HSP60, SPA-807, Enzo Life Sciences), anti-Hsp70 monoclonal antibody (IgG2a mouse clone BB70, immunogen: chicken Hsp70/Hsp90 complex, SPA-822, Enzo Life Sciences), and anti-β-Actin monoclonal antibody (IgG1k mouse clone C4, MAB1501, Millipore) were used for detection of proteins of interest. The immunoblot was incubated with Pierce ECL (enhanced chemiluminescene) Western Blotting Substrate (Thermo Scientific). The blot was then exposed to X-ray film in a dark room to visualise the presence of protein bands. Optimisation of immunoblotting was not successful for Hsp32 even after several attempts at troubleshooting. Thus Hsp32 was excluded from this study.

Densitometric and data analyses. X-ray films were digitised by scanning films on a Bio-Rad GS-800 calibrated imaging densitometer. The pixel density of the scanned bands was quantified with the ImageJ free software of NIH Image software package. For each immunoblot, the intensities of Hsp60 and Hsp70 were normalised against the intensity of the internal loading control (i.e., β-Actin).

Results and Discussion

In summer 2014, no difference was apparent between coastal and reef sites for both Hsp60 and Hsp70 protein levels (Fig 3). However, during the 2015-2016 El Niño event, where harsher environmental conditions were prevailing (high temperature in combination with higher light intensity), healthy coastal colonies had higher levels of both Hsp60 and Hsp70 compared to bleached reef colonies; results were statistically insignificant for Hsp70. Inter-species differences

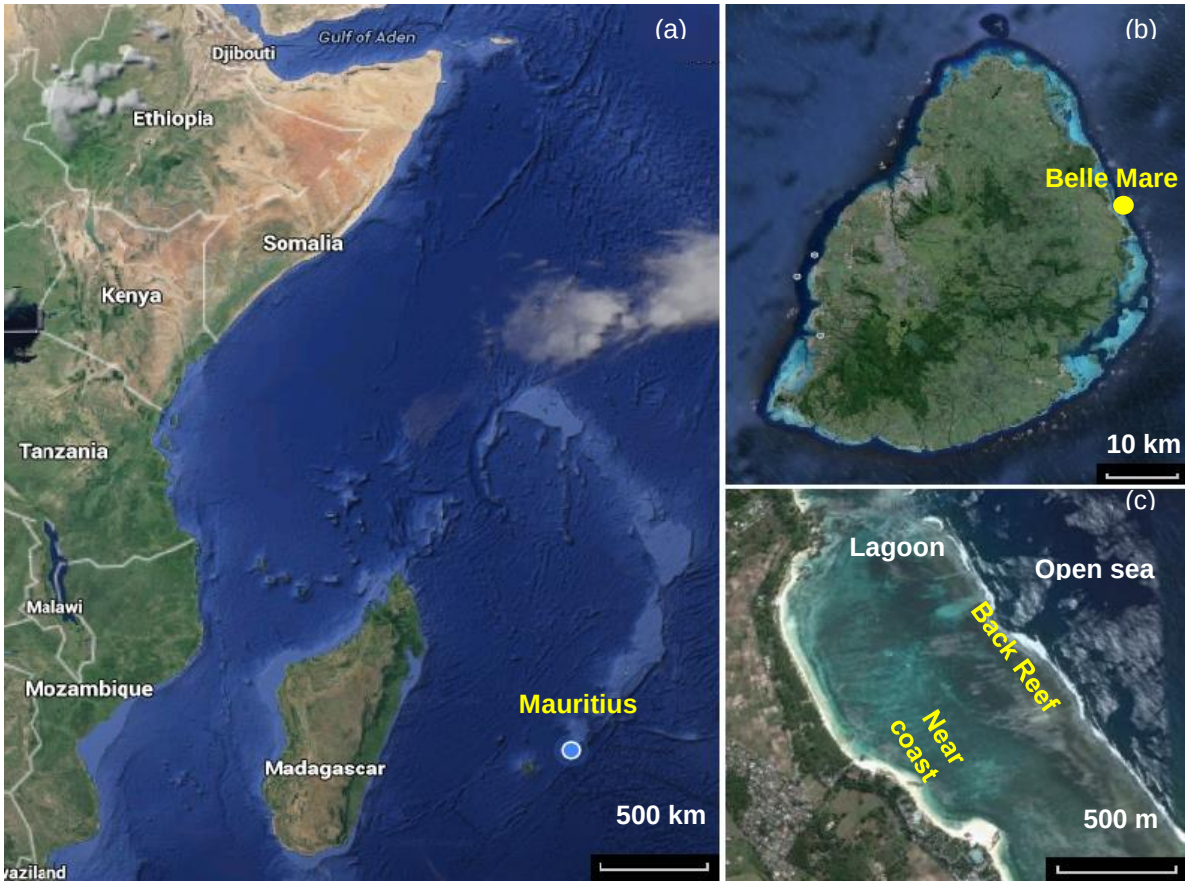

Figure 2. *(a) Mauritius is located at 20.2000°S, 57.5000° E in the Indian Ocean, (b) Belle Mare Lagoon is located on the East coast of Mauritius, (c) The two study stations at Belle Mare, near-coast and back reef stations (Source: Google Earth)*

in modulation of Hsp60 have been reported previously, with the most tolerant species having the highest level of Hsp60 during heat/light stress (Chow et al., 2009; Seveso et al., 2014). These observations suggest that the Hsp60 tested could be contributing to an enhanced thermotolerance in *A. muricata*, thereby explaining the differential bleaching pattern at the coast-reef scale. Understanding these heterogeneous responses provides insight into mechanisms that confer resilience to thermal stress. This study is the first documented report of intra-species difference in protein modulation from two spatially distant *A. muricata* populations in Mauritius.

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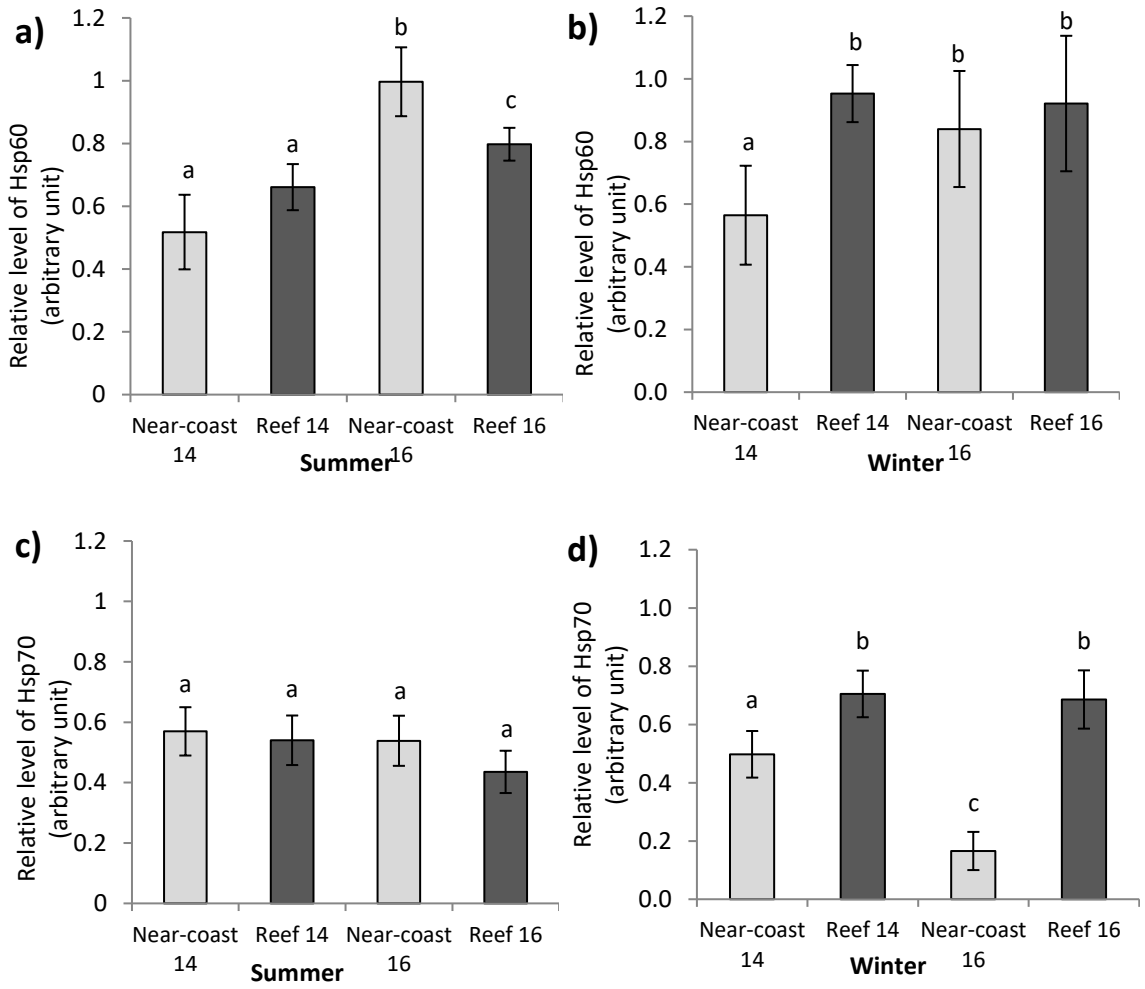

Figure 3. *Relative change in the protein expression of Hsp60 (a and b) and Hsp70 (c and d) between years (2014 &2016), seasons and sites. The values were determined by densitometric analysis. Signals for six different immunoblots were analysed. Data are expressed as arbitrary units and as mean ± SEM. Light grey bars represent near-coast samples whereas dark grey bars represent reef samples. Different letters above bars represent significant difference in relative Hsp60 and Hsp70 level between near-coast and reef samples for the two sampling years (p<0.05).*

REEF ENCOUNTER
The News Magazine of the International Coral Reef Society
Graduate Fellowship Reports

Molecular and microbial mechanisms of thermal adaptation in the keystone urchin, *Echinometra* sp. *EZ,* along the Arabian Peninsula

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Climate change has resulted in warming of coastal aquatic habitats around the world at almost every latitude, threatening all habitats, including coral reef ecosystems, with a significant loss in biodiversity, and occurring at a rate that may exceed species ability to adapt (Levitus et al. 2012; Munday et al. 2013). Maintenance of populations for coral reef species in these habitats is dependent on not only acclimation to these changing environmental conditions over the course of an organism's lifetime, but also adaptation over many generations. Two complementary mechanisms for coping with environmental change are differential selection of particular alleles in populations experiencing different stressors over time (classic Darwinian evolution), and shifts in the associated microbial community, which can happen on a timescale of hours to days. For the former, phylogeographic analysis of population genomic data is a powerful approach to identify potential genetic mechanisms for how coral reef species will persist through ongoing and future climate change, allowing identification of alleles unique to populations currently inhabiting warmer locations. In addition, microbial communities have been shown to confer a competitive advantage in their animal hosts when acclimating to different environmental parameters so that investigating these communities may elucidate specific microbes, or a community of microbes, that are crucial for acclimation to climate change (Ziegler et al. 2017). A research approach that investigates both evolutionary adaptation and microbial acclimation will provide a more complete understanding of if, and how, marine organisms may cope under climate change conditions. Further, investigating thermal adaptation and acclimation in extreme reefs will help identify the processes that will govern future responses by reef organisms to climate change.

The Persian/Arabian Gulf (herein referred to as the PAG) is an example of an extreme environment because it experiences the warmest coral reef temperatures on the planet (summer maxima ~35-36°C, but can exceed 37°C) (Sheppard 1993; Smith et al 2017) (Fig. 1). Further, the PAG experiences seasonal fluctuations of over 20°C and exceeds climate change predictions for the Indo-Pacific in the next century (Riegl et al. 2011; Coles and Riegl 2013). Lastly, it links to the neighboring Gulf of Oman, which experiences markedly different environmental conditions; summer maxima of ~30-32°C and seasonal fluctuations of 10°C (Burt et al. 2011). This environmental gradient provides a unique comparative study system, as there is significant species overlap between the two water bodies. The mechanisms of thermal adaptation/acclimation of marine organisms in the PAG and Gulf of Oman remain an untapped resource for understanding how species have adapted to thermal extremes.

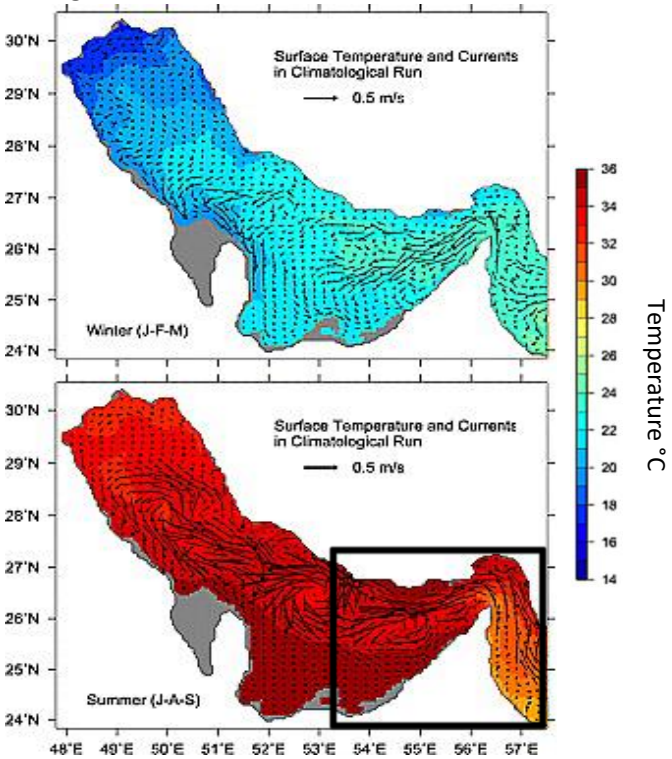

Figure 1: Temperature map of the PAG in winter (top) and summer (bottom)(3). The black square represents the area depicted in the Figure 2 sampling map.

Echinometra sp. *EZ,* is an abundant invertebrate that resides in both the Gulf of Oman and PAG (Ketchum et al. 2018) and has a significant role in the health and dynamics of coral reef ecosystems as a major bioeroder (Peyrot-Clausade et al. 2000). *E.* sp. *EZ* is a key herbivore that consumes

Picture 1: *Left: PhD Candidate, Remi Ketchum, extracting tissues from a sea urchin in Oman. Right: Echinometra sp. EZ (otherwise known as the rock-burrowing urchin) on a reef in the Persian/Arabian Gulf. It is important to note that this species was previously thought to be* Echinometra mathaei, *but we have recently shown that to be incorrect (Ketchum et al. 2018) and have found no evidence of* E. mathaei *in/around the Arabian Peninsula. Photos by: Grace O. Vaughan.*

predominately algae, this being a critical activity as it prevents overgrowth of corals by algae and supports nutrient cycling (Mills et al. 2000). The more well-studied keystone urchin, *Diadema antillarum*, experienced a mass disease-induced mortality event in 1983 in the Caribbean which led to a devastating phase shift on many of the reefs they once inhabited. There was also widespread coral bleaching, disease and nutrification, resulting in deterioration of many coral reefs in the Caribbean, since they were not able to recover in the absence of *D. antillarum*. This demonstrates the importance of these key herbivores and the need to understand how they will adapt/acclimate under climate change (Mumby et al. 2006). To date, there have been no studies that investigate the genomic basis of thermal adaptation in *E.* sp. *EZ,* and no comparative assessment of microbial gut communities. Consequently, this species provides an excellent opportunity to study the mechanistic processes that occur across timescales in an ecologically vital urchin species, the rock-burrowing urchin.

The Graduate Fellowship provided through the International Coral Reef Society (ICRS) has allowed me to do fieldwork in the United Arab Emirates and Oman. With the help of the NYU Abu Dhabi Marine Biology Lab, I was able to collect 15 urchins from seven different sites in the PAG and the Gulf of Oman (Fig. 2). Restriction Site-Associated DNA sequencing (RADseq) and 16S gene amplicon sequencing has been implemented to investigate candidate genes under selection, and characterize microbial gut communities, respectively. The first product to come from this grant was a publication in Frontiers in Marine Science (Ketchum et al. 2018), where we investigated the role that DNA extraction method plays in the characterization of microbial communities.

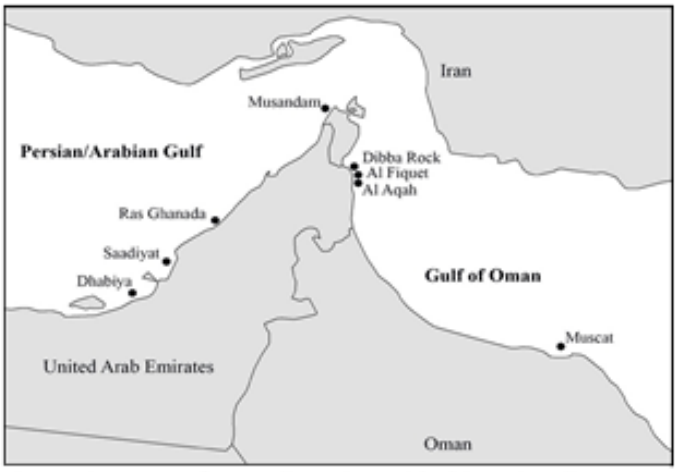

Figure 2: Map of sampling sites; Dhabiya, Saadiyat, Ras Ghanada, Musandam, Dibba Rock, Al Fiquet, and Al Aqah.

We tested urchin gut samples collected from Dhabiya (in the PAG), and Al Aqah (in the Gulf of Oman). The purpose of this experiment was to deduce the best extraction method to apply to our much larger sampling set consisting of seven populations. We compared three DNA extraction procedures and showed that community composition was significantly different between the different methods. Our results showed that the addition of bead-beating and a lysozyme step more effectively capture traditionally difficult to lyse taxa, such as gram-positive bacteria. Additionally, the extraction method played an important role in estimates of Shannon diversity (see Fig. 3). Diversity indices were higher when a lysozyme and bead beating step was used. Finally, diversity was overall higher in the PAG sites than the Gulf of Oman sites, which could point to population specific levels of diversity and is a promising outcome with respect to our upcoming analysis of all seven populations.

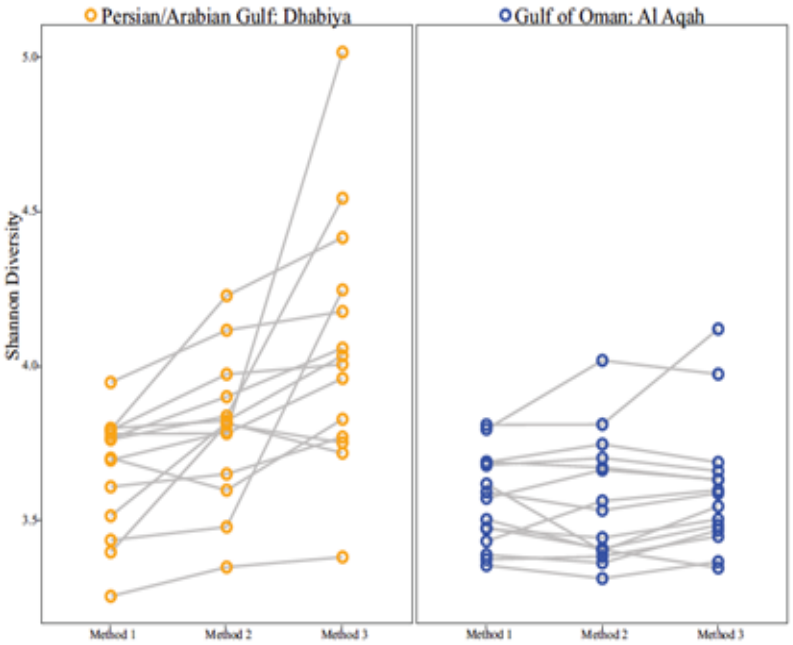

Figure 3: Shannon diversity indices of Persian/Arabian Gulf samples (left) and Gulf of Oman samples (right). Each node corresponds to an individual sample and each line connects one individuals tissue subjected to the three DNA extraction methods.

In addition to microbial community composition analysis, we also used RADseq to look for potential regions of the genome that may help these urchins survive under extreme environmental conditions. Our sampling strategy for these collections mirrored the strategy used for our microbial collections (seven populations and 15 individuals from each population), except that we collected gonadal tissue in this case. We have finished sampling and DNA extractions, and the samples have been sequenced. We are currently working to analyze these data and should have interesting findings within the month!

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Reconstructing historical shark communities in the Caribbean using dermal denticle assemblages

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Introduction

Today, there are relatively few sharks in the Caribbean (Ward-Paige et al. 2010). This makes it difficult yet vital to census and manage their populations, which can play important and multifaceted roles in coral reef ecosystems, from structuring food webs to altering the behavior of prey (Roff et al. 2016). But what did healthy predator communities look like on Caribbean coral reefs in the past? Historical accounts from explorers, naturalists, and ship logs often depicted high densities of sharks that contrast with contemporary reports in the same regions (Jackson et al. 2001; Ward-Paige et al. 2010). Evaluating these anecdotes' reliability is troublesome, because the degradation of Caribbean ecosystems long preceded the first ecological studies of their community structure and processes (Jackson 1997; Pandolfi et al. 2003). For example, some coastal shark populations have declined by more than 50% over the last several decades, as documented by visual surveys and fisheries catch data (Baum and Myers 2004; Ferretti et al. 2010). However, subsistence fishing can also deplete fish populations (Fitzpatrick and Keegan 2007), so these survey findings might have been predicated on an already shifted baseline. Longer quantitative records of change in shark communities on coral reefs over centuries to millennia are unavailable. Without these baseline data, it is challenging to determine historical shark abundance, characterize natural variation over time and space, interpret sharks' roles in intact and human-impacted ecosystems, and set appropriate management targets.

The recent fossil record can recover relevant ecological information about past ecosystems that can be used to establish baselines and inform modern-day conservation (Dietl and Flessa 2010). For example, coral reef sediments contain a treasure trove of skeletal material – including molluscs, coral skeletons, sponge spicules, urchin spines, and fish teeth and otoliths – that can help reveal reefs' ecological histories and historical ranges of variation (Pandolfi and Jackson 2006; Cramer et al. 2019; Lin et al. 2019). These data can be used to explore trajectories and drivers of change over time, understand ecosystem functioning, and help tackle reefs' current and future threats.

Study Area

We assessed change over time in the assemblages of shark denticles (small tooth-like scales) (Fig. 1) in three regions of the Caribbean: Panama, the Dominican Republic and Curaçao. Panama (Bocas del Toro) and the Dominican Republic (Enriquillo Valley) are home to the only known exposed mid-Holocene reefs in the Caribbean. In the Bocas del Toro region of Panama, the earliest archaeological records date from 3830 to 2355 cal BP (Baldi 2011), and people are thought to have settled on Hispaniola around 6000 to 3000 cal BP (Fitzpatrick and Keegan 2007). Consequently, these fossil reefs offer a unique window into pre-human conditions with which the modern reefs can be compared. On

Curaçao, we sampled reefs with varying amounts of modern-day fishing pressure and human infrastructure – ranging from sites near the capital and busy port of Caracasbaai to the more remote Klein Curaçao – to explore how different types of human activities affect relative shark abundance across the island. We also excavated samples from 125 ka Pleistocene terraces (Lower Terrace) to test whether denticles are preserved in this older, consolidated limestone.

Methods

In each of these three regions, we collected replicate 10 kg bulk samples of fine surface sediments from modern and fossil coral reefs to access the denticle record (Fig. 2). Sampling was constrained to low-energy habitats to reduce the likelihood that the denticle assemblages had been transported, sorted, reworked, or exposed to physical taphonomic biases prior to collection (Kidwell 2013). On the modern reefs, samples were excavated from the uppermost <10 cm of sediment using SCUBA in patches of mud, silt and sand with branching coral matrix (*Acropora cervicornis*), which limits vertical mixing. To characterize historical ranges of variation, we sampled a suite of *in situ* mid-Holocene reefs in Bocas del Toro, Panama (ca. 7.0-6.5 ka) and in the Enriquillo Valley, Dominican Republic (ca. 9.4-5.4 ka; Mann et al. 1984) in similar sheltered environments, yielding comparable bulk samples of fine sediments. Coral pieces were collected for Uranium-Thorium dating to determine temporal context at sites without existing dates.

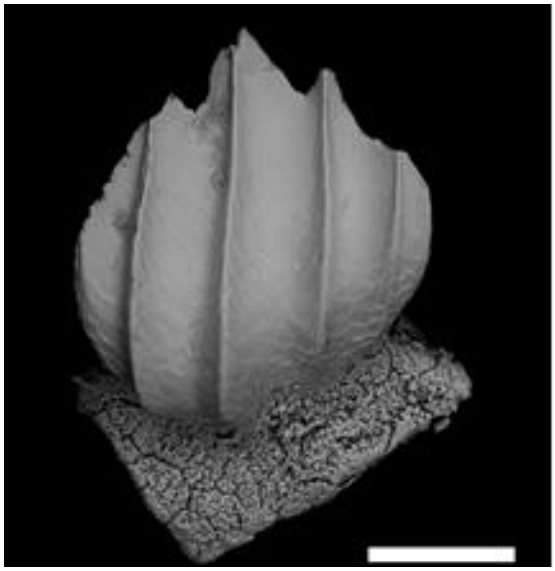

Figure 1. Scanning electron microscope image of a shark dermal denticle recovered from a mid-Holocene reef in Bocas del Toro, Panama. Scale bar = 100µm. Image credit: E. Dillon and J. Ceballos.

After collection, we sieved and processed the bulk sediment samples following a protocol adapted from Sibert et al. (2017) to isolate the denticles. Denticles were counted, measured, and identified to functional morphotype and shark family using our reference collection (Dillon et al. 2017). Denticle accumulation rates (denticle count per kg sediment per year) and denticle assemblage composition were compared between the modern and fossil reefs to determine how much relative shark abundance and community composition had shifted from their fossil-defined historical ranges of variation in each region. Finally, denticle assemblages recovered from the modern reefs were compared to explore spatial variation across the Caribbean, given differences in oceanographic conditions and levels of modern-day human impact.

Figure 2. Collecting bulk sediment samples from (A) modern and (B) fossil reefs. (C) Sieving the samples to extract the shark dermal denticles.

Baseline Caribbean Live Science Blog

While in the field, we shared written stories as well as photos and videos taken by a Smithsonian Tropical Research Institute photographer and videographer on the Baseline Caribbean live science blog run by the O'Dea lab group. To learn more about our field work, check out the blog posts from Panama, the Dominican Republic, and Curaçao.

Results and Discussion

Denticles were recovered from sediments in all three regions and were sufficiently well-preserved, allowing most to be identified. Mean denticle abundance varied across regions, ranging from 2 denticles per kg sediment in the Dominican Republic, to 5 denticles per kg sediment in Panama and 8 denticles per kg sediment in Curaçao (including 10 denticles per kg sediment in Klein Curaçao). Ichthyoliths were rare in the Pleistocene material collected from Curaçao, although more work is needed to determine their suitability for study. Around 90% of the overall denticle assemblage was composed of *drag reduction*, *abrasion strength*, and *ridged abrasion strength* denticles (Fig. 3), which characterize most reef-associated shark taxa.

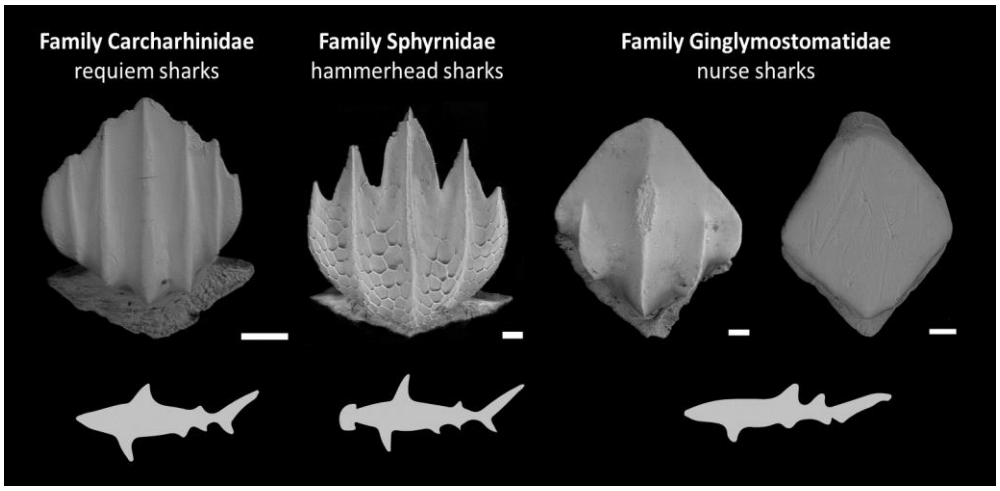

Figure 3. Scanning electron microscope images of denticles from the three main shark families represented in our samples. From left to right: Carcharhinidae (blacknose shark, *Carcharhinus acronotus* denticle shown, *drag reduction*), Sphyrnidae (scalloped hammerhead, *Sphyrna lewini* denticle shown, *drag reduction*), and Ginglymostomatidae (nurse shark, *Ginglymostoma cirratum* denticle shown, *ridged abrasion strength* and *abrasion strength*). Scale bar = 100µm. Image credit: E. Dillon and J. Ceballos.

Shark communities, as represented by their denticle assemblages, changed both in their relative abundance and composition over the last several millennia in our study regions. In Panama, the mean denticle accumulation rate was around five times higher on the mid-Holocene reefs than on the adjacent modern reefs, indicating an 80% decrease that rivals many of the records of decline since the 1950s in other areas of the Caribbean (Baum and Myers 2004). Denticle assemblage composition also shifted over time. There was around a 50% decrease in the relative abundance of *drag reduction* denticles over the last 7000 years. This functional morphotype is commonly found on fast swimming taxa, including many requiem and hammerhead sharks (Fig. 3), which tend to occupy higher trophic levels (Reif 1985; Roff et al. 2016). Moreover, there was around a 40% increase in the relative abundance of *abrasion strength* denticles, which characterize nurse sharks (*Ginglymostoma cirratum*), although this change was not statistically significant. A similar trend was observed in our samples from the Dominican Republic, although the patterns were less robust due to the low overall denticle abundance.

This first study of change in shark communities over the last several millennia using the denticle record suggests that there might have been a major shift in the dominant ecological roles played by sharks on these reefs. Not only were there potentially many more, or larger, sharks in the past, but the relative abundance of different shark taxa changed over time – notably including a loss of requiem and hammerhead sharks – which could have altered food web structure. These data can provide historical context for interpreting recent change. They also help characterize natural variability and inform shark management goals in each region, based on their local histories and fossil-defined baselines.

Acknowledgements

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Measuring structural changes during coral decalcification using micro computed tomography

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The structure and morphology of coral skeletons reflect and shape the life histories of the animals that build them. Shape, strength and growth rates vary within and between species, defining broad distributions, as well as survival and recovery from destructive events (Fantazzini et al. 2015). Tiny structural aspects affect how well corals capture and concentrate light, correlating with species' thermal tolerance and therefore their ability to withstand climate change (Swain et al. 2018). Historical growth patterns are used to measure past climates and can generate baselines

against which we compare the effects of the Anthropocene upon coral reefs (Barkley and Cohen 2016). Diverse assemblages of corals build structurally complex reefs through the process of building their skeletons, and this structural complexity underpins the reefs' aesthetic, ecological and economic value (Graham and Nash 2013).

Unfortunately, we still lack the data needed to fully understand and predict how the structure and properties of coral skeletons will change through the Anthropocene. This is partly due to a lack of recent advancement in tools we use to study skeletal decay. In particular, we have lacked the resolution needed to study rapid and small changes in physical skeletal architecture. For the first chapter of my PhD, I have been adapting techniques in micro computed tomography (µCT) from the geological sciences, and applying them to coral skeletons to help understand how the internal structure of coral skeletons changes under climate change scenarios. Supported by an ICRS 2018 Graduate Research Fellowship, I have been training and collaborating with the National Laboratory for X-ray Micro Computed Tomography (CTLab) at the Australian National University in Canberra, applying their technical expertise to my biological question.

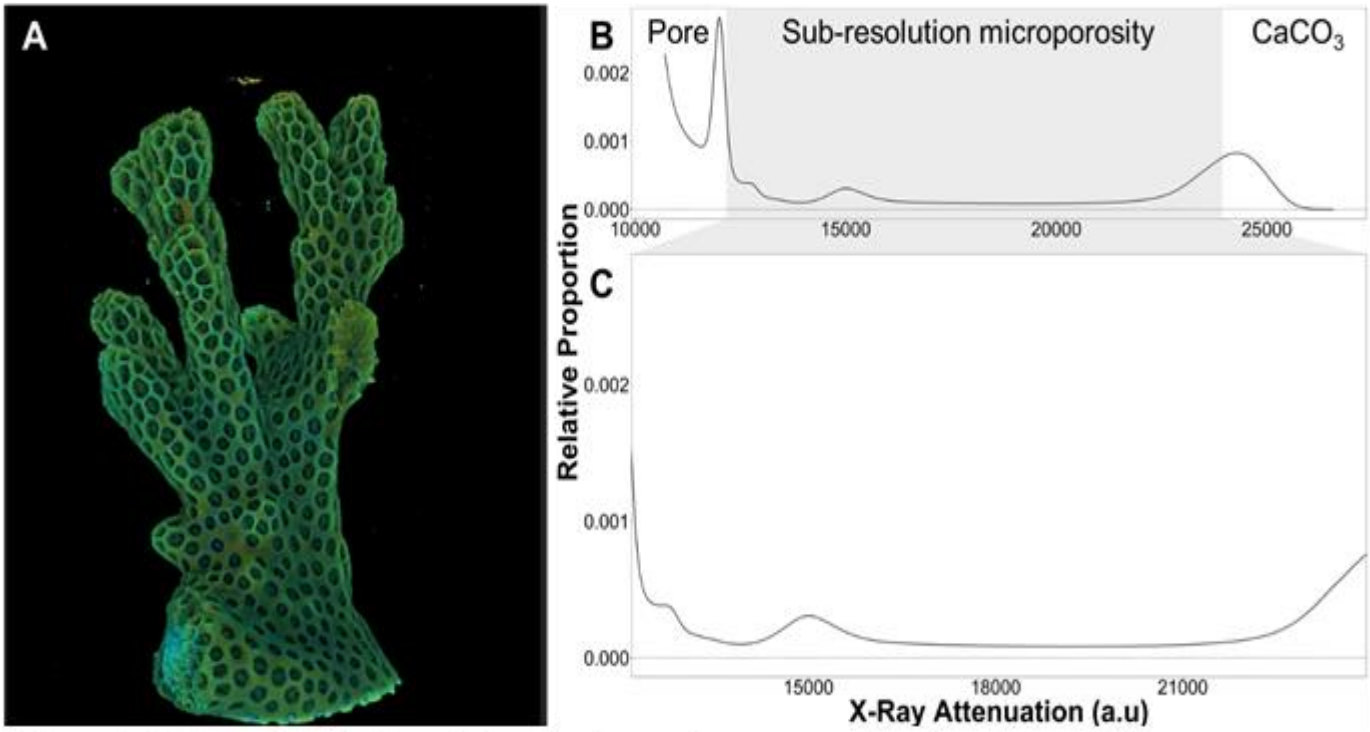

Figure 1 (A) *A snapshot of a 3D model produced using the open source Drishti software;* ***(B)*** *Tomograms are accompanied by a histogram representing the voxel-wise distribution of densities in the 3D image, expressed as relative X-ray attenuation. These samples have two peaks for air and calcium carbonate with a trough in between which represents the intermediate phase* ***(C)*** *used to calculate microporosity.*

Three novel techniques to study acute change

The analytical workflows were all designed using an expanded version of our dataset, recently published in *Current Biology* (Leggat et al. 2019). This study identified and quantified accelerated bioerosion of corals by resident endolithic microbes living within the skeletons *Pocillopora damicornis* and *Acropora aspera*. Our experiment for this work took place over eight weeks and compared healthy corals to those subjected to intense thermal stress, mortality and subsequent bioerosion. The limited time frame is in stark contrast to the many months or years that similar studies take place over and makes this dataset ideal for designing novel, sensitive techniques. The three methods that evolved from this work are intended to complement the more common approach of measuring overall skeletal porosity (Roche et al. 2010; Fantazzini et al. 2015); here I term this *macroporosity* to distinguish it from the other methods I introduce.

Microporosity Analysis. Resolution is always a limiting factor. As you scale down from millimetre, to micrometre, to nanometre, the information you see changes. But as the resolution gets higher, the maximum allowable size for your piece of coral shrinks. Do you sample from old growth or new? The top or the base? The smaller your sample, the harder it is to generalise your results to a broader system. The larger your sample, the lower the maximum resolution. Microporosity analysis attempts to minimise the costs associated with this trade-off by estimating the *sub-resolution porosity* of our samples (Sheppard et al. 2006). In this case, these are pore spaces smaller than our voxel (a 3D pixel) size of 26.2 cubic microns.

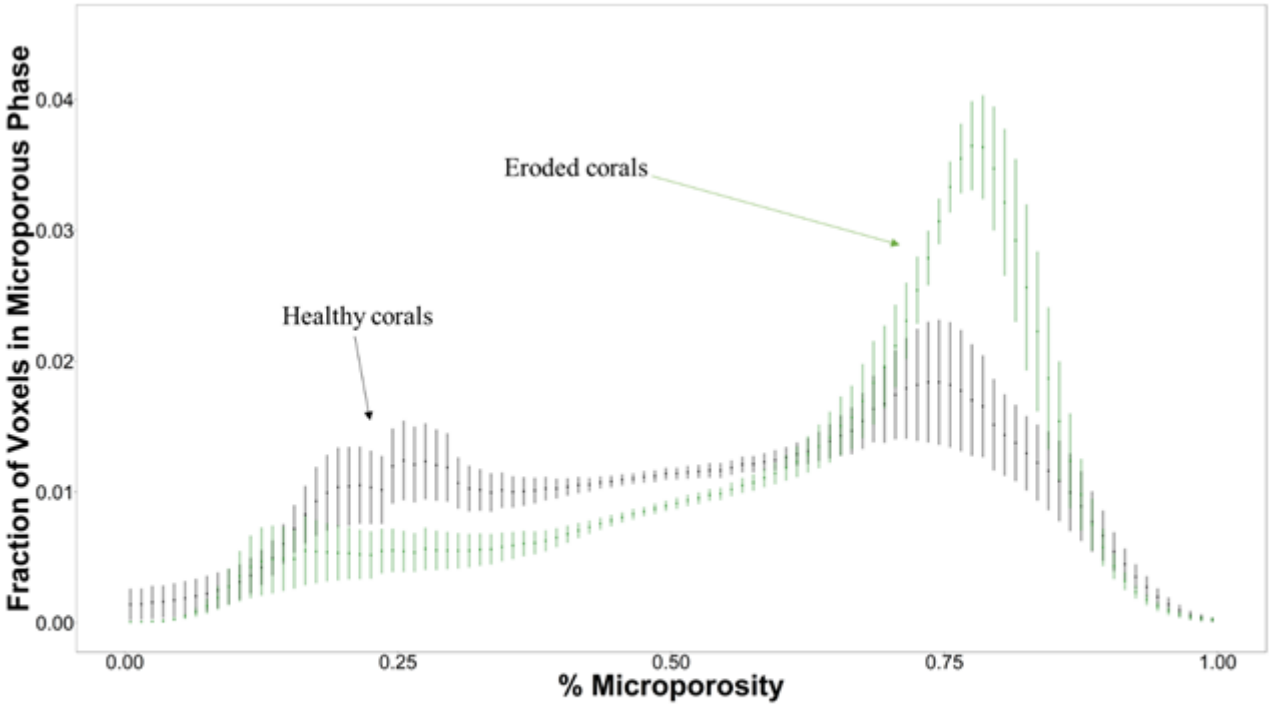

Figure 2. The distribution of partially filled voxels within the microporous phase, after binning voxels into 100 categories based on the estimated % of air in each voxel. Note the shift towards higher voxel-wise microporosity as a result of microbial bioerosion.

First, I defined a third, intermediate 'phase' in the 3D tomograms in addition to solid calcium carbonate and air (i.e. pore space) (Fig. 1). In this phase, voxels had a range of density values (expressed as X-ray attenuation; Fig. 1) that were less than solid $CaCO_3$ due to different amounts of microporosity. Assuming that voxel-wise density negatively correlates to microporosity in a linear relationship, I then estimated the volume of air contained in this phase. In these samples, we saw a greater than two-fold increase in microporosity in *P. damicornis* despite no significant change in macroporosity (i.e. *resolvable* porosity). This makes sense given that the agents of bioerosion in this case are often < 10 microns in diameter (Tribollet 2008). But as well as detecting these acute changes, we can also plot the distribution of these 'intermediate' voxels and through this I highlight a shift towards higher microporosity that likely precedes any changes visible in macroporosity. This suggests that together microporosity and macroporosity can be used to track the progression of skeletal decay over short time scales.

Pore Size Distribution Analysis. Macroporosity is a summary metric, it tells us what the total volume of air is inside the skeleton. But there is a lot more information to be mined from a tomogram without needing microporosity analysis. For imperforate corals such as *P. damicornis*, the internal pore space is characterised by distinct pores separated by dissepiments created as polyps produce new basal plates during calcification. This makes these skeletomorphs amenable to grain size distribution analysis, traditionally used to assess the size-frequency distributions of different grains in polymineralic samples (Sheppard et al. 2006). Instead of grains, I wanted to examine the distribution of individual pores; hence the slight amendment to the geological term. The idea to examine the distribution of pore sizes is not novel in coral reef biology, but previous techniques have been unable to produce the

same resolution of data nor been able to actually measure the size of pores (Fantazzini et al. 2015). Samples had an average of 9700 pores and much to my surprise, pores within corals subjected to microbial bioerosion were 50% more variable in size and almost half as small on average. Though counterintuitive when considered out of the context, this tells a clear story when paired with data from the macro- and microporosity of *P. damicornis* (Fig. 2). As microporosity increases and the distribution shifts, some micropores are being widened enough to be detected in the macroporosity phase. Those previously large micropores are now small macropores. As this analysis is applied to the macroporosity phase, this explains why your average pore is smaller in bioeroded corals. This is consistent with the observed higher number of pores per cubic millimetre seen in eroded corals.

Maximal Inscribed Sphere Analysis. Of course, not all corals have their skeleton neatly partitioned into individual pores. On the opposite end of the spectrum we have fast-growing acroporids with complex, highly connected pore spaces that make pore size analysis impossible. But as some the most significant reef builders, it is of particular interest how acroporid skeletons decay and what changes occur in skeletal architecture. To gain more understanding into changes in pore space morphology, I applied a method known as the Maximal Inscribed Sphere technique (Sheppard et al. 2006). It is akin to filling the pore space with sequentially smaller, overlapping imaginary spheres and then analysing the size-frequency distribution of these spheres in the final image. Consistent with the results of pore size analysis in *P. damicornis*, we found the median sphere size to be smaller and variation in sphere size to be greater in *Acropora aspera* that had undergone mortality and microbial bioerosion in spite of an overall 107% increase in macroporosity.

Figure 3 *At the end of the pore size distribution analysis, tomograms are transformed into a 3D version of this "stained glass coral" wherein occluded pores have been defined and can then be quantified.*

Future directions

This work is in the first stages of review for *Methods in Ecology and Evolution*. Together with my collaborators and supervisors, we describe in great detail the step-by-step processes needed to conduct these analyses. The paper is intended to be a comprehensive guide to tomogram image analysis and a guide for new users to help understand the underlying concepts in µCT scanning. One of the biggest restrictions of µCT is arguably how much it costs: higher resolution costs more money and requires a smaller physical sample in most cases. The methods developed through this project are intended to improve the resolution of the data we extract by µCT scanning without necessarily suffering the costs associated with this trade-off (Fig. 3). Hopefully this helps promote the use of µCT scanning as a powerful technology that can provide multiple insights into coral life history.

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Sincere thanks to the International Coral Reef Society for awarding me a 2018 Graduate Research Fellowship that funded my training and collaboration with the CTLab at ANU. The technicians and analysts at ANU have been extremely helpful and patient. They are an integral part of the success of this work and I look forward to continuing to work with them in the future. Finally, the support of my supervisors has been a key element in giving me the confidence to undertake this project in an unfamiliar field.

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DAMSL: A New Photographic Database of Marine Species

The Rosenstiel School of Marine and Atmospheric Sciences (RSMAS) is proud to announce the launch of a new version of DAMSL, the Digital Atlas of Marine Species and Locations, available on line at www.damsl.org. DAMSL is a digital website, viewing the underwater world of over 3,500 marine species from the most prolific coral reefs in every prominent equatorial system of our ocean world. The images were captured by world-renowned underwater photographer Myron Wang and donated to the Rosenstiel School by Myron and his wife Nicole. The website will be of interest to students, academicians and enthusiasts enabling them explore worlds beyond their classrooms and books. RSMAS intends to lead the way in studying the science and metrics of the species covered, providing full encyclopedic content for the digital atlas.

Josh Coco, Ed. D.
Executive Director, RSMAS

A sample set of images from the DAMSL database

PROGRAMS & PROJECTS

Citizen Science Dives Deep on the Fore Reef Slopes of Mayotte (South West Indian Ocean)

Recently a group of photographers and tech divers have established a not-for-profit citizen science association, "*Deep Blue Exploration*", in Mayotte, a high island encircled by a well-developed barrier reef in the south west Indian Ocean. The major aim of the Association is to explore, study and protect the local and ultimately regional coral reef ecosystems, particularly in their deepest and least known parts, referred to as the mesophotic coral environment. Its activities include exploratory surveys and data collecting on the bathymetric, topographic and biological features of the deep fore reef slope of the extensive barrier reef (200 km long) surrounding the island.

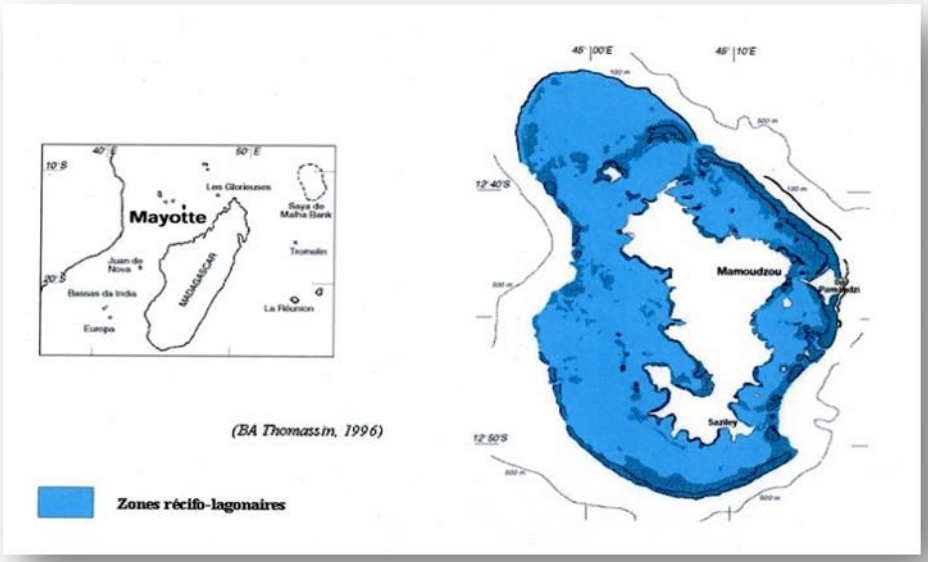

Figure 1. *Location of the island of Mayotte in the south west Indian Ocean*

While the association's explorations are conducted by tech divers, it has established collaborations with scientific experts of various groups of organisms and mesophotic assemblages drawn from several French and foreign research institutions. The blueprint for *Deep Blue Exploration* activities was provided by the results obtained a few decades ago by the expedition organized by Geomar (Kiel, Germany), following the deployment of the research submersible "JAGO" at 19 stations around the barrier reef, each surveyed at depths of between 50 and 350 m (Dullo *et al.* 1998)

A taxonomic inventory and a photo gallery of the major benthic (invertebrate and fish) components have been initiated, backed by very high resolution photographic records and utilisation of advanced techniques such as 3-D photogrammetry modelling, and horizontal and vertical panoramic assemblages, providing information on the structure and zonation of the mesophotic assemblages.

Results to date have provided new records for Mayotte of invertebrates (corals, echinoderms and decapods) and fish, thereby extending the geographic distribution of such species, and also a number of new depth records have been documented (e.g. Barathieu et al. 2019).

Figure 2. *Typical aspect of the mesophotic environment on the outer slope of Mayotte barrier reef. (Depth 70-85 m) © G. Barathieu.*

A few permanent study sites have been established at mesophotic depths and are being monitored on a regular basis, so as to allow collection of time series data. For example, events such as coral bleaching and recovery after bleaching have been documented, besides which such data provide information more generally on the state of health of mesophotic assemblages. Some of the major results to date will be presented during the upcoming ICRS 2020 Symposium to be held in Bremen.

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Figure 3. Astrosarkus idipi, *a seastar regularly observed in the mesophotic environment of Mayotte (Depth 90 m) © G. Barathieu.*

For further information please email:
contact@deep-blue-exploration.com

Gabriel Barathieu and
Olivier Konieczny

Building Resilient Reefs: Biosphere 2 and Beyond

The ecological crisis on coral reefs, driven by human-caused climate change, is beyond dispute; we have lost half the world's coral and will lose much of the rest if warming continues. In October 2017, the Biosphere 2 convened reef scientists to map out how an understanding of reef resilience can be translated into innovative solutions for reef restoration and increasing resistance to stress. We are beginning to understand the critical processes and mechanisms for enhancing reef resilience. Novel, even radical approaches offer potential for (re)building resilient reefs to better withstand warming and acidification. However, the research community lacks a testbed to safely explore these interventions. Thus, we do not know whether restored reefs will survive future climate scenarios, nor can we characterize how microbial, trophic and community interactions contribute to the long-term resilience of restored reefs.

To fill this urgent gap, the University of Arizona's Biosphere 2 is rejuvenating the 2.6-million-liter ocean mesocosm (built in 1991) into an experimental reef that accelerates research on solutions to ensure critical reef structure, function, and ecosystem services under a changing climate. The Biosphere 2 Ocean (B2O) mesocosm captures much of the structural complexity of natural fringing reefs (from fore-reef to back-reef lagoon, Fig. 1), while offering precise control of environmental conditions to simulate future climate variability and change (Atkinson et al. 1999; Sagarin et al. 2016). For example, the new state-of-the-art titanium plate and frame heat exchanger permits the background temperature of the B2O to be manipulated across a broad range of temperatures (from 25 to 35°C) at up to 2°C per day – a rate commonly observed during extreme bleaching events and even across a diurnal or tidal cycle on many reefs. This combination of scale and control enables testing of interventions such as transplanting species, selective breeding, and assisted evolution – solutions that cannot be applied to natural systems without understanding their consequences. By capturing many intrinsic reef processes, the B2O will allow these solutions to be "scaled up" from laboratory studies to identify interactions across levels of complexity (molecular to community), functional groups, and trophic levels. Critically, this closed system permits innovative research into the role of microbes in mediating key reef processes. Finally, B2O experiments are not bound by existing ecological associations or biogeographical constraints, allowing us to explore whether combining species differently can enhance reef resilience.

We have held three international planning workshops with leading reef scientists to identify community needs and shape this research vision. At the B2O Reef Ecology Workshop (Jan 24-25, 2019 at the Biosphere 2), twenty-five attendees presented **grand challenges** in reef ecology, and identified four overarching research themes:

1. Bioremediation: recovery dynamics across succession to healthy reefs: What is the capacity for remediating reefs through controlled manipulations of herbivory and water quality, and what insights emerge about reef recovery processes? The algae-dominated reef state of the current B2O – similar to that of a degraded reef – presents a unique opportunity to investigate recovery processes and explore solutions for rebuilding resilient coral reefs. Through the implementation phase of the project (and beyond), we will closely monitor all physical, chemical, and biological conditions of the B2O in its current degraded state to establish a baseline for the system and determine the timescales across which key parameters change on the reef. The biogeochemical succession from a degraded to healthy reef system will provide new insights into recovery and patch dynamics at an unprecedented scale.

2. Interventions for resistance: What interventions for reef-building corals (e.g., stress hardening, probiotics, phage therapy, symbiont manipulation) create persistent resistance to environmental stressors? Innovative research has yielded major advances in techniques for reef restoration and increasing resilience through interventions such as stress hardening (via warming and ocean acidification), probiotic treatment, phage therapy, and assisted evolution (see recent review by NASEM, 2018). These approaches offer great potential for (re)building resilient reefs that can

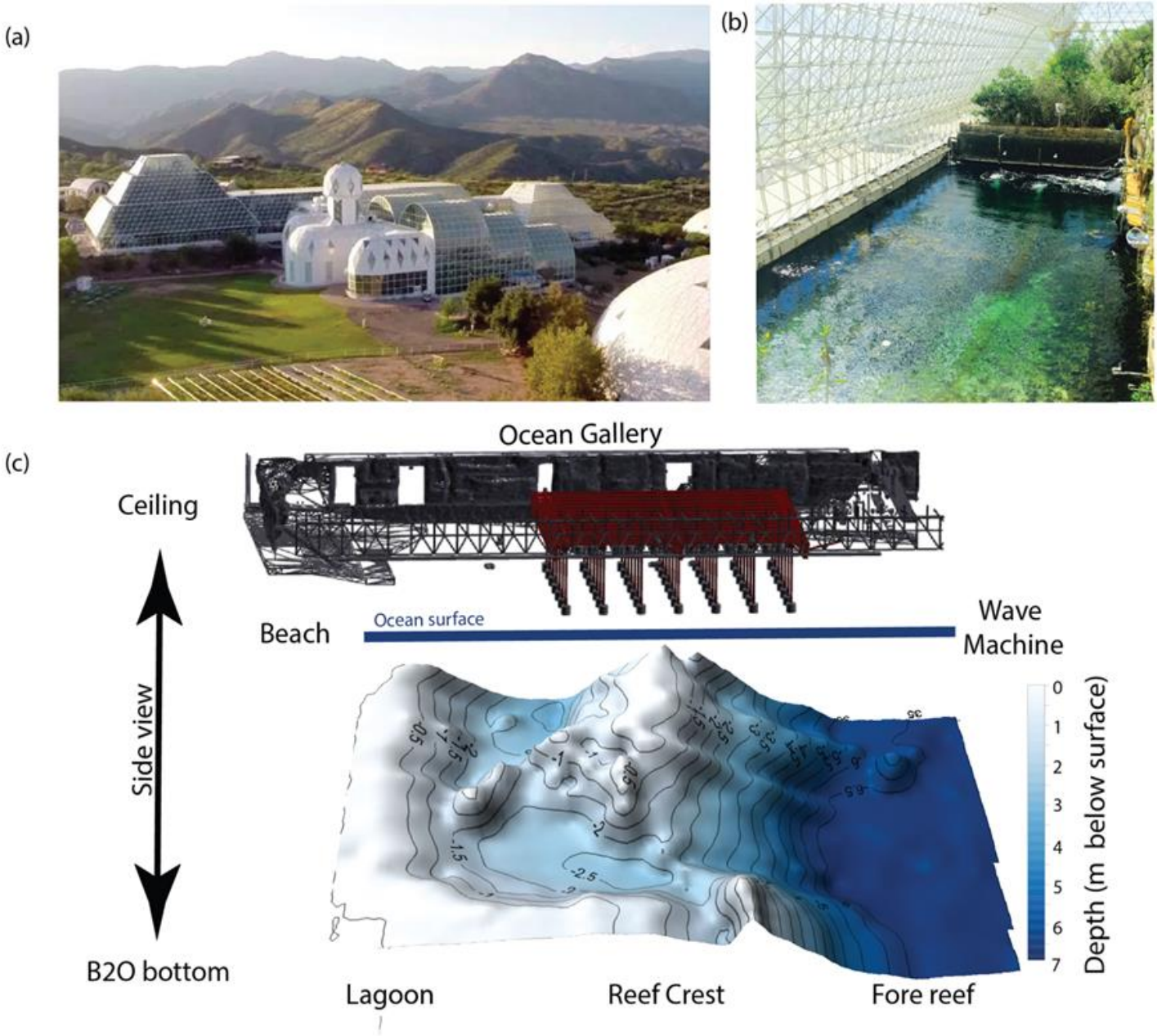

Figure 1. Schematic of the planned B2O lighting system (top) and the underlying ocean bathymetry (bottom).

better withstand warming, disease, and acidification. The B2O provides a unique opportunity to test technological advances and innovations for scaling up these novel reef restoration solutions.

3. Novel species interactions on pan-global reefs: Will the functioning of novel tropicalized systems become similar to tropical habitats, such as coral reefs, or should entirely new ecosystem functions be expected? Do biogeographically diverse species assemblages enhance resilience, and what are the consequences of transplanting reef species? Entirely novel ecosystems are developing as a result of shifts in species distribution under a changing climate. These novel ecosystems create challenges for reef conservation and management, as novel interactions re-define functional roles, ecological niches, and ecosystem services. For example, building a "global" reef assemblage in the B2O would offer unique opportunities to test the stability of host-Symbiodiniaceae combinations when new species converge and assess the role of the holobiont microbiome in the specificity and flexibility of the symbiosis.

4. Reef calcification and biomineralization under a changing climate: What is the impact of environmental stressors on calcifying organisms? The B2O mesocosm provides a unique opportunity to isolate the impacts of temperature and acidification on calcifying reef organisms at ecosystem scale (e.g., Langdon et al. 2000), and in turn, identify their impact on climate records generated from carbonate skeletons (e.g., corals, coralline algae, bivalves, and foraminifera).

Research on bioremediation – e.g., the role of microbes in remediation – is already underway as we build a resilient reef in the B2O. More information is online as reports from three workshops ("Envisioning science for reef solutions in the Biosphere 2 Ocean," "Can microbes help save coral reefs?", and "Building resilient reefs: Biosphere 2 and beyond"): https://biosphere2.org/research/model-system/reef-solutions-biosphere-2-ocean

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Scientific letters or notes describing observations or data

Coral reproduction on high-latitude reefs at Sodwana Bay, South Africa

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Understanding patterns in coral reproduction is a critical tool in being able to manage and hence, potentially, preserve or restore coral reefs. Various aspects of coral reproduction have been studied in detail in the Pacific, Caribbean and Red Sea, and include events such as the mass coral spawning of the Great Barrier Reef (Harrison et al. 1984; Babcock et al. 1986), one of the most impressive mass reproductive events in the world and a major attraction for divers.

The Western Indian Ocean is, by contrast, much less studied, although reefs in Kenya appear to have asynchronous spawning patterns (Mangubhai and Harrison 2009) while observations in Madagascar (Gress et al. 2014) and Mozambique (Sola et al. 2016) suggest a more synchronous pattern. In South Africa, research into coral spawning by individual species has been undertaken on coral communities since the late 1990s in the iSimangaliso Wetland Park (iSiMWP), a World Heritage site, under the direction of Professor Michael Schleyer (Kruger and Schleyer 1998; Kruger et al. 1998; Schleyer et al. 2004; Massé et al. 2013; Montoya-maya 2013; Montoya-Maya et al. 2016). However, *in situ* observations of corals reproducing on these reefs are usually precluded due to safety concerns in conducting night dives under difficult conditions. Reefs occur below 12 m and are only accessible by semi-rigid inflatable craft from an exposed beach launch site which frequently experiences large waves. Furthermore, significant surge is frequently experienced on these reefs, precluding the attachment of spawning nets over corals. The timing of coral reproduction on these reefs has thus hitherto been inferred from the disappearance of mature gametes during gametogenesis studies on selected coral taxa, and from *ex situ* spawning observations of gravid samples collected from the reef and maintained in the Oceanographic Research Institute research aquarium.

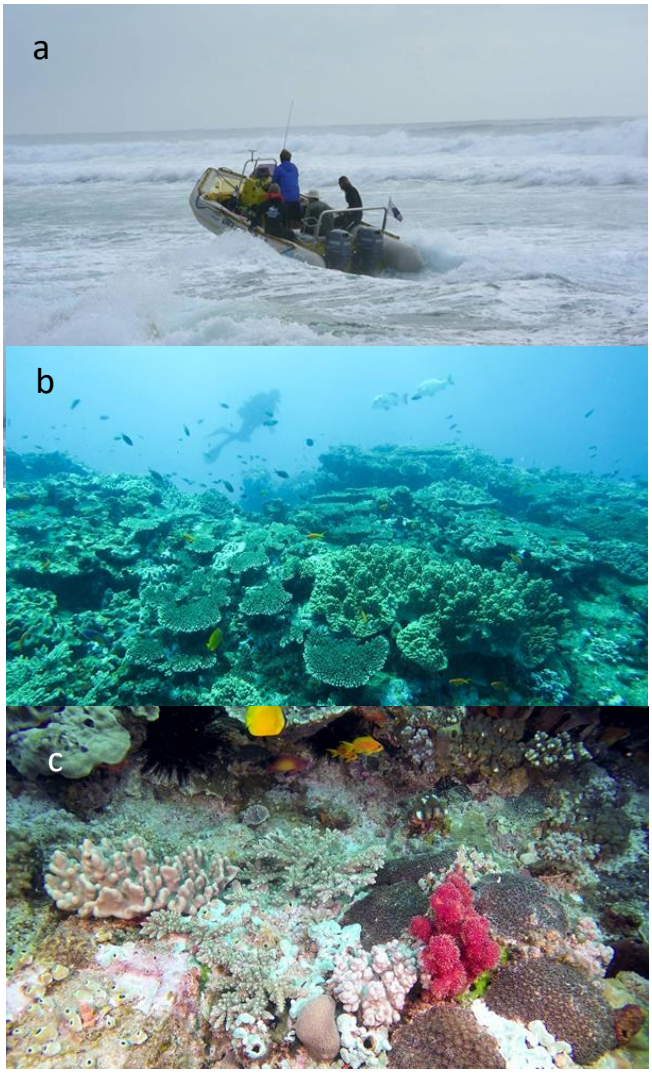

Figure 1. *The reefs at Sodwana Bay in the iSimangaliso Wetland Park in South Africa are marginal but exhibit a high level of biodiversity (b,c) with at least 90 hard coral and 40 soft coral species. Getting to them requires a beach launch, often in challenging conditions (a).*

Southern African coral communities form a continuum from the more typical, accretive reefs in the tropics of East Africa to their marginal, southernmost African distribution in the province of KwaZulu-Natal, South Africa. Their occurrence here is mediated by the

Agulhas Current, one of the strongest of the warm, western boundary currents (mean velocity ~2 $m.s^{-1}$, seasonal transport ~70 x 10^6 $m^3.s^{-1}$). Despite being marginal, they are rich in biodiversity (see Schleyer et al., 2018). In terms of prominent biota, they comprise at least 40 species of soft and 90 species of hard corals, with some 30 species each of sea squirts and sponges (Fig. 1). Overall, the reef communities consist of an admixture of tropical and temperate Indo-Pacific fauna and include numerous endemic species, both of invertebrates and fish. Because of the marginal conditions, the coral communities are non-accretive and grow as a veneer on sandstone reefs that initially developed as Late Pleistocene dune- and beach-rock, becoming reefs with the Holocene submersion of earlier coastlines. Alcyonacean soft corals, rather than Scleractinia, are preponderant on most of the reefs, this again being attributable to their marginal nature and the turbulence found on reefs at these high-energy southern latitudes (Schleyer and Celliers 2005; Celliers and Schleyer 2008; Porter et al. 2017; Schleyer et al. 2018).

Early research demonstrated reproduction in both the soft and hard corals at Sodwana Bay (Kruger and Schleyer 1998; Kruger et al. 1998; Schleyer et al. 2004) in the central region of the iSiMWP (27°31.5' S; 32°41.0' E). Emphasis was placed on two soft corals (*Anthelia glauca* and *Sarcophyton glaucum*) and a single hard coral (*Pocillopora verrucosa*) in view of their prominence on the iSiMWP reefs. *Anthelia glauca* proved to be a gonochoric, pharyngeal brooder with egg transfer and fertilisation occurring at full moon, and larval release after new moon over multiple months in summer (January to March)(Kruger et al. 1998). *Sarcophyton glaucum* is a gonochoric, seasonal broadcast spawner that releases gametes in March between full and new moon (Kruger et al. 1998; Schleyer et al. 2004). It has the unusual attributes of protracted egg maturation (16-18 months) and a low incidence of hermaphroditism (Schleyer et al. 2004). *Pocillopora verrucosa* is a hermaphroditic seasonal broadcast spawner which spawns in late January at the new moon.

These early studies were undertaken to establish whether coral reproduction did, in fact, occur at high latitude under the marginal South African conditions. Subsequent studies primarily concentrated on scleractinian broadcast-spawning species. More recent comparative gametogenesis research that assessed the breeding season of *Acropora austera* and *Platygyra daedalea* in South Africa and Reunion revealed that the reproductive season of these two broadcast-spawning corals occurs between October and March at both locations, with spawning of *P. daedalea* occurring after a February or March full moon (Massé et al. 2013). Gametogenesis of *P. daedalea* and *A. austera* has been found to be synchronized on two prominent reefs at Sodwana Bay (Two-mile reef and Five-mile reef) and appears to peak with spawning occurring after full moon in February or March (Massé 2014). Spot assessments of gamete maturation based on the pigmentation of eggs in January 2014 revealed that a variety of acroporid oocytes are sometimes darkly pigmented a few days prior to the full moon in January, and absent prior to a February full moon (Hart pers. obs), indicating that the spawning of some corals may also occur after the January full moon. Pigmented eggs were found during a spot assessment of a variety of Acroporids two days following the full moon in February 2017 (Fig. 2). *Anomastrea irregularis*, a prominent hard

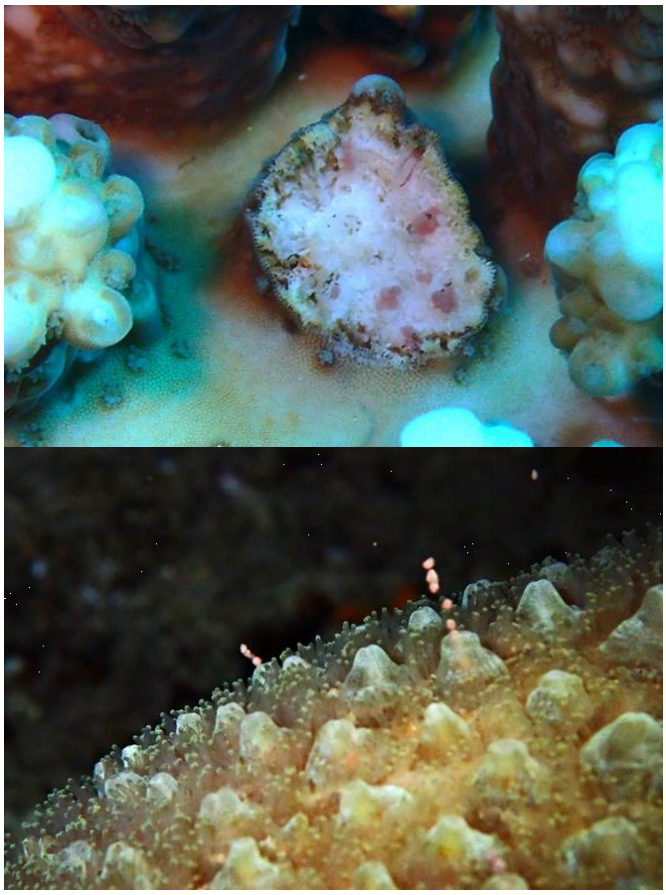

Figure 2. (above) *An acroporid coral with heavily pigmented oocytes two days after the full moon in February 2017*
Figure 3. (below) Anomastrea irregularis *spawning in an intertidal pool at Sodwana Bay 2 NAFM in February 2017*

coral within intertidal pools at Sodwana Bay, was observed spawning five to six hours after sunset in the intertidal pools at Sodwana Bay 2 NAFM in February 2017 (Fig. 3).

Figure 4. *Collection of* Acropora austera *gametes for fertilization experiments following spawning in the Oceanographic Research Institute research aquarium*

In order to assess aspects associated with fertilization, larval development and settlement of corals on these reefs, gravid fragments of *Acropora austera*, *Hydnophora exesa* and *Platygyra daedalea* were collected from Sodwana Bay reefs and maintained at the Oceanographic Research Institute Research Aquarium (Masse 2013; Hart 2018). All three species released gametes over at least three consecutive nights, with different peaks in release by *Hydnophora exesa* (2 nights after full moon (NAFM) at 18:40), *Platygyra daedalea* (4 NAFM, at 20:30) and *Acropora austera* (7 NAFM at 22:20) (Fig. 4). Being indoors, the lighting regime within the ORI research aquarium differs from that on the reef from which coral fragments were collected, and it remains to be confirmed whether the *ex situ* spawning period of corals corresponds with that on the reef from which they were collected.

Armed with this knowledge, a two-week field study was undertaken at Sodwana Bay from full moon in February 2019, with the aim of studying the dynamics and timing of what appears to be the primary spawning event. Assessment of gamete maturity of a number of corals from different genera revealed strongly pigmented oocytes in a diverse range of genera, including various species of *Acropora* (Fig. 2) and massive species such as *Porites*.

To elucidate the potential pattern of larval dispersal, including the extent to which larvae are retained on their natal reefs versus being dispersed more widely, GPS-enabled drifters were deployed on each day during the spawning period.

We were fortunate to have relatively benign weather during the first week of the spawning period and were able to undertake early evening dives on two nights, 2 and 5 days after the full moon (Fig. 3). Due to the regulations of the iSiMWP, these dives were restricted to the hour following sunset. Despite this restricted timeframe, we were able to observe active spawning of *Galaxea fascicularis* (Fig. 3) during the hour following sunset on 2 NAFM and observe egg-sperm bundles set for release in two species of *Acropora* (Fig. 3) during 5 NAFM. In addition, localised spawning slicks were observed in the early morning if the current and winds were not too strong.

We were thus able, for the first time, to observe coral spawning *in situ* on a high-latitude reef in South Africa. This confirms that these reefs, despite their marginal nature, undergo a multi-species, simultaneous spawning event that peaks after the full moon in February, although some spawning activity does occur in January and March. This lends additional support to the hypothesis that reefs at high latitudes primarily undergo synchronized multi-species spawning. Anecdotal evidence suggests that other reef invertebrates such as holothurians and *Tridacna* also spawn during this period.

Given the logistical challenges involved in directly observing spawning on these reefs, we are now looking at other methods, such as metabarcoding, to determine the timing of spawning of the various coral species, and the presence and persistence of coral larvae. Genetic studies (Montoya-Maya 2013; Montoya-Maya et al. 2016) have clearly demonstrated that a significant number of coral larvae are retained on Two-mile Reef but the potential for long-range transport is currently

Figure 5. *Direct* in situ *observation of corals on Two-mile Reef just after sunset (a) on nights two and five after the full moon revealed spawning of (b*) Galaxea fascicularis *(2 NAFM), and two species of* Acropora*, likely (c)* A. aspera *and (d)* A. clathrate*, with egg and sperm bundles set for release (5 NAFM (see insets)).*

less well understood. This knowledge will enable us to better model the distribution and retention potential of corals and, hence, better understand the resilience and potential survival trajectories for these reefs in a changing local and global environment.

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First record of the 'golden nautilus' (*Allonautilus scrobiculatus*) from Solomon Islands

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Between the 2-13th of November 2019 we studied nautilus populations in the Central and Western Province of the Solomon Islands. We baited nautilus traps with fish and set them overnight against reef walls or on the sea floor at depths ranging from 200-350 m. Sixteen traps were set during this survey, with twenty-five *Nautilus pompilius* and five *Allonautilus scrobiculatus* captured. All five *A. scrobiculatus* were captured in the southern end of Marovo Lagoon, Western Province, Solomon Islands. Prior to this survey live-caught specimens of A. *scrobiculatus* had only been captured in the Bismarck Sea. Live specimens of A. *scrobiculatus* were first captured in1984 at Drova Island, Manus Province, Papua New Guinea (Saunders et al. 1987; Ward and Saunders 1997), and in 2015 several live specimens of *A. scrobiculatus* were captured at Mait Island, New Ireland Province, Papua New Guinea (Hausheer 2016). This recent discovery represents a significant range extension for *A. scrobiculatus*, with the capture locations in Marovo Lagoon situated 1000 kilometres south east of Mait Island. From a conservation perspective our discovery is encouraging, as although *A. scrobiculatus* is naturally rare and patchily distributed, we now know that it lives in two tropical seas. The common name for *A. scrobiculatus* is the fuzzy nautilus, but a more apt common name would be the golden nautilus.

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This survey was undertaken by the Bishop Museum and The Nature Conservancy, in partnership with the Solomon Islands government. Willie Atu, Marjorie Awai, Bruce Carlson, Brian Greene, Martin Wisner and Simon Vuto were members of this team effort. The photo was taken at night by Dave Abbott from Liquid Action Films.

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Fig. 1. *Allonautilus scrobiculatus*

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Autogrooming in the bottlenose dolphin, *Tursiops truncatus* (Montagu 1821)

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Rubbing body parts on animate and inanimate objects is part of the diversity of behaviors recorded in cetacean species, and it is particularly common among delphinids (Dudzinski et al., 2012). A number of questions arise from this behavior, the foremost being why? Do these dolphin species rub against objects for play, social interaction, to remove parasites, to groom their bodies, or just to scratch an itch? Unfortunately, it may be impossible to know the root cause of these behaviors without repeated field observations and/or deliberate experimental studies (Dudzinski et al. 2012).

In August 2017 while diving on the hardbottom communities off Port Everglades in southeastern Florida, we encountered a pair of bottlenose dolphin, *Tursiops truncatus* (Montagu 1821) that appeared to be self-grooming (autogrooming) by repeatedly rubbing their head and body against colonies of the Caribbean vase sponge, *Ircinia campana* (Lamarck 1816) (Fig. 1). These sponges were observed to bend and flex, but not break as the dolphins aggressively rubbed against them (Precht 2018). This chance encounter with two wild *T. truncatus* lasted approximately five minutes. During this time, each of the dolphins surfaced for air multiple times and every time they returned to the bottom they were observed to use the same sponge for additional grooming.

Autogrooming is specifically defined as the grooming behavior of an animal by itself (Encyclopedia.com 2018). Some cetacean species have been observed to autogroom primarily by chafing, or rubbing up against hard inanimate objects and/or geological structures (Sakai et al. 2013, Hill et al. 2016). Dolphins may also allogroom other dolphins by using their rostrum and pectoral fins (Dudzinski et al. 2009). The rationale for a hygienic origin to this behavior is likely related to the removal of the more than 300 species of macroscopic worm and arthropodan ectoparasites known to affect marine mammals (Evans and Raga 2001), some with dire consequences (Aznar et al. 1994).

Most upright, vase-shaped Caribbean sponges would likely break, crumble or become dislodged by this vigorous physical interaction, however, the rubbery texture and flexible nature of *I. campana* makes it an ideal grooming tool. In addition, *Ircinia* spp. are known to contain high concentrations of linear furanosesterterpene tetronic acids (FTAs) and produce and exude low-molecular-weight volatile compounds (e.g., dimethyl sulfide, methyl isocyanide, methyl isothiocyanate) that give these sponges an unpleasant garlic-like odor (Pawlik et al. 2002). FTAs have been shown to possess a wide range of biological functions including antiviral, antibacterial, anti-inflammatory, antitumor, and protein phosphatase inhibitory activity (Choi et al. 2004). The volatile, low-molecular-weight compounds also have strong antimicrobial and antifouling properties (Duque et al. 2001) that may also serve to assist the dolphin in removing and excluding ectoparasites from their surface. Specifically, these antimicrobial and antifouling properties may form a chemical basis for the selective use of *I. campana* over other sponges. Thus, based on both the physical and chemical properties of *I. campana* we speculate that *T. truncatus* specifically keys on this sponge for use as a grooming tool. This may be analogous to bison rubbing against woody aromatic vegetation such as cedar and pine to reduce harassment by insects while simultaneously performing other functions such as shedding of winter pelage and reducing insect irritation (Coppedge and Shaw 1997).

Based on these initial observations, however, it is hoped other researchers having similar encounters with *T. truncatus* record and document these behaviors and share with the scientific community at-large. It will only be through the continued observations of the behaviors of *T. truncatus* populations that a consistent picture of the types and kinds of objects that dolphins use to autogroom will emerge. In addition, the comparison between local environmental and ecological factors, will help to illuminate the likely function and ontogeny of autogrooming behaviors in wild dolphins.

Figure 1. *The bottlenose dolphin,* Turciops truncatus *using the sponge* Ircinia campana *to autogroom.*

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REEF VIEWS

Coral-reef science or coral-reef engineering? Part 2

In 1993 Reef Encounter contained my note "Coral reef science or coral reef engineering" (Ware 1993). That short note suggested that the future of coral reef science would be dominated by engineering approaches that would have the following three characteristics:

1. The research would be goal oriented, that is, a specific problem would be identified, and the research would be geared to solving that problem.
2. The research would be conducted by fairly large teams. The days of the one- or two- person research would be nearing an end.
3. The teams would consist of people with varying backgrounds and capabilities and individuals would be assigned specific subsets of the major problem under study.

The purpose of this note is to consider the accuracy of those predictions, and it was inspired by a recent paper in Nature: "*Large teams develop and small teams disrupt science and technology"* (Wu et al. 2019). In this context 'disrupt' is a positive term referring to publications that present new ideas. Wu et al. (2019) concluded, among other things, that the increases in team size observed in much of science are the result of specialization and the complexity of the problems considered.

As an aside, I counted the number of authors of the 18 Articles or Letters in the same issue of Nature in which Wu et al. appeared (02 May 2019). There were a total of 342 authors or an average of 21.4 authors per paper and 75% of the papers had 5 or more authors. However, one Letter had 141 authors. If this 'outlier' is deleted from the statistics, the average number of authors per paper is reduced to 13.4. Still a number that indicates that team size is typically large in a high-impact journal.

History shows the truth of the "disrupt" portion of the Wu et al. 2019 title. Darwin, Watson and Crick, and Einstein immediately come to mind. In our own field of coral reef science two ideas that spawned immediate controversy and expanded research (the 'disrupt' of Wu et al. 2019) were Peter Sale's 'lottery hypothesis' (Sale 1974) and Buddemeier and Fautin's 'adaptive bleaching hypothesis' (Buddemeier and Fautin 1993). For example, in my own, admittedly small collection, I have 50 papers that allude to the 'lottery hypothesis' and over 100 papers that either refer directly to the 'adaptive bleaching hypothesis' or are based on the ideas contained in the original paper.

The question remains, is coral-reef science showing a trend with regard to a larger number of authors per publication and does this represent a change over the past three decades or so as I predicted in 1993? To answer this question, I examined the journal Coral Reefs for the years 1988 and 1989 and compared the author data for those years with the author data in Coral Reefs for 2018. I used two years for the older comparison because the smaller number of papers per year could possibly result in skewed data because of small sample size. For the years 1988 and 1989 the average number of papers per issue (four issues per year) was 6.00, the average number of authors per paper was 2.15 and the percent of papers with 5 or more authors was 2.08 (one paper of the 48 total papers). In sharp contrast, for 2018, the average number of papers per issue was 22.5, the average number of authors per paper was 4.88 and the percentage of papers with 5 or more authors was 48.9.

In addition, the average number of authors per year for 1988/89 was 51.5 while for 2018 there were a total of 439 authors. Making the questionable assumptions that there were few duplicate authors in either case and that the number of authors contributing to Coral Reefs is somehow representative of the state of coral-reef science as a whole, then there is some evidence that there are now more than 8 times as many coral-reef scientists (or people related to coral-reef science) than just 30 years ago!

So, to answer my own question: Coral-reef science or coral reef-engineering? Although I do not have data to directly address the first and third parts of my predictions, it seems clear that coral-reef science has transitioned to coral-reef engineering. I should also mention that about 2 years ago I wrote on the Coral List words to the effect that 'while global climate change has been bad for coral reefs, it has been very good for coral reef scientists'. I believe that this assertion has also been confirmed.

References: Ware J (1993) Coral reef science or coral reef engineering. Reef Encounter 13:8-9; Wu L, Wang D, Evans JA (2019) Large teams develop and small teams disrupt science and technology. Nature 566:378-382; Sale PF (1974) Mechanisms of co-existence in a guild of territorial fishes at Heron Island. 2nd Int Coral Reef Symp 1:193-206; Buddemeier RW, Fautin DG (1993) Coral bleaching as an adaptive mechanism: a testable hypothesis. BioScience. 43(5):320-326

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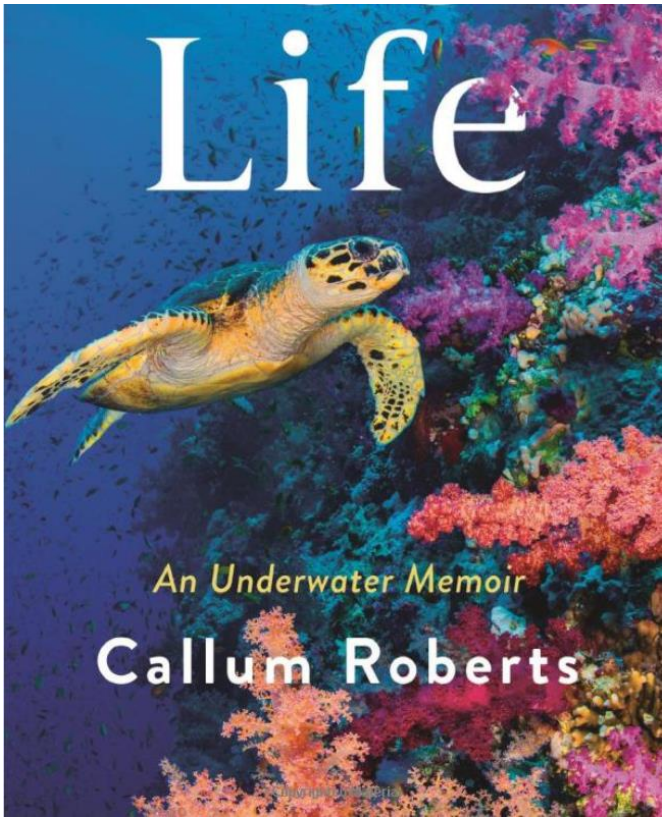
REEF SHELF

Book and Equipment Reviews



Reef Life:
An Underwater Memoir
Callum Roberts

Profile Books (368 pages) Nov. 2019 (£11.89 $19.56)
ISBN-10: 1788162153 ISBN-13: 978-1788162159

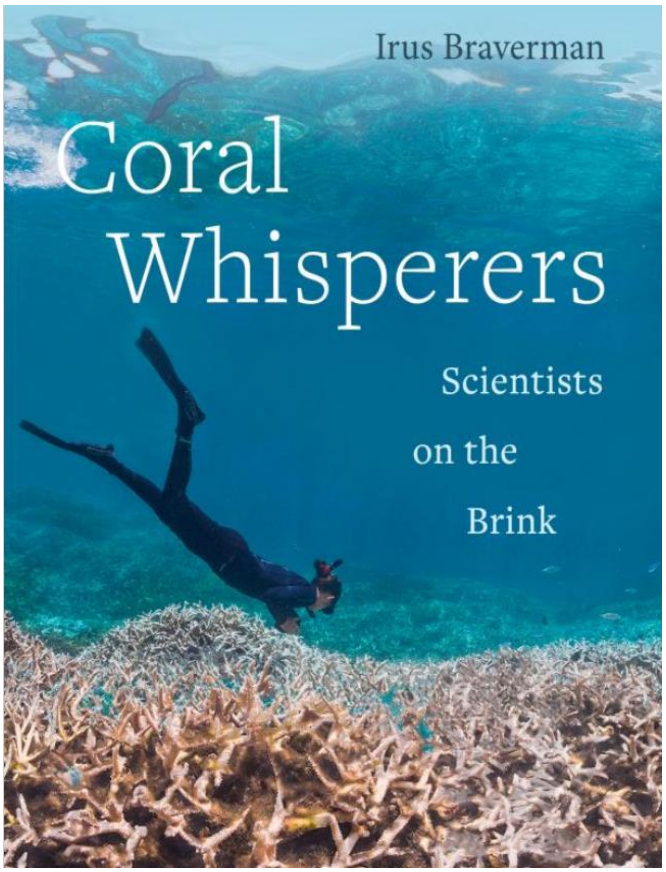
This delightful book is in some senses a sequel to Callum Robert's previous two, increasingly popular volumes "The Unnatural History of the Sea" and "Ocean of Life", which, in the UK at least, have become recommended reading for students and politicians alike. It differs however in being also an entertaining account of his varied experiences in progressing from biology undergraduate to professor, while pursuing his passion for marine life in general, and coral reefs in particular. The story arc of his adventures carries the reader along, but cunningly interspersed with the biographical sections are more serious accounts of the behaviour of reef fish and of the nature of corals, of reefs, and of the great crisis they face. Many readers will improve their understanding of reef ecology in a manner they are unlikely to have done from attempting a more formal account of coral reef natural history, let alone wading through academic reviews of reef biology.

"Reef Life" contains some well-honed accounts of such experiences as his first encounter with large sharks, his much narrower escape from an emotional Saudi coastguard, and his and colleague Charles Sheppard's battles with Egyptian bureaucracy. But, at the same time, it includes the most successful and lyrical accounts of the overwhelming beauty of SCUBA diving on a pristine reef that I can recall. I am sure many Reef Encounter readers will like me have attempted to describe, either in conversation with friends or relatives, or in writing to acquaintances, just what an overwhelming aesthetic and inspirational experience a dive on a high diversity reef can be. Where I and others to whom I have mentioned this admit to failing – Callum Roberts succeeds. His eye for detail and the palette of colours and similes he employs will remind many of us of our most memorable dives, but more significantly they will give the terrestrial reader a vivid impression of just why coral reefs are so important to humans and human life, and why they are so very worth saving for the future.

Before giving a verdict on the book I must declare an interest in that, among the *personae dramatis* so entertainingly described, I find myself. In general, however, kind words are balanced by gentle mockery, so I believe I can make a fair assessment of the work. (I do however insist that I was not wearing a towel on my head for a season of field work in the southern Red Sea, but an Omani *shemagh*!) And my assessment is - I most strongly recommend the book to any student with an interest in tropical marine biology. It will not only give them a fine idea of the tribulations and rewards of a career in marine science, but soundly reinforce their knowledge and understanding of coral ecosystem ecology. More experienced scientists will also find Callum Robert's tales an entertaining break from their own labours at the reef face.

Rupert Ormond

Pictures from the book are on the cover and pages 48 & 87



Coral Whisperers: Scientists on the Brink

Irus Braverman

University of California Press (320 pages) Nov. 2018
$21.92 £23.00
ISBN-10: 0520298853 ISBN-13: 978-0520298859

Irus Braverman's interesting and significant book is a good read. It resembles Callum Robert's volume (previous page) in that it intersperses its principal text with sections explaining corals, coral reefs and coral bleaching to the more general reader, and in so doing must improve public awareness of the critical nature of the coral reef crisis.

The book principally consists however of the author's thoughts on discussions with many of the senior reef scientists involved in the fight to secure the future of corals against the ravages of climate change, together with transcripts of interviews with some of the great and the good of our subject, including Peter Sale, Jeremy Jackson, Ove Hoegh-Guldberg, and most significantly in hindsight, Ruth Gates, to whom the book is dedicated.

It is moving now to read some of Ruth's remarks: "Working on coral reefs for twenty-five years…I am as fascinated and wowed by them today…as when I started." "Coral reefs are my cathedral – that's how I feel when I am on a coral reef." One can see how her enthusiasm and persistence to do something really positive persuaded foundations to support her efforts to breed super corals that might survive the next century. She also bewails the increasing burden of the academic system under which many of us have suffered: "The academic system is broken (sic). Peer review is broken." She argues that although critics have reacted badly to the idea of GMO corals, she was only attempting what nature was doing more slowly.

The account of discussions with Ken Nedimeyer was different since he is an aquarist rather than a scientist; he spearheaded efforts to establish coral nurseries and restore living corals to devastated Florida reefs. He was clearly bemused by the technical objections of the various authorities to his well-intentioned efforts, yet nevertheless persisted in establishing nurseries that have grown hundreds of thousands of coral colonies intended for restoration of degraded reefs. I can fully understand the authorities' concerns, which were not really explained, but nevertheless found myself admiring his persistence.

The book is unusual in that Irus Braverman is not a scientist, but a lawyer with interests in the sociological and cultural aspects of her subject. Her writing is thus of value in informing us scientists of the legal take on our discipline. The insights are both positive and negative. In chapter four she discusses how "traditional focus on species by conservation laws such as the US Endangered Species Act disadvantages corals", while "nearly all Marine Protected areas in the United States allow multiple uses including fishing." But I felt her fairly US-centric approach ignored the successes of MPAs in the majority of reef countries where most protected areas successful restrict almost all damaging activities.

One of the strengths of Irus Braverman's book is that she has been able to talk the scientists she has met into frank discussion of their subject and their research. Often thoughts are reported which might not otherwise have been made available to collaborators let alone competitors. Jeremy Jackson's comments on the concept of unimpacted oceans are a case in point: "But in the ocean, there's all this *pristine seas* bullshit." There is much more in this vein to be gleaned from this provocative, but at times frustrating, volume.

Rupert Ormond

CONFERENCE REPORTS

Arabian Coral Reefs Conference, Abu Dhabi

11th – 13th November 2019
New York University, Abu Dhabi, UAE

New York University Abu Dhabi hosted a conference titled "*Arabian Coral Reefs: Insights from Extremes*" from 11 to 13 November, 2019, in Abu Dhabi, United Arab Emirates. The purpose of this conference was to bring together researchers studying coral reefs in the seas surrounding the Arabian Peninsula to exchange recent research and to engage in dialogue towards developing collaboration. Attended by speakers from over 15 nations, this pan-regional conference included presenters from many of the nations bordering the region, including talks on coral reefs in the Red Sea, Gulf of Aden, Sea of Oman and the Persian/Arabian Gulf. This is the third region-wide conference hosted by NYU Abu Dhabi, with plans underway to turn this into a recurrent event to occur every four years midway between ICRS conferences. Many of the conference presenters and attendees are members of the Mideast Coral Reef Society (www.MideastCRS.org), who have recently submitted a proposal to become a regional chapter of ICRS with the goal of increasing international awareness of the unique and valuable coral reefs of the middle east region.

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The Gulf of Mexico Coral Reef Report Card

Tarjeta de reporte de los arrecifes coralinos del golfo de México

14th-15th November 2019
Merida, Mexico

Stakeholders from Mexico, the United States, and Cuba are collaborating to establish a tri-national report card for coral reefs of the Gulf of Mexico (GoM). The Harte Research Institute (HRI) and the Universidad Nacional Autónoma de México (UNAM), Campus-Sisal hosted the first preliminary meeting in November 14-15, 2019 in Merida, Mexico. Participants included 27 attendees from 21 institutions. The workshop was facilitated by Dr. Heath Kelsey, Director of the Integration and Application Network at the University of Maryland Center for Environmental Science (IAN-UMCES).

The results of the meeting included a preliminary draft of a GoM coral reef report card, an informational video, and workshop synthesis report. We found reefs in good condition in the three countries although these were scarce and many of them have increasing anthropic pressures. The team is working to identify potential funding sources to expand this report card by synthes-

Actores claves de México, Estados Unidos y Cuba están colaborando para establecer una tarjeta de reporte tri-nacional sobre los arrecifes coralinos del golfo de México (GoM). El Harte Research Institute (HRI) y la Universidad Nacional Autónoma de México (UNAM), Campus-Sisal lideraron un taller preliminar durante el 14 y 15 de noviembre de 2019 en Mérida, México. En este taller participaron 27 personas de 21 instituciones. El taller contó con la facilitación del Dr. Heath Kelsey, director del Integration and Application Network at the University of Maryland Center for Environmental Science (IAN-UMCES).

Los resultados de la reunión incluyeron un borrador preliminar de la tarjeta de reporte de los arrecifes coralinos del GoM, un video informativo y un informe sintético del taller. Encontramos arrecifes con buena condición en los tres países, aunque estos fueron escasos y muchos de ellos tienen presiones antrópicas

izing additional scientific data to provide more in-depth indicators regarding the status of reefs in the region. Currently, the core working group is made up of HRI, UNAM, The Ocean Foundation (TOF), the National Oceanic and Atmospheric Administration (NOAA), the National Commission of Protected Natural Areas (CONANP), academic and research institutions from the US, Mexico and Cuba. We aim to host a larger meeting in 2020 with participation of key tri-national stakeholders. If you are interested in becoming involved or would like more information, please contact Dr. Nuno Simoes, at gmxreefcard@gmail.com. Stay tuned at www.bdmy.org.mx.

crecientes. El equipo está trabajando para identificar posibles fuentes de financiación con el fin de ampliar este informe sintetizando datos científicos para proporcionar indicadores más detallados sobre la situación de los arrecifes en la región. Actualmente, el grupo de trabajo está integrado por el HRI, la UNAM, la Fundación del Océano (TOF), la Administración Nacional del Océano y la Atmósfera (NOAA), la Comisión Nacional de Áreas Naturales Protegidas (CONANP) así como instituciones académicas y de investigación de México, Estados Unidos y Cuba. Nuestro objetivo es organizar una reunión más amplia en 2020 con la participación de los principales actores interesados a nivel tri-nacional. Si está interesado en participar o desea obtener más información, por favor, póngase en contacto con el Dr. Nuno Simoes, en gmxreefcard@gmail.com. Manténgase informado en la página web www.bdmy.org.mx.

Coral Bleaching Research Coordination Network Workshop

22nd – 24th May 2019

Ohio State University, Ohio, USA

Temperature stress is the single largest threat to coral reefs globally and the focal topic of the newly established Coral Bleaching Research Coordination Network (CBRCN). The goal of the CBRCN is to work with the broader coral reef research community to develop protocol recommendations over the course of three workshops, and to facilitate interdisciplinary collaborative team formation. Developing a framework of best practices is key to moving the science of coral bleaching research forward faster and more efficiently, and to facilitating large-scale data assimilation and meta-analysis. These objectives are imperative given the ongoing coral bleaching crisis.

On 22-24 May 2019, the first workshop was held in the School of Earth Sciences at The Ohio State University. Twenty-seven investigators from the USA, Germany, and Australia assembled to develop best practice recommendations for coral bleaching experimental designs, to identify baseline variables that all studies should include, and to facilitate cross-study comparisons. The workshop was a success. The group achieved all goals and the outlines of two manuscripts were developed during the workshop. With writing tasks assigned, the goal was to submit both manuscripts for publication by the end of the summer or early fall. A webinar outlining the findings of the workshop will be presented in late-spring.

The Director of the CBRCN is Professor Andréa Grottoli. Steering committee members are Professors Robert Toonen, Robert van Woesik, Rebecca Vega Thurber, and Mark Warner. For additional information see the CBRCN website at http://u.osu.edu/grottoli.1/coral-bleaching-rcn/ or email Professor Grottoli directly at grottoli.1@osu.edu.

Andréa Grottoli
grottoli.1@osu.edu

REEF DEPARTURES

Tributes to recently departed members and reef scientists

Ruth D Gates

Coral reef scientists and conservationists are still mourning the loss of Ruth Gates, who died just over a year ago on October 25, 2018, and none more so than members of ICRS. In 2015, Ruth became the first woman to be elected President of ICRS (at that time, named the International Society for Reef Studies). Her sad and untimely death aged 56 as a result of surgical complications, unrelated to but whilst also suffering from a debilitating brain cancer, deprives us of a talented scientist, untiring mentor and superb science communicator.

In the short time that she was President, Ruth oversaw initiatives to reshape the Society, successfully increase its membership and promote research awards across all age groups. The 2016 International Coral Reef Symposium would not have been the event that it was without her inspirational leadership, rallying call for action in terms of both research and conservation, and skill at engaging and motivating everyone she talked to: aspiring young scientists, donors and policy makers, those struggling to manage reefs in low income countries, others involved in the media, enthusiastic environmentalists, established academics – she treated all equally and made everyone feel that they had a vital role to play.

Dr Ruth Gates pioneered research into the breeding of 'super corals' able to withstand rising sea temperatures resulting from global warming. Her research examined what traits made some corals better survivors than others with the aim of reinforcing these traits through selective breeding, propagating these individuals before ultimately transplanting them on to damaged reefs. In all of what Ruth did, her life's goal is probably best summed up by what she told the media in 2016: "I have watched some reefs disintegrate before my eyes. I just can't bear the idea that future generations may not experience a coral reef. The mission is to start solving the problem, not just study it"

Much of her life's work was based at the Hawaii Institute of Marine Biology where she had been Director since 2015. During her time in Hawaii she received numerous research accolades. In 2013 she won a $10,000 essay competition sponsored by Microsoft co-founder Paul Allen which particularly inspired her and in 2015, together with Professor Madeleine van Oppen from the Australian Institute of Marine Science, she was awarded a $4 million grant from the Paul Allen Foundation to pursue research into the 'assisted evolution' of corals. This involved complex experiments focussed on selective breeding of corals and manipulations of the diverse assemblages of symbionts to generate stocks with enhanced abilities to cope with global warming. While some scientists were sceptical of the work, Ruth robustly maintained that the dire state of many of the world's coral reefs made it

imperative that all possible solutions should be explored.

Ruth Deborah Gates was born in Akotiri, Cyprus on 28 March 1962 where her father John Amos Gates was stationed with the Royal Air Force. Her mother, Muriel (Peel) Gates was a physiotherapist. After private schooling in England, and inspired by Jacques Cousteau, Ruth began an undergraduate course in Marine Biology at the University of Newcastle upon Tyne in 1984, graduating with both a BSc and then a PhD in 1990. Her post-graduate training, funded by the Leverhulme Trust, allowed her to study the coral reefs on the north shore of Jamaica where she first observed the bleaching responses of corals to increased sea temperatures. In her first published paper she described the natural seasonal paling of corals as a result of loss of their symbiotic algae and the variable responses of different species and individuals, a theme which she was to return to much later in her career.

In 1990 she moved to the University of California Los Angeles and commenced a period of post-doctoral research into coral bleaching responses. She remained there for over a decade, building up research skills in cell and molecular biology and evolutionary genetics. In 2003 she moved to Hawaii following her appointment as a research faculty member at the Institute of Marine Biology on Coconut Island in Kane'ohe Bay. Here she gained tenure in 2007 and subsequently led the 'Gates Coral Lab' until her death, with a devoted team who have described her as a "fearless leader and an incredible beacon of hope for coral reefs".

Not only a pioneering research scientist, Ruth also had many other skills, including training and mentoring her large laboratory of PhD and postgraduate students, many of whom have become internationally recognised experts in their field. Ruth was an accomplished sub-aqua diver and in her spare time, she pursued her love of karate, achieving a third degree black belt, and founding a local karate school.

She also emerged as an effective and engaging public speaker and science communicator. Audiences were captivated by her commitment and passion for the science and her optimism in face of an increasingly dire future for coral reefs. In a message written only two weeks before her death she spoke of how much importance she attached to this ability to engage with the general public and young people about the need to conserve coral reefs. In 2017 she appeared in the Emmy award-winning Netflix documentary 'Chasing Coral' and was a regular commentator in the media. She modestly attributed her success as a charismatic speaker to her boarding school English accent.

I taught and supervised Ruth during her time at Newcastle University where I witnessed the determination and optimism which was to become the hallmark of her later life. Like all of those who met Ruth I feel privileged to have known her. She is survived by her wife Robin Burton-Gates whom she married in September 2018 and her brother Tim Gates.

Barbara Brown

Edgardo Dizon Gomez

Thoughts from those he taught, worked with and inspired in his home country:

The Philippine science and conservation community, and particularly those concerned with coral reefs, is mourning the loss of National Scientist and Academician, Emeritus Professor Edgardo Dizon Gomez who passed away on December 1, 2019. He was 81.

Prof. Gomez, Ed to his friends and 'Sir' to the rest of us, was a high school student when he was first introduced to coral reefs by his teacher, Br. Alfred Shields FSC, who established the now eponymous marine station of De La Salle University in the Philippines. Ed got so engrossed with reefs that he stayed out too late and ventured too far, much to Br. Alfred's distress.

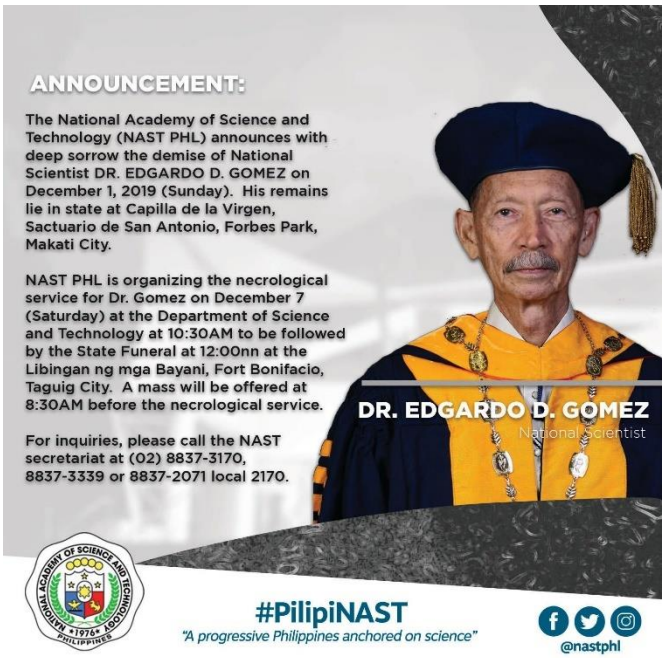
Prof. Gomez graduated with a double degree, a Bachelor of Arts and Bachelor of Science, in English and Social Science Education, respectively, summa cum laude, from De La Salle University. He earned his MSc in Biology from St. Mary's University in Minnesota, and his PhD. in Marine Biology from the Scripps Institution of Oceanography at the University of California in San Diego. A year after he got his PhD, he established in 1974 what is now the Marine Science Institute of the University of the Philippines, the leading marine science institution in the Philippines and in Southeast Asia, and mentored the generation of scientists that run it now. All from a room, a chair, a desk, and a phonebook.

He planned and built the world class Bolinao Marine Laboratory on the water in Pangasinan, with facilities for field work in the Lingayen Gulf, extensive indoor laboratories and outdoor holding tanks for experiments. The BML became a base for mentoring marine science students to become field ecologists, experimental scientists and socio-economists; for growing high-value reef organisms, especially giant clams, sea urchins and sea cucumbers that Gomez's national survey had shown to be depleted; and for implementing of community-based coastal resource management and marine protected areas. For most of his career Dr. Gomez quietly used his stock of giant clams to set up mini "nurseries" on reefs in many locations throughout the Philippines, and in his later years he became involved in planting indigenous trees.

International groups rapidly became interested in his work, such as the ASEAN-Australia Coastal Living Resources Project, and the doors of the best institutions abroad were opened for Ed's young cadre of students. By the early 1990s, Dr. Gomez's flock of young Filipino scientists came back with their PhDs, new knowledge and skills, to become the next generation of Filipino professors and researchers. They were imbued with Gomez's vision to carry out world class science and improve lives in local communities. As a result of Gomez's leadership, in 1994, MSI was declared a National Center of Excellence in Marine Science by former President Fidel V. Ramos. After over 20 years of leading MSI, Dr. Gomez served as the exemplar for subsequent MSI Directors who were surrounded by a large group of colleagues and students committed to Gomez's goals. In recent years, Dr. Gomez donated his marine science expertise to marine conservation and protecting the South China Sea islands of the Philippines. In 2014, Gomez was declared by former President Benigno Aquino to be a National Scientist of the Philippines, joining an elite group.

The list of Prof. Gomez's many achievements and the accolades he received could fill this newsletter issue. He and his work live on in the countless people he inspired, taught, mentored, supported, and led. His

goal in every undertaking was to deliver excellence. Whatever you are doing, if you are doing an excellent job of it, then you are contributing your share to uplift society. He advocated honesty in the workplace, from financial accounting to working hours, to data collection and analyses, to writing manuscripts. He said that by building on honesty, the output of work will always be trusted and will attract others to work with you.



He chose his team well, recruiting brilliant students and diamonds in the rough at the outset. He reached out to local and international collaborators, paved the way for short- and long-term partnerships, opened doors for his students to access scholarships, grants, and research programs. He built the country's marine science program from ground zero when no one was thinking about coral reef protection. Knowing that coral reef ecosystem protection and management will be bigger than any one group, he formed bridges between local and international institutions and mentored his students to be competent scientists and focal point persons to work with these institutions.

Prof. Gomez, we will always remember your love for country, your critical thinking, your spot-on discernment, your superhuman determination, your generosity. Know that you have an army saluting you with love and respect, ready to carry out your mission.

As Laurie Raymundo said: "Ed, you were a mentor, a guide, an inspiration to so many of us. In my own small way, I have aspired to be the type of leader you were, though I never told you that...I wish I had. You deserved to know how much you meant to all of us. Philippine reef conservation has lost a champion." Prof. Gomez told us in a critical moment in our nation's history: "The best thing you can do for this country is to be the best in what you do." Sir, we are honored to have been taught by and worked with the best. We will do our best in honor of your legacy.

Wilfredo Licuanan & Suzanne Mingoa-Licuanan with contributions from
Laurie Raymundo, Perry Alino, and others.

Memories and recognition from the international community:

Ed Gomez was also known and greatly admired around the globe, many of us having worked with him on the numerous research and conservation issues that he was involved with.

"The first major attempt to alert the global coral reef science community to the threats posed to coral reefs was in 1981 by Edgardo Gomez, who subtitled the 4th International Coral Reef Symposium in Manila, May 1981, as The Reef and Man". Written by Clive Wilkinson in 2006[1] , this was probably how he first made his mark internationally. The symposium, with the proceedings that Ed edited with Chuck Birkeland, Bob Buddemeier and Bob Johannes, drew attention to the beginning of what we now recognise as one of the most catastrophic declines of a marine ecosystem, at a time when the ocean and its inhabitants were considered largely indestructible. Attended by some 700 participants and observers, including Russian and Chinese scientists which was very unusual in those day, the symposium was a major international event. With his courteous, gentlemanly and modest manner, Ed presided over it all with a twinkle in his eye.

[1] *Wilkinson, C. 2006. Setting the Stage.Chap 1. In: Côté, I. and Reynolds, J. (eds.): Coral Reef Conservation. Cambridge University Press.*

A long-standing member of ICRS, Ed was one of the first to realise that the long-term survival of reefs and their inhabitants was far from assured, and that good science has a critical role to play in their conservation. He was an inspiration and wonderful mentor to those of us from overseas who were lucky enough to work with him. In the late 1970s, he welcomed and supported U.S. Peace corps volunteers who were keen to work on marine issues in the Philippines. Alan White remembers how he, Kent Carpenter, Gregor Hodgson, John McManus, Mike Ross, and others would bounce their idealistic ideas and plans off Ed and invariably be encouraged to proceed with coral reef monitoring, setting up marine protected areas and whatever else seemed to have potential to promote marine science and conservation. Ed was never put off by "foreigners" and positively encouraged their involvement in the emerging national efforts to protect reefs at a time of rapid coastal development.

When Sue Wells appeared in his office in 1981, nervously explaining that statistics in the dusty Trade Records Offices in London had revealed the Philippines as the main source of ornamental corals and shells on sale around the world, he didn't bat an eyelid. A young Perry Alino was summoned and told to escort her around Cebu, interviewing collectors and retailers (transport was Perry's motor bike). This led to a long collaboration, with Ed leading the call for tight regulations on the national and global coral, shell and aquarium trade, and helping with the eventual listing of marine species, notably the giant clams of which he was so fond, on CITES.

Ed realised early on that in order to study reefs and manage then sustainably, you need to know both their location and their main characteristics. In the Philippines he organised one of the world's first national-scale assessments of coral reefs and subsequently he supported the various international reef mapping and monitoring initiatives as they evolved. As time went on, he also saw that more active interventions and carefully applied research would be needed. His scientific leadership in the region, and pioneering work on coral and clam restoration, led to his involvement in the Global Environmental Facility/World Bank Coral Reef Targeted Research and Capacity Building for Management programme, serving as the Coordinator of the Southeast Asia Center of Excellence and Co-Chair of the Restoration and Remediation Working Group.

Ed's influence and recognition was global, but he had no pretensions and was always happy to meet up. Many of us will have similar memories to this note from Alan White: "Some of my fondest memories of Ed are when I would be in Manila and he would invite me for a chat since he was genuinely interested in my work and learning about what was going on in projects outside his immediate realm. In May 2019, my wife Vangie and I were traveling from Batangas to Manila and we texted Ed to see if he was around and at short notice met him in a nearby Starbucks. He was in good spirits, full of ideas and plans and wanting to know what we were up to, with his inquisitive and open mind which is how I remember him!"

Gregor Hodgson, Barbara Brown, Alan White & Sue Wells

Barbara H Lidz

The Geology profession lost one of its greats on September 26, 2019. Barbara H. Lidz passed away at Bayfront Hospital due to respiratory failure brought on by pneumonia. Barbara was a well-known research geologist recently retired from the U.S. Geological

Survey. She was a graduate of Smith College before beginning a long history of contributions in the field of micropaleontology. She was most happy when peering into a microscope identifying tiny organisms with long unpronounceable names. Later in her career she prepared complicated diagrams for publication and comprehensive maps of Florida's coral reef ecosystems. She spent many days at sea on research vessels both large and small and served as editor of Special Publications for the Society of Sedimentary Geology. During that time, she authored and co-authored dozens of scientific publications. Her career culminated with the position of scientist emerita with the U.S. Geological Survey Coastal and Marine Science Center in St. Petersburg, Florida.

Before moving to St. Petersburg, she held every office in the Miami Geological Society including Editor, Vice President, and President. Barbara conducted research at the University of Miami's Rosenstiel School of Marine and Atmospheric Science before joining the Department of Interior U. S. Geological Survey where she worked at a field station on Fisher Island for 15 years. Barbara moved to St. Petersburg in 1989 where she conducted research in the USGS office located near the University of South Florida College of Marine science.

Barbara's husband, Louis Lidz and daughter Carolyn Elizabeth Lidz predeceased her in 1967. She is survived by her daughter Lauralee (from Scarborough, Maine), a sister, Darcy Holland (from Newbury, Massachusetts), a brother, John Holland (from Copper City, Michigan), two nieces (Caitlin Cardell Holland of New London, New Hampshire, and Cindy Leberman of Chester, New Jersey), and one nephew (Peter Goulazian of Woodstock, Vermont). Barbara also leaves her beloved cat, Peaches.

Eugene Shinn

The coral associated longnose filefish *Oxymonocanthus longirostris*. Illustration from the book "A Reef Life" by Callum Roberts (see book review in REEF SHELF section) – photo by Alex Mustard.

ICRS MEMBERSHIP

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

- Receipt of the Society's scientific journal *Coral Reefs* (either on-line or hard copy)
- Receipt of the Society's newsletter/magazine *Reef Encounter* (by email or on-line)
- Access to the Society's on-line membership services, including the on-line Membership Directory
- Reduced registration fees for the International Coral Reef Symposium and other meetings sponsored by the Society.

Full / Individual Member
Membership includes all the benefits listed above, but rates vary depending on whether a hard-copy subscription or on-line access to the Society's academic journal Coral Reefs is preferred, and according to the mean income level of the member's country.

Student Membership
The benefits are the same as for a Full / Individual Member, and include hard copy or on-line access to Coral Reefs at a much reduced rate.

Family Membership
Family memberships are available for partners who live at the same address. Each receives the same benefits as Full Individual Members, but only one hard copy of any journal is supplied.

Sustaining Membership
Sustaining Membership is for those Members who would like to contribute extra to support the work of the Society. They receive additional minor benefits and their support is acknowledged in Society publications.

Honorary Membership
Honorary Membership has been conferred on a small number of members who have rendered special service to the society or otherwise distinguished themselves in the field of reef science.

Membership services are now operated by Schneider Group which provides such services to academic societies. They may be contacted at:

ICRS Member Services
5400 Bosque Blvd, Suite 680
Waco, Texas 76710-4446 USA
Phone: 254-399-9636
Fax: 254-776-3767
email: icrs@sgmeet.com

The membership subscription varies considerably depending on the type of membership selected and the primary country of residence of the member. Very generous membership rates are available for students and residents of developing countries. For low to low-middle income countries, full membership costs only $40 (US) per year, and student membership only $20 (US) per year.

For details of current rates and to complete the on-line membership form or download a hard copy please go to the society's membership portal at:

https://icrs.memberclicks.net/

NOTES FOR CONTRIBUTORS

Reef Encounter welcomes the submission of Scientific Articles, News Items, Announcements, Conference Reports and Book and Product Reviews, relevant to the coral reef researchers and managers. We especially welcome contributions by young researchers with a fresh perspective and seasoned reef scientists able to integrate a lifetime of experience.

Colour pictures or other illustrations (normally 1-3 according to article length) are welcome to accompany an item. Cartoons and stand-alone pictures of special note may also be submitted. Different types of item should be sent directly (preferably by email) to the relevant section editors (see inside front cover - page 2 – for details).

Types of Article

Reef Encounter accepts three distinct type of "Scientific Article". Note that, for any of these types of article, priority will normally be given to authors who are members of ISRS.

The **REEF PERSPECTIVES** section takes 2-4 page articles which express a fact-based opinion about a scientific or management issue. Our goal is to encourage thoughtful and stimulating discussion within and across disciplines and generations. Authors thinking of offering an opinion-type item are encouraged to consult the editor. Readers are encouraged to respond by writing to letters to the **CORRESPONDENCE** section, but such responses should be well reasoned and respectful (in contrast to the faster-paced open discussion characteristic of coral-list).

REEF CURRENTS takes 1-5 page articles which overview a topic or a programme with which the author is familiar or has become acquainted. Priority will be given to articles focusing on subjects which are relatively new or poorly known or often misunderstood.

REEF EDGE takes short scientific notes or papers (scientific letters) of three-quarters of a page to two and a half pages in length. The intention is to provide a forum for recording observations of scientific or management value that may be too limited in scope to form the basis of a full scientific paper in a quality journal (such as Coral Reefs). It is especially intended that this section provide a useful vehicle for young scientists or those whose first language is not English. Nevertheless submissions must be based on adequate data and appropriate analysis.

For any of the above type of article no standardised division into sections is required; rather authors can propose section headings as best suited to their material. Similarly abstracts will not be used. However articles should be properly referenced, with typically 3 -12 publications cited in a reference section at the end. All types of article will be subject to refereeing by one or more suitably experienced referees.

Style and Format

Contributions should be clearly written and divided into paragraphs in a logical manner. They should normally be in English, but editorial policy is to accept one article per issue written in French or Spanish, but with an abstract in English.

Pages are set with margins as follows: Top 1 cm; Bottom 1.5 cm; Sides 1.3 cm
Reef Currents articles are set as a single column across the page. Reef Perspectives and Reef Edge (and also Reef News) items are set as double columns with the gap between columns = 1 cm
The standard font is: Calibri size 11, with section headings in Calibri 11 Bold. Sub-headings are also in Calibri 11 bold, but set into the beginning of the paragraph. References are in Calibri font size 10, and footnotes in Calibri font size 8.

Paragraph settings are: line spacing = single with a 10 pt line space after a return or at the end of a paragraph, but no additional line spacing before. There is no indentation on either side, except when lists or bullet points are inserted.

Figures & Pictures should have a resolution of at least 350 dpi and be of a size suitable to the format. Each should have an explanatory caption either below or alongside it. Captions should be reasonably full, but not too long. Leave a single line between a figure and a caption below it. Use “Fig.” (i.e. abbreviated) in the text, but “Figure” (e.g. Figure 1) to start a caption

Tables may be single column or page width, but large tables are not normally being suitable for publication in Reef Encounter. Each should have an explanatory caption either below or alongside it. Leave a single line between a table and a caption below it.

References

The style of References follows that used by Coral Reefs with no points or stops after initials or abbreviations, but with parentheses / brackets around dates, e.g. for journal papers and books:

Matsuura H, Sugimoto T, Nakai M, Tsuji S (1997) Oceanographic conditions near the spawning ground of southern bluefin tuna; northeastern Indian Ocean. J Oceanogr 53: 421-433

Klimley AP, Anderson SD (1996) Residency patterns of white sharks at the South Farallon Islands, California. In: Klimley AP & Ainley DG (eds) Great white sharks: ecology and behaviour. Academic Press, San Diego, pp. 365–374

Each reference should have a hanging first line with subsequent lines indented by 0.5 cm. A full list of abbreviations can be found and downloaded from the Springer website at http://www.springer.com/life +sciences/ecology/journal/338