Volume 32, No. 1
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Number 45

REEF ENCOUNTER

Third Global Coral Bleaching Event
CHASING CORALS – the movie!
ECRS 2017 and ICRS 2020
Elections, Prizes, Honors and Awards
Graduate Fellowship Reports
Chagos, Cuba, India, Mexico, Virgin Islands

The News Journal of the
International Society for Reef Studies

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REEF ENCOUNTER

Reef Encounter is the Newsletter and Magazine Style Journal of the International Society for Reef Studies. 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. Please submit items directly to the relevant editor (see the back cover for author's instructions).

INTERNATIONAL SOCIETY FOR REEF STUDIES

The International Society for Reef Studies was founded in 1980 at a meeting in Cambridge, UK. Its aim under the constitution is to promote, for the benefit of the public, the production and dissemination of scientific knowledge and understanding concerning coral reefs, both living and fossil.

CORAL REEFS - THE JOURNAL

The International Society for Reef Studies 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: Seaview surveying on Glover's Reef (Photo by XL Catlin Seaview Survey - The Ocean Agency - Christophe Bailhache).

EDITORIAL

I have spent much of the last few months moving home from the east to the west coast of Scotland, to the Isle of Mull. While this move to probably the best marine life area in the country has proved well worthwhile, it has also proved far more time consuming than I had anticipated, so this issue is again appearing a little later than I had hoped. But the wait will I trust have proved worthwhile.

Most notably in this issue, we have a series of articles concerning the recent extended global bleaching event. Mark Eakin and colleagues at NOAA provide an overview of the later stages of the event, following their previous report of a year ago; they also describe further refinements to their Coral Reef Watch work. We also have short reports on the effects of recent coral bleaching, in Cuba, southern India and the Chagos Islands. And of special interest Bre Graziano provides an account of the filming of the award-winning documentary CHASING CORAL. The film is a hard hitting but very informative account of how rising ocean temperatures have been causing the death of corals and decimation of reef communities in every tropical ocean. Society members played a major part in the production, one sequence of which was filmed at ICRS13 in Honolulu last year. CHASING CORAL is now available on "Netflix", and we not only urge you to watch, but to please insist that all your friends and family and colleagues likewise experience it. (It is unlikely to appear on your Netflix home screen, but is quickly located using the search function!)

We are also pleased to include in this issue reports by three past winners of the Society's graduate fellowships, which offer grants to graduate students to cover the costs of additional research, either in the field or at another institution. Historically the society offered only two fellowships per year, but given the huge demand for these awards and the improved financial position of the society, this year we were able to increase the number of awards to six, three being reserved for students from developing countries. In consequence we anticipate further stimulating reports in future years.

Finally, may I draw to members' attention, first the increasing activity of the Society's committees, including Honors and Awards, Social Media, Conservation, Education and Students' Committees, and second, plans to establish a number of regional chapters , for Latin America, Europe, the Middle East and East Asia & the Western Pacific. These committees and chapters provide an array of opportunities for any member who wishes to become involved in the work of the Society. Never has the need for us to work together to protect the reefs we love been greater.

Rupert Ormond
Corresponding Secretary ISRS & Editor, Reef Encounter
Honorary Professor, Heriot-Watt University, Edinburgh, UK

RECORDING SECRETARY'S REPORT

Having this year taken over from Kiho Kim the role of Society Recording Secretary, I am enjoying the challenge of recording the many significant issues discussed during the Society's Council meetings. These now take place on line, using the programme "Zoom". They are also scheduled as two calls, so that all Council members, wherever they are based around the globe, can participate in one session or the other. To help keep Society members abreast of developments and promote transparency we, on this occasion as an experiment include below the abridged minutes of the most recent Council calls. We trust these will be of interest.

Liz Drenkard
ISRS Recording Secretary
Scripps Institution of Oceanography
La Jolla, California 92037, USA

ISRS Council Meeting / Conference Calls
Minutes of the Meetings of August 7-8, 2017

Call I: Ruth Gates, Rupert Ormond, Lisa Rodrigues, Erinn Muller, Elizabeth Drenkard, Ania Banaszak
Call II: Ruth Gates, Erinn Muller, Elizabeth Drenkard, Thamasak Yeemin, Ilsa Kuffner, David Baker, Stacy Jupiter, Kazuo Nadaoka, Tracy Ainsworth, Morgan Prattchet

1. **Minutes from May Council Call (8th/9th May 2017):** Reviewed and approved
   - Corrections:
     - Re Awards and Honors Committee – there had been questions regarding eligibility
     - The graduate fellowships had already been approved by Council by email
2. **Treasurer's Report (annex 2):**
   - Erinn reviewed the treasurer's report which will also be included in Reef Encounter. Since May, we have received all ICRS "profits" giving a current bank balance of approximately $180K.
   - A majority of our income comes from society membership. Erinn drafted renewal reminder letters. Rupert pointed out the increase in ISRS Facebook membership, which Ruth noted, now exceeds that of the society itself. ISRS has always been exclusive in primarily limiting membership to scientists.
   - Ruth described the double approval system in place involving her and Erinn that enabled more checks and greater transparency over ISRS expenditure.
   - Ruth and Erinn discussed the possibility of investing our funds, thus establishing an endowment that would allow for greater financial flexibility.
3. **European Coral Reef Symposium 2017 (annex 3) & future meetings/conferences**
   - Kirsty Richards sent an update: the meeting has expanded to accept 440 participants (vs. 400 originally planned); we will likely recover all invested funds.
   - As a session organizer, Ania reported she'd had to reject some abstract submissions. Ruth expressed concern that students would be first among those rejected thus defeating the purpose of these conferences and perhaps we should reconsider having smaller, more frequent meetings.
   - Rupert and the conference organizing committee had agreed an ISRS council member should be appointed to the committee awarding the student travel grants for ECRS; it was agreed to appoint Serge Planes to fill this role.

- Ania is co-organizing the 10th Mexican Coral Reef Symposium (2018) and will be requesting "seed" money. Ruth indicated that ISRS support would be consistent with the precedent set by the European conference. Rupert suggested re-branding as a "Latin American" meeting in order to attract a broader geographic range of scientists and Ania mentioned this idea had been considered.

4. International Coral Reef Symposium 2020 (annex4)

- Rupert reviewed Christian Wild's update, which will be included in Reef Encounter. The conference dates have been set for July 5th – July 12th. Preparations seem well in hand. There are funds available for two officers to visit Bremen to check on progress - Ruth and Rupert plan to visit in early November.
- Ruth presented and advocated for Barbara Brown's proposal to produce a reef-themed ballet, to be co-sponsored by ICRS for the Bremen meeting. Ruth estimated an ISRS payment (not loan) of about 15K Euro. This was well received by council members.

Decision: Council approved moving forward with ballet project

5. Amendments to criteria for Society Awards & Honors (annex 5a&b)

- Ilsa presented the Award committee's edits to the website/nomination form:
  - The world reef award is now open to 2 recipients per year
  - Candidates may be nominated for more than one honor on a single form
  - There is clarification of ISRS fellow criteria
- We discussed objectives of the ISRS fellow award and what distinguishes it from other honors; suggested additional modification to the criteria to emphasize service, in addition to scientific achievement or conservation
- Ania suggested award for eminence in conservation to parallel research award, but concern was expressed that this might compete with the World Reef Award; it was agreed to discuss the matter further in due course.
- Ruth indicated we want to be sure that we're seeing representation across our membership and not just getting applications from a few regions.

Decision: Council approved the proposed changes to the award application form

6. Proposal for establishment of "Special Interest" chapters (annex 6 & 7)

- Ilsa is serving on the steering committee for the Coral Restoration Consortium. They inquired as to whether ISRS would endorse them as a special interest chapter with implementation following guidelines for regional chapters
- Ruth advised caution. One concern is that less than 50% of CRC members are members of ISRS and not all have declared their professional/scientific affiliations. Additionally, CRC is a relatively new organization and their mission/ structure are not yet clear.
- We as a society will develop a mechanism and requirements for establishing special interest chapters.

7. ISRS website (annex 8) & logo

- We discussed making the website more modern in appearance and mobile phone friendly. Objectives include finding a better design, formatting in an editable language and having more people involved in keeping the site up-to date
- Ilsa proposed several new pages:
  - A history webpage to include names of past presidents, past Editors-in-Chief of Coral Reefs, and locations + dates of past ICRS meetings
  - PDF of the oldest past volumes of Reef Encounter (these are now inserted)
  - A "Reef Heroes" page to commemorate accomplishments of deceased members
- Erinn explained that our hosting arrangement with the Schneider group is oriented around handling membership payments.
- Ruth explained that the proposed new logo is being re-rendered to include the ISRS name around or alongside the coral image. It and will soon be distributed to council members for their assessment. It is hoped it can be finalized in time for the Year of the Reef.

8. Additional Business

- Rupert indicated that the student committee is moving along well; they sent a set of minutes and welcome any feedback for them.
- Morgan reported on work with Coral Reefs as EIC. He is trialing preemptively rejecting papers that won't get accepted prior to sending them to topic editors and reviewers. He expressed concern over a recent drop in impact factor
- Ruth suggested communicating these issues back to the community.
- Stacey suggested, on the topic of rebranding, sending out a questionnaire to current ISRS members to get a sense of our demographics and how ISRS can best serve them.

9. Next Meeting

- The next meeting (conference calls) will be on Nov 13/14

TREASURER'S REPORT

Increased Support for Graduate Fellowships and Regional Meetings through 2017

We are proud to report that the International Society for Reef Studies (ISRS) remains in solid financial standing with an unliened balance of $180,785.69 USD on May 31st, 2017 (Fig. 1). Income for ISRS primarily comes from membership dues, which doubled during 2016 thanks to the highly successful 13th International Coral Reef Symposium in Honolulu, Hawaii. The uptick of income for ISRS in 2016 has resulted in a 50% increase in graduate research fellowships, from four to six, and a $30,000 loan to the Zoological Society of London in order to offset initial costs related to the European Coral Reef Symposium (ECRS) (Fig. 2). The ECRS will be held in Oxford, UK from December 13th to the 15th, 2017.

Additional expenditures for 2017 include monthly management fees and other anticipated routine costs estimated at approximately $40,000 USD, leaving the Society with at least $140,000 USD by the end of 2017. ISRS is exploring and considering several ways to invest the surplus of funds including increasing fellowship opportunities, updating the ISRS website experience, supporting additional regional meetings, and establishing more opportunities for young scientists to interact with senior Society members.

Figure 1. Monthly uncommitted funds held by ISRS from 1 January 2009 until 31 May 2017.

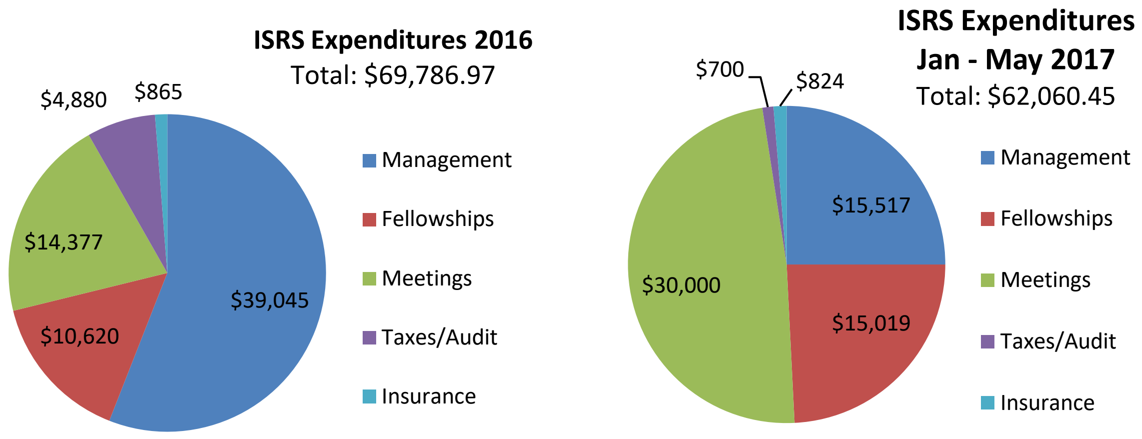
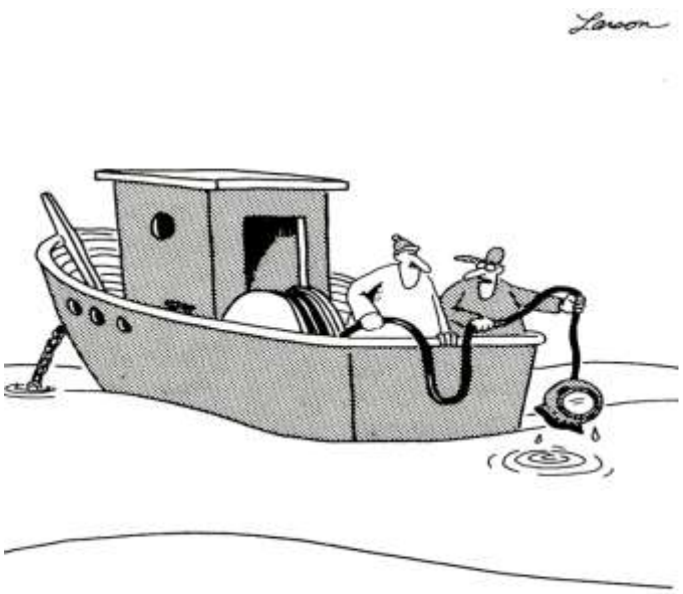


Figure 2. Identified expenditures for the International Society for Reef Studies in 2016 (left) and from 1 January 2017 until 31 May 2017.

Erinn Muller
ISRS Treasurer, Mote Marine Laboratory
Sarasota, Florida 34236, USA



Well, that's ISRS membership income down a notch!

(with apologies to Larson!)

European Coral Reef Symposium, Oxford, UK, 13th-15th December 2017

The European Coral Reef Symposium is taking place in Oxford, UK, over 13th – 15th December 2017, organised by the Reef Conservation United Kingdom (RCUK) Committee. The meeting is sponsored by ISRS, RCUK, The Zoological Society of London (ZSL) and the University of Oxford, and will take place in the historic Examinations Buildings (Examination Schools) of the University. Interest in the meeting has far exceeded the organisers' expectations, with 440 oral presentations and 80 posters being submitted. To allow for the participation of a greater number of delegates, the event has been expanded to include more than 20 sessions (up to 5 running concurrently) covering a wide range of disciplines, spanning from tropical coral reefs to cold water coral ecosystems, gene scale to reef scale, and ecology to geology. There are also a number of workshops selected to allow insight into an emerging technology or provide a taste of a different research area.

Details of the Symposium, including a list of the sessions and an outline programme, can be found on the RCUK website (http://www.reefconservationuk.co.uk/ecrs-2017.html). Registration is via the Zoological Society of London website at https://www.zsl.org/science/whats-on/european-coral-reef-symposium-ecrs-2017.


The Examinations Schools, Oxford

Please note that Early Registration closes on 15th September, and Standard Registration on 13th October, 2017. Thus, if you wish to attend you should register as soon as possible.

As a further indication of interest in the meeting, 124 applications were received for eight student travel bursaries, to be funded by ISRS. The successful applicants are being selected by a four-person panel, including an ISRS Council appointee, and will be notified shortly.

The 14th International Coral Reef Symposium (ICRS14) Bremen, Germany, July 5th -10th, 2020

At the end of 2016 we received the pleasant news from ISRS that the 14th International Coral Reef Symposium (ICRS 2020) could take place for the first time in Europe, in our city of Bremen. Immediately afterwards, we agreed the exact dates for ICRS14 with ISRS: these will be **Sunday July 5 until Friday July 10**. Most of the halls and rooms at the Bremen Exhibition and Conference Centre (CCB) are now booked for the event.

Since then we have had several meetings with representatives of the Ministries of Science, Economy, and Environment of the state of Bremen, with the objective of discussing financial support options in order to establish a conference secretariat of coordination staff in order to ensure that all is well prepared for the event. Our proposals have been approved by the Ministries of Science and of Economy so that the ICRS conference secretariat can be opened in September this year with at least two supporting staff members. Soon after, the first meeting of the organizing committee will take place at University of Bremen to discuss the scientific program, procedures, schedule, and publication plans. The organizing committee, now of more than 20 members, includes representatives of all the institutions involved in coral reef research in Bremen plus colleagues from neighboring German and Dutch institutions. We envision having the conference homepage, with regular progress updates and relevant information, working from the beginning of 2018. Details of the website will be advertised through ISRS and coral-list.

street in the oldest part of the city

With the support of the Bremen Ministry of Environment and associated energy agencies we have made progress in developing a strategy and funding proposal for presentation to the German Ministry of the Environment, with the aim of making ICRS14 as climate-friendly and CO_2-neutral as possible. We have also started to work on the sponsorship and media partnership strategies. Also, in the next few months, we intend to specify the details of the pre- and post-symposium field trips, along with the accompanying persons program.

Overall, we have the feeling that event preparation is well underway and that we have assembled an active and motivated organization team. We are especially happy with all the support and interest we have received, particularly from the University and the State Government of Bremen. Of course we also feel the challenge of organizing this unique once-in-a-lifetime event and are becoming increasingly excited at the prospect. Above all, come the summer of 2020, we greatly look forward to welcoming the global coral reef community to Bremen.

Prof. Dr. Christian Wild
(on behalf of the ICRS14 organizing committee)
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SOCIETY AWARDS AND HONORS 2017

The Society announced in May the award of its 2017 honors to the following members:

Eminence in Research Award: Ove Hoegh-Guldberg and Tim McClanahan
Mid-Career Award: Morgan Pratchett
Young Scientist Award: Emily Darling
World Reef Award: Joseph Maina Mbui and Lorenzo Alvarez-Filip
Elected ISRS Fellow: Christine Schonberg

Congratulations to the successful candidates and thanks to all members who participated.

Society Elections, January 2017

As a result of the elections held at the beginning of the year the following members were elected to the available officers' posts:

TREASURER: Erinn Muller, Mote Marine Laboratory, Sarasota, Florida, USA (emuller@mote.org)

RECORDING SECRETARY: Elizabeth Drenkard, Scripps Institution of Oceanography, San Diego, California, USA (liz.drenkard@gmail.com)

In addition the following members were elected to the COUNCIL:

Tracy Ainsworth, James Cook University, Townsville, AUSTRALIA (tracy.ainsworth@jcu.edu.au)

Anastazia (Ania) Banaszak, Universidad Nacional Autónoma de México, Puerto Morelos, MEXICO (banaszak@cmarl.unam.mx)

Aileen Maypa, Silliman University, Dumaguete City, PHILIPPINES (aileenpmaypa@su.edu.ph)

Héctor Reyes-Bonilla, Universidad Autónoma de Baja California Sur, La Paz, MEXICO (hreyes@uabcs.mx)

Lisa J Rodrigues, Villanova University, Villanova, Pennsylvania, USA (lisa.rodrigues@villanova.edu)

Christian Wild, University of Bremen, Bremen, GERMANY (christian.wild@uni-bremen.de)

A total of 18 members offered themselves as candidates and we are most grateful to them all for their interest in becoming involved in the management of the Society. We are especially grateful to the retiring officers (Don Potts and Kiho Kim) and also to the retiring council members, for their considerable work on behalf of the Society, during their terms of office.

ISRS Graduate Fellowships / Research Grants

The Society announced in April the award of its 2017 Graduate Fellowships to the following graduate student members:

Ashani Arulananthan (Sri Lanka)
Institution: Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.
Research topic: A Baseline Survey of coral reefs and genetic diversity analysis of coral species in Jaffna Peninsula, Sri Lanka.

Wing Chan (Hong Kong)
Institution: School of BioSciences, University of Melbourne, Parkville, Victoria & Australian Institute of Marine Science, Townsville, Queensland, Australia
Research Topic: Assisted evolution via hybridization: A new potential approach in coral reef restoration.

Louis Yohan Didier (Mauritius)
Institution: University of Mauritius, Réduit, Mauritius
Research Topic**:** Spatial and temporal modulation of the expression of Heat Shock Proteins in the coral *Acropora muricata* before and during the 2016 El Niño.

Erin Dillon (USA)
Institution: Ecology, Evolution & Marine Biology, University of California - Santa Barbara, Santa Barbara, California, USA
Research Topic: Reconstructing historical shark communities on Curaçao using a novel paleoecological tool.

James Price (USA)
Institution: School of Earth Sciences, Ohio State University, Columbus, Ohio, USA
Research Topic: Coral resilience to global change: roles of the microbiome and animal physiology.

Aida Sofia Rivera Sotelo (Colombia)
Institution: Department of Anthropology, University of California Davis, California, USA
Research Topic: Coral Ecologies - An Ethnography of social relations in the Caribbean coast of Colombia.

Congratulations to the successful applicants and thanks also to the other ISRS members who submitted research proposals. 24 applications were received and assessed independently by a panel of six Council members who commented on the overall very high quality of the proposals.

32nd General Meeting of ICRI

The next General Meeting of the International Coral Reef Initiative (ICRI) will be held, from 7th-9th December, 2017 in Nairobi, Kenya, back to back with the third meeting of the UN Environment Assembly (UNEA 3).

More information is available on the ICRI website.

Formation of an ISRS European Chapter

It is hoped there will be an opportunity towards the end of ECRS2017 in Oxford for interested members to discuss two items of business. First, it is proposed to organise a European Chapter of ISRS, to which European or Europe based members may become affiliated. A committee is required to run the chapter and a call will be made at the meeting for members interested in serving on it. Other members not attending the conference may also offer their services by emailing or otherwise contacting the Society's Corresponding Secretary, Prof. Rupert Ormond at rupert.ormond.mci@gmail.com.

Second, expressions of interest will be sought to host the subsequent European Coral Reef Symposium, anticipated to be held in 2022, two years after ICRS14 in Bremen, Germany. While the date appears a long way ahead, time needs to be allowed for potential hosts to consider whether a bid is feasible, in terms of facilities and financial support. However, it is not anticipated that a formal call for bids will be issued before late 2018, when selection of a preferred venue can be considered by the committee of the European Chapter referred to above.

Winners of the Best Paper Award: Coral Reefs volume 35 (2016)

For the first time in its history, the Best Paper Award for the ISRS journal Coral Reefs (established 1982) is awarded jointly to two papers, authored by teams led by Ashley Frisch (James Cook University, Queensland, Australia) and Daniel Holstein (The University of Miami, Florida, USA). Congratulations to these two teams on the quality of both their original research and their Reports. Both studies shone new light on issues which are of great intrinsic interest and great relevance to informed conservation and management of coral reef ecosystems: the trophic role of reef sharks, and the connectivity between mesophotic and shallow-water corals. Their Abstracts are reproduced below. The Award consists of a plaque and cash donated by the journal's publisher Springer. ISRS thanks Springer for their ongoing support of this Award.

Not too far behind in the voting (by the 21 members of Coral Reef's editorial board) were two others on the shortlist, with senior authors Océane C. Salles ('CORAIL', Perpignan, France) and Brian Strehlow (University of Richmond, Virginia, USA). The diversity of topics, approaches and institutions represented in the short list (below), and indeed the entire content of Volume 35, is a tribute to the maturity of coral reef research at a time when it is more important than ever that decisions affecting coral reefs are based on the deep knowledge and insights revealed in papers such as these.

The short list

Reassessing the trophic role of reef sharks as apex predators on coral reefs: Ashley J. Frisch, Matthew Ireland, Justin R. Rizzari, Oona M. Lönnstedt, Katalin A. Magnenat, Christopher E. Mirbach, Jean-Paul A. Hobbs

Abstracts
Joint winners of Coral Reefs Best Paper Award, Coral Reefs Volume 35, 2016

Frisch et al. (2016) Reassessing the trophic role of reef sharks as apex predators on coral reefs. Coral Reefs 35: 459 - 472

Abstract Apex predators often have strong top-down effects on ecosystem components and are therefore a priority for conservation and management. Due to their large size and conspicuous predatory behaviour, reef sharks are typically assumed to be apex predators, but their functional role is yet to be confirmed. In this study, we used stomach contents and stable isotopes to estimate diet, trophic position and carbon sources for three common species of reef shark (*Triaenodon obesus*, *Carcharhinus melanopterus* and *C. amblyrhynchos*) from the Great Barrier Reef (Australia) and evaluated their assumed functional role as apex predators by qualitative and quantitative comparisons with other sharks and large predatory fishes. We found that reef sharks do not occupy the apex of coral reef food chains, but instead have functional roles similar to those of large predatory fishes such as snappers, emperors and groupers, which are typically regarded as high-level mesopredators. We hypothesise that a degree of functional redundancy exists within this guild of predators, potentially explaining why shark-induced trophic cascades are rare or subtle in coral reef ecosystems. We also found that reef sharks participate in multiple food webs (pelagic and benthic) and are sustained by multiple sources of primary production. We conclude that large conspicuous predators, be they elasmobranchs or any other taxon, should not axiomatically be regarded as apex predators without thorough analysis of their diet. In the case of reef sharks, our dietary analyses suggest they should be reassigned to an alternative trophic group such as high-level mesopredators. This change will facilitate improved understanding of how reef communities function and how removal of predators (e.g., via fishing) might affect ecosystem properties.

Keywords Elasmobranch Food web Stable isotope analysis Top-down control Trophic ecology

Holstein et al. (2016) Modeling vertical coral connectivity and mesophotic refugia. Coral Reefs 35: 23 – 37

Abstract Whether mesophotic reefs will behave as refugia for corals threatened by global climate change and coastal development depends on vertical exchange of larvae between diverse habitats. Here we use a biophysical model of larval dispersal to estimate vertical connectivity of a broadcasting (*Orbicella faveolata*) and a brooding (*Porites astreoides*) species of coral in the US Virgin Islands. Modeling predicts subsidy to shallow areas by mesophotic larvae of both species based on local hydrology, adult reproductive characteristics, larval traits, and a wide range of scenarios developed to test depth-sensitive factors, such as fertilization rates and post-settlement survivorship. In extreme model scenarios of reduced fertilization and post-settlement survivorship of mesophotic larvae, 1–10 % local mesophotic subsidy to shallow recruitment is predicted for both species, which are demographically significant. Although direct vertical connectivity is higher for the broadcaster, the brooder demonstrates higher local multigenerational vertical connectivity, which suggests that local *P. astreoides* populations are more resilient than those of *O. faveolata*, and corroborates field studies. As shallow habitat degrades, mesophotic–shallow subsidy is predicted to increase for both species. This study is the first of its kind to simulate larval dispersal and settlement between habitats of different depths, and these findings have local, regional, and global implications for predicting and managing coral reef persistence in a changing climate.

Keywords Mesophotic coral ecosystems Ecological modeling Population connectivity Refugia Coral reef

Modeling vertical coral connectivity and mesophotic refugia: Daniel M. Holstein, Claire B. Paris, Ana C. Vaz, Tyler B. Smith

Genetic tools link long-term demographic and life-history traits of anemonefish to their anemone hosts: Océane C. Salles, Pablo Saenz-Agudelo, Glenn R. Almany, Michael L. Berumen, Simon R. Thorrold, Geoffrey P. Jones, Serge Planes

The potential of azooxanthellate poriferan hosts to assess the fundamental and realized *Symbiodinium* niche: evaluating a novel method to initiate *Symbiodinium* associations: Brian Strehlow, Sarah Friday, Mark McCauley, Malcolm Hill

The short-listed papers were those that received most nominations from a long-list of 24 Reports nominated by the editorial board, also including the 20 below, listed alphabetically by senior author.

Benneke	*In situ* growth rates of deep-water octocorals determined from 3D photogrammetric reconstructions
Bernard	The ups and downs of coral reef fishes: the genetic characteristics of a formerly severely overfished but currently recovering Nassau grouper fish spawning aggregation
Bramanti	Density-associated recruitment mediates coral population dynamics on a coral reef
Cowan	Predation on crown-of-thorns starfish larvae by damselfishes
Hamilton	Hyperstability masks declines in bumphead parrotfish (*Bolbometopon muricatum*) populations
Hoadley	Contrasting physiological plasticity in response to environmental stress within different cnidarians and their respective symbionts
Kok	Climate-driven coral reorganization influences aggressive behaviour in juvenile coral-reef fishes
Levas	Can heterotrophic uptake of dissolved organic carbon and zooplankton mitigate carbon budget deficits in annually bleached corals?
McNeil	New constraints on the spatial distribution and morphology of the *Halimeda* bioherms of the Great Barrier Reef, Australia
Nitschke	Horizontal transmission of *Symbiodinium* cells between adult and juvenile corals is aided by benthic sediment
Plass-Johnson	Experimental analysis of the effects of consumer exclusion on recruitment and succession of a coral reef system along a water quality gradient in the Spermonde Archipelago, Indonesia
Robbins	Foraging mode of the grey reef shark, *Carcharhinus amblyrhynchos*, under two different scenarios
Roik	Spatial and seasonal reef calcification in corals and calcareous crusts in the central Red Sea
Santodomingo	Understanding the murky history of the Coral Triangle: Miocene corals and reef habitats in East Kalimantan (Indonesia)
Saunders	Tectonic subsidence provides insight into possible coral reef futures under rapid sea-level rise
Schmidt	Large-amplitude internal waves sustain coral health during thermal stress
van de Leemput	Multiple feedbacks and the prevalence of alternate stable states on coral reefs
Viladrich	Variation in lipid and free fatty acid content during spawning in two temperate octocorals with different reproductive strategies: surface versus internal brooder
Wilkinson	The distribution of intra-genomically variable dinoflagellate symbionts at Lord Howe Island, Australia
Woods	Environmental factors limiting fertilisation and larval success in corals

Terry Done, Panel Chair, Member of Editorial Board, Coral Reefs, July 2017

Regional and Topic Chapters

In the past few years a number of proposals have been made to Council for the establishment of both Regional Chapters (or sections) and Topic (or particular interest) Chapters, such as now operate in many other large international scientific societies. Accordingly Council is finalising rules to lay out how these chapters would operate within the ISRS constitution, and moves are currently underway to establish three or four Regional Chapters and at least one Topic Chapter. Council has also agreed the principle that chapters may include non-ISRS members as associates. The draft rules are shown in full below, and any group of members interested in forming a regional or Topic Chapter is encouraged to raise the idea with one or more Council members (see the list on the inside front cover of this issue or the Society website).

Rupert Ormond, Corresponding Secretary, ISRS

General Rules Concerning the Formation of Regional and Topic Chapters.

1. Any group of ISRS members may propose the formation of a Regional or Topic Chapter (or Group), to which may become affiliated other members from (or working in) a particular region of the globe that includes a significant number of countries and members, or working in or interested in a particular subject area, the formation of any proposed Regional or Topic Chapter being subject to final approval by ISRS Council.

2. A Regional or Topic Chapter should be managed by a committee of at least five (and no more than ten) paid-up members of ISRS from among whom one should be elected as chair, one as secretary and one as treasurer.

3. The Chapter Committee should meet to conduct business either in person or through a conference call at least two times per calendar year. Minutes of the meeting should be recorded by the secretary and forwarded to the Council of ISRS for its information and comment.

4. A Regional or Topic Chapter may organise regional meetings and promote relevant training, public awareness, research or management activities within the region, and may initiate other activities consistent with the aims of the Society, subject to the approval of ISRS Council.

5. A Regional or Topic Chapter may also produce and distribute a regional newsletter or news bulletin, although normally such material should also be made available for publication in Reef Encounter if considered of sufficient interest to the wider membership.

6. Normally ISRS Council shall approve for use by each Regional Chapter a small annual allowance to cover basic operating costs such as office expenses. Provisionally the sum of US $500 or $1,000 per annum (according to number of members) is proposed, subject to annual approval by ISRS Council.

7. A Regional Chapter may also apply to ISRS Council for a grant or a loan of a larger sum to support a specific proposal, for example for a pump-priming loan to facilitate the organisation of a regional conference between successive ICRS conferences.

8. Full accounts should be maintained by the chapter treasurer of the use of any funds provided by ISRS Council, and details made available to the ISRS Treasurer when requested.

9. The Committee of a Regional Chapter may also apply independently to other organisations or individuals for grant-aid to support their activities, such as a regional conference or training programme.

10. Members of a Regional Chapter Committee may like any other member stand in elections for ISRS council members or officers, and if successful may be delegated by the Committee of the Regional Chapter to speak for it on Council. In the absence of any committee member being elected by the full membership the chair of a Regional Chapter Committee may attend or participate in ISRS Council Meetings of conference calls in order to speak on behalf of the Regional Committee, but may not under the present constitution act or vote as a member of Council.

11. A group/chapter may not enter into financial commitments on behalf of the society (other than in relation to its operational costs) without the approval of the council of the society.

12. A group/chapter may not issue statements to the public or media or claim to speak on behalf of the society without the approval of the Council.

13. Any group/chapter that fails to operate within the society's rules and constitution shall be disbanded and/or no longer considered part of the society.

Additional Rules Concerning Regional or Topic Chapters/Groups that Include Non-members of the Society

1. Members of the International Society for Coral Reefs (ISRS), referred to below as the society, may join with other non-members to set up, or invite non-members of the society to join, a regional chapter or topic group that, subject to Council approval, may nevertheless be accepted as an integral part of ISRS, and have the legal status of a sub-division of the society, subject to the following conditions:
2. A minimum of 20% of the group/chapter should be paid-up ISRS members.
3. Non-ISRS members who join the topic group/chapter shall be considered as "associate members" of the group/chapter.
4. Associate members of a group/chapter are not entitled to the cost-bearing benefits of paid-up society members, such as free on-line access to the Society's academic journal Coral Reefs, but are entitled to non-cost bearing benefits (e.g. to receive and contribute to the Society's news journal Reef Encounter).
5. Associate members shall complete a membership form comparable to that completed by full members to insure that relevant details of all group/chapter members are known and available.
6. Associate members may include organisations, including both commercial businesses and non-profit organisations, provided they declare any conflicts of interest and abide by the rules and constitution of the society.
7. A group/chapter including associate members should (like other groups/chapters) be managed by a formally constituted committee, in addition to which the chair and at least 50% of the committee should be paid-up members of the society.
8. The committee should (like the other sub-committees) meet (physically or on-line) at least twice a year, minutes should be kept of the proceedings, and the minutes forwarded to the council of the society for comment or approval.
9. The chapter may (like other groups/chapters) apply to the council for an annual budget to cover its basic operational costs (e.g. $500 or $1000); further amounts may be requested for specific purposes (e.g. to pump-prime or subsidise a workshop).

IYOR 2018: Third International Year of the Reef

As described in the last issue of Reef Encounter, 2018 has been designated as the third IYOR. This provides an opportunity to build the critical mass of public attention that is needed to initiate the fundamental policy and behavioural changes required to save coral reef ecosystems. IYOR 2018 will be a worldwide campaign to raise awareness about the value and importance of coral reefs and threats to their sustainability and to motivate governments, communities and people to act to protect them.

Scientific understanding of coral reef ecosystems has increased dramatically over the last 20 years and, in comparison to the first and second IYORs held in 1997 and 2008, there is now broad consensus about the key challenges. IYOR 2018 will help to bring the informed opinions of global scientific leaders to policy-makers worldwide, demonstrating that inaction and business-as-usual is no longer possible. IYOR is aimed at responding to the following calls for action:

- ✓ **Increased efforts by governments, the private sector and civil society to reduce CO_2 emissions.**
- ✓ **A step-change in the effectiveness of local and regional governance of tropical coastal and marine ecosystems, including greater attention on marine spatial planning, building local stewardship for fisheries management and marine protected areas, and recognising and addressing the impacts of land-based activities (mining, agriculture, waste-disposal etc.) on the marine environment.**
- ✓ **Ensuring that policy makers understand the full ecological, economic, social and cultural value of coral reefs and associated ecosystems.**

Thus ISRS members and reef conservationists should encourage their governments to support the Paris Accord and the target reductions in atmospheric CO_2 that the signatories have pledged to achieve.

There needs to be further support and expansion of existing local reef management efforts including MPAs, coastal and marine spatial planning, stewardship of watersheds and catchments where activities affect reefs, and public outreach efforts, including citizen science and other forms of community engagement.

For ISRS and its members, a particular role also lies in supporting research into coral adaptation, resistance to high temperatures, resilience and reef restoration. Given the funding and effort now being invested in restoration, there is a particular need to ensure that this is ***science-based*** and that efforts are better co-ordinated and grounded in the best available science, with standardisation of methods and data processing where possible to provide opportunities for global learning and knowledge sharing.

IYOR activities in each region and country are decided upon and organized at national and local levels and all individuals, governments, corporations, schools and organizations are actively encouraged to participate. A website is being set up and the logo will be available for use by any organization taking part. The IYOR 2018 Organising Committee has representatives from a range of groups, including Reef Check, the Japan Wildlife Research Center, Coral Guardian, the Reef World Foundation and the Great Barrier Reef Foundation, and will be helping with co-ordination.

The campaign will take place throughout the year and around the world. Activities will range from science workshops and report publications to beach clean-ups and art exhibits. For example, in Germany there are plans to form an informal coordination group, and then to organise exhibitions, public lectures, and outreach to divers with universities, research centers, museums, and NGO; and Denmark is preparing a range of activities. The recently released film *Chasing Coral* will provide an invaluable resource and the aim will be to hold as many screenings of this in as many countries as possible (see pages 46 & 49).

The global launch of IYOR 2018 will be at the ICRI annual meeting in Nairobi in December 2017, and European launch will be held that month during ECRS in Oxford, UK (see page 9).

ISRS members were major players in previous IYORs and the organisation will provide key support in 2018, with the added advantage that we now have two relevant committees, one for Conservation and one for Education. We will continue to use *Reef Encounter* to report on IYOR progress.

Individuals and organisations can help by:

- ✓ **Nominating a point of contact and registering with IYOR 2018 (send contact details to fstaub@icriforum.org)**
- ✓ **Developing activities that will help to achieve the aims of IYOR 2018**
- ✓ **Spreading the word about IYOR 2018 within and beyond your organization about the urgent need to save coral reefs**
- ✓ **Supporting the IYOR 2018 with in-kind or financial contributions (contact fstaub@icriforum.org)**

Sue Wells, chair ISRS Conservation Committee
(email: suewells1212@gmail.com)

GRADUATE FELLOWSHIP REPORTS

Phylogeographic Reconstruction Reveals Extensive Cryptic Diversity in a Common Symbiosis from the Tropical Western Atlantic.

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Introduction

The recognition and delimitation of "species" is a fundamental pursuit in ecological and evolutionary research (e.g. Carstens et al. 2013). Failure to recognize and delimit cryptic and independently evolving lineages can bias estimates of genetic structure, migration, and connectivity, leading to flawed phylogeographic inference and an inability to disentangle extrinsic barriers to dispersal from intrinsic aspects of species biology (reviewed by Pante et al. 2015). Ultimately, poor inference limits our ability to explain broad scale patterns that generate and maintain biodiversity within ecosystems, and is misleading to conservation biologists tasked with applying basic research to the management of natural resources.

Over the past few decades molecular biology has shed light on the extent to which biodiversity in under-described in many ecosystems (e.g. Plaisaince et al. 2009; Pante et al. 2015). This is particularly true on coral reefs where marine biodiversity peaks, but where it is expected that the majority of the species-level diversity is yet to be described (Leray & Knowlton 2016). Much of the diversity are likely small hard to study invertebrate species (Plaisaince et al. 2009; Leray & Knowlton 2016), but recent work has expressed surprise at the extent to which larger invertebrate taxa also remain uncharacterized (Al-Rshaidat et al. 2016).

In her 2016 plenary talk at the 13th International Coral Reef Symposium in Honolulu, Hawai'i, Nancy Knowlton called for renewed effort at exploring undescribed marine biodiversity, especially for poorly known invertebrates, and recounted her own background working on the sexual selection, behavior, and life history of the symbiotic snapping shrimp *Alpheus armatus*. An obligate symbiont of the corkscrew sea anemone *Bartholomea annulata*, *A. armatus* was nominally a single species, but Knowlton's work discovered that *A. armatus* was in fact a species complex (e.g. Knowlton & Keller 1983; Knowlton & Keller 1985). There are now five described species within this complex: three are obligate associates of *B. annulata* that have diversified in sympatry, each occupying a distinct depth and reef zone; another has undergone a host switch to the knobby sea anemone *Laviactis lucida* (a close relative of *B. annulata*); and a final species is currently described as endemic to Brazil (reviewed by Hurt et al. 2013).

The symbiosis between *B. annulata* and members of the *A. armatus* species complex is not a simple reciprocally obligate mutualism between host and symbiont. The alpheids are obligate to *B. annulata*, but *B. annulata,* which is the most abundant large anemone species in the Tropical Western Atlantic (TWA), can live solitarily (Briones-Fourzan et al. 2012; Titus et al. 2017a). Further, *B. annulata* hosts the most diverse assemblage of crustacean

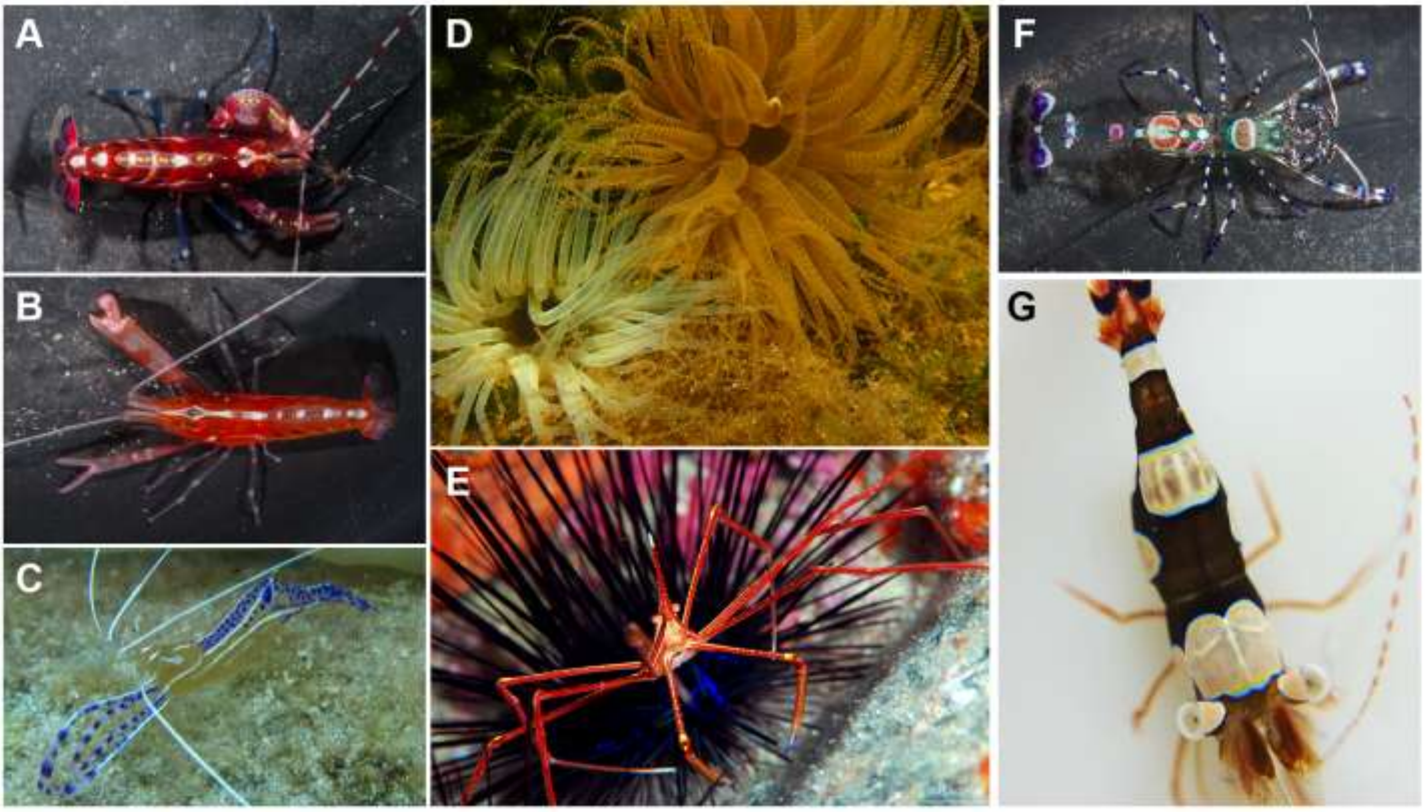

Figure 1. Focal study organisms. A) *Alpheus armatus*, B) *A. immaculatus*, C) *Ancylomenes pedersoni*, D) *Bartholomea annulata*, E) *Stenorhynchus seticornis*, F) *Periclimenes yucatanicus*, and G) *Thor amboinensis*. Photos by Ben Titus and Stella del Curto.

symbionts of all anemone species in the TWA (Briones-Fourzan et al. 2012). Many of these crustacean symbionts vary in their host specificities (i.e. anemone specialists, host generalists, facultative symbionts), and will co-occur on the same individual anemone through clear microhabitat partitioning (Titus & Daly 2017). The diversity and variation in host specificity makes this symbiosis an ideal system for understanding the co-diversification process, and for understanding the implications of a symbiotic lifestyle, since these partners are not simply co-distributed, but simultaneously co-occur in the same microhabitat.

Our research uses the *B. annulata* symbiosis and a comparative phylogeographic framework to ask general questions about Caribbean marine phylogeography and about the evolution of biodiversity in tropical marine symbioses. In addition to the anemone host *B. annulata* (Fig 1), we focus on five of the most common crustacean ectosymbionts that all vary in their host specificities: 1) the pistol snapping shrimp of the *Alpheus armatus* species complex, 2) Pederson's cleaner shrimp *Ancylomenes pedesoni*, 3) the spotted cleaner shrimp *Periclimenes yucatanicus*, 4) the sexy shrimp *Thor amboinensis*, and 5) the yellowline arrow crab *Stenorhynchus seticornis* (Fig. 1). As described above, three members of the *Alpheus armatus* species complex are *B. annulata* obligates, forming reciprocally protective mutualisms with their hosts. We have focused on the two most common and wide-ranging members - *A. armatus* and *A. immaculatus* (Fig. 1a & 1b). Both *A. pedersoni* (Fig. 1c) and *P. yucatanicus* (Fig. 1f) are ecologically important cleaner species (e.g. Titus et al. 2015a, b; Titus et al. 2017b) that are sea anemone obligates, but host generalists (Briones-Fourzan et al. 2012). Both *T. amboinensis* (Fig. 1g) and *S. seticornis* (Fig. 1e) are facultative symbionts that associate with anemones, corals, sponges, other invertebrates, or live solitarily (Briones-Fourzan et al. 2012; Titus & Daly 2017). All species are native to the Tropical Western Atlantic, with the exception of *T. amboinensis*, which is described as a single circumtropical species.

This system is ideal for phylogeographic research because the participants are abundant on coral reefs across the TWA, the anemones are easy to locate, each species being brightly colored and/or relatively large (>2cm), and each

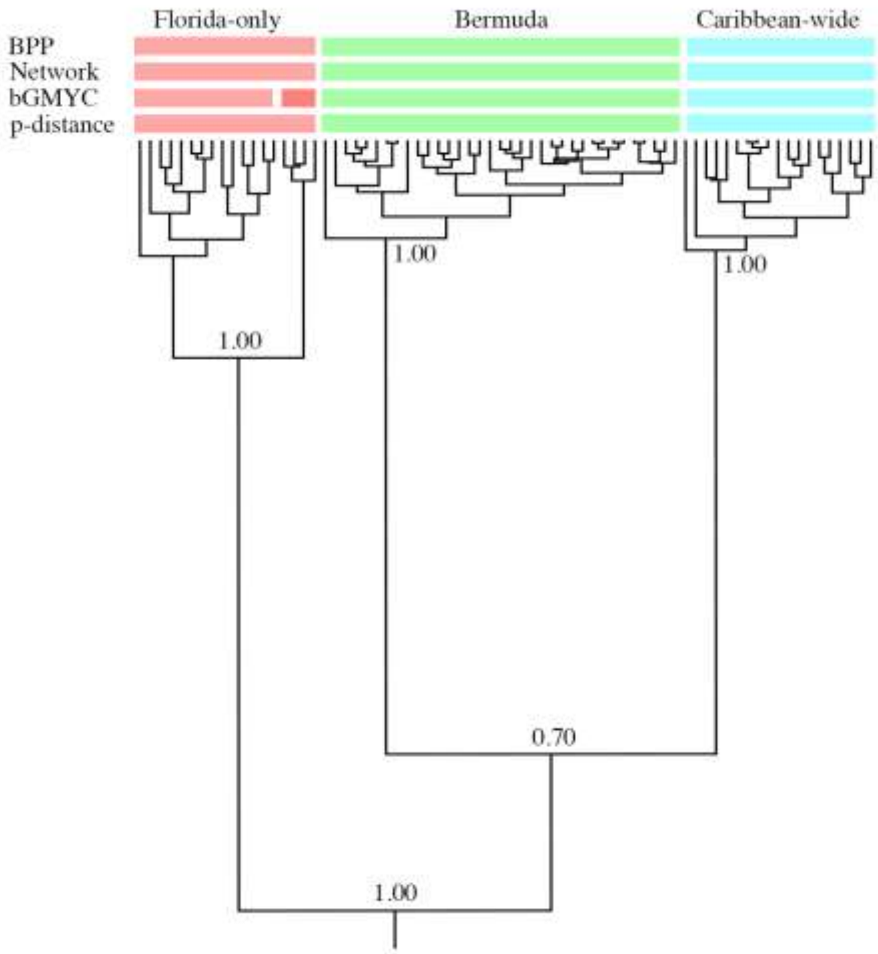

Figure 2. Summarized results from all species delimitation analyses represented on a Bayesian phylogenetic tree using all loci and concatenation for *Ancylomenes anthophilus* (Bermuda) and the Caribbean-wide and Florida-only lineages of *Ancylomenes pedersoni* (see Titus & Daly 2015, 2017). Single marker species discovery analyses (p-distance, bGMYC, and haplotype network construction) were conducted with the cytochrome *c* oxidase subunit I (COI) data only, whereas the species validation approach (BPP) was conducted using multi-locus data (COI, 16S, and enolase). Colored bars above phylogeny represent hypothesized species groupings. Only bGMYC delimited more than three species. Node labels represent posterior probabilities.

species has been subject to a moderate amount of research into their ecological role, life history, reproduction, larval duration and development, and morphology (e.g. Yang 1976; Knowlton & Keller 1986; Baeza & Piantoni 2010; Titus et al. 2015a, b; 2017a, b). Because the participants are so well known, we did not anticipate that this system would be rife with cryptic diversity. The molecular diversity of the crustacean symbionts of *B. annulata* highlights the power of symbioses to generate and support biodiversity and serves as a reminder that even larger and more well-known species may represent multiple species.

Molecular species delimitation of cryptic crustacean symbionts

Following fine-scale sample collection throughout the Florida Reef Tract (FRT) and preliminary DNA barcoding, it became apparent that Pederson's cleaner shrimp *A. pedersoni* and the spotted cleaner shrimp *P. yucatanicus* were both cryptic species complexes (Titus & Daly 2015 2017). Through molecular species delimitation analyses (e.g. Automatic Barcode Gap Discovery, haplotype networks, bGMYC), we identified two sympatric lineages for both *A. pedersoni* and *P. yucatanicus*: one each that appear to be endemic to Florida, and one each that is more widely distributed throughout the Caribbean (Titus & Daly 2015, 2017). Our investigation into the Bermudan species *Ancylomenes anthophilus* using multi-locus sequence data and the coalescent species delimitation program Bayesian Phylogenetics and Phylogeography (BPP) confirms the hypothesis of Okuno & Bruce (2010) that *A. anthophilus* is a true Bermudan endemic and not a junior synonym of *A. pedersoni* (Titus et al. 2015c; Fig. 2). Preliminary analyses from DNA barcode data also hint that the widespread Caribbean lineage of *P. yucatanicus* may contain distinct lineages in the eastern and western TWA (Fig. 3), which would bring the total recovered species within this complex to three. The recovery of unlinked haplotype networks using DNA barcodes is often an indication of cryptic species, and our sampling suggests no shared haplotypes between *P. yucatanicus* from the Virgin Islands and those from the

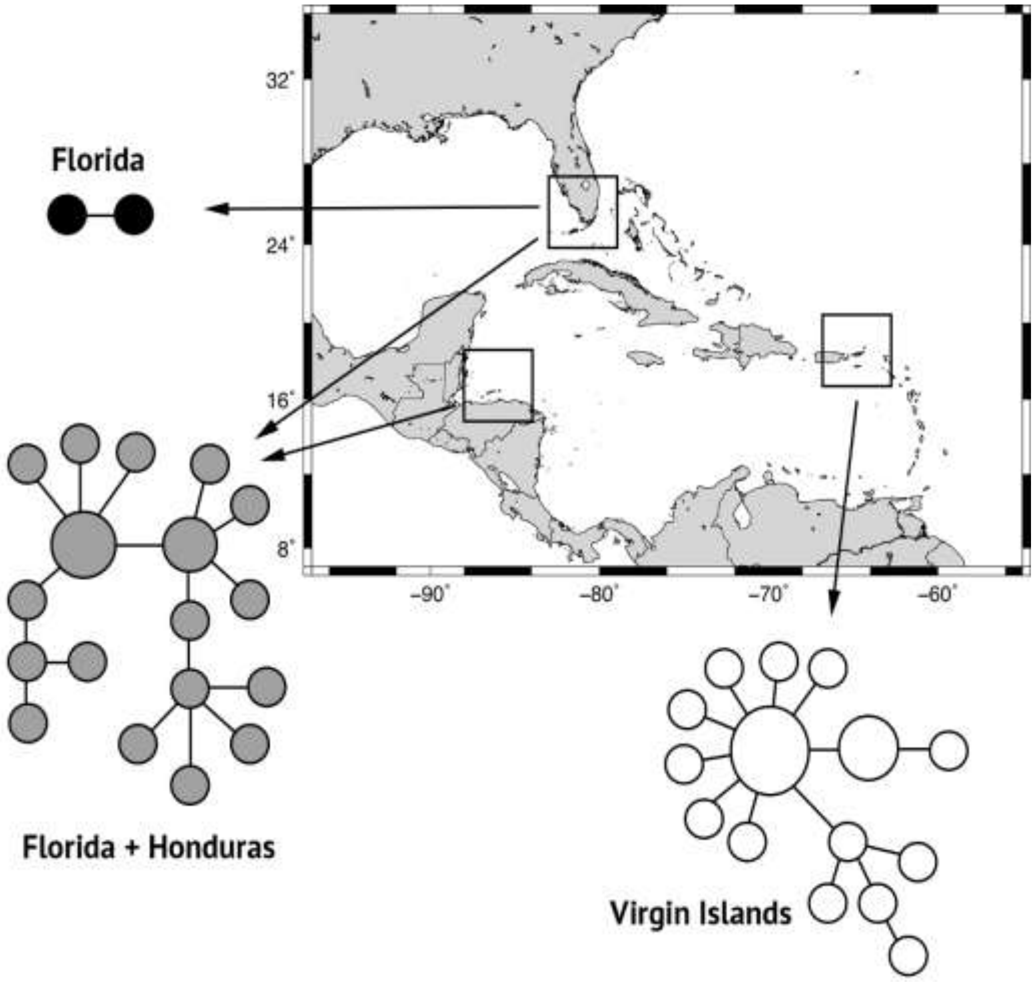

Figure 3. Preliminary evidence for the existence of cryptic eastern and western Caribbean species within the *Periclimenes yucatanicus* species complex. Data are visualized using statistical parsimony haplotype networks for cytochrome *c* oxidase subunit I (COI) sequence data.

western Caribbean. Additional sample collection and sequence data will be needed to determine whether these also are truly distinct lineages, whether these lineages split in isolation or with migration, or whether this species is simply exhibiting the intraspecific east/west phylogeographic break commonly recovered in the region.

Finally, we have extended our species delimitation work to the globally distributed *T. amboinensis.* To date we have recovered only a single species in the Caribbean (Titus & Daly 2017), but Bartolloti et al. (2016) have found evidence for cryptic species-level diversity in the Indo-Pacific. Multi-locus sequence data from samples from across the range of this cosmopolitan tropical species suggest that *T. amboinensis* contains at least five divergent lineages (Titus et al. submitted). In combination with Knowlton's work on *Alpheus,* a minimum of nine previously undescribed species associating with *Bartholomea annulata* on coral reefs in the Tropical Western Atlantic have now been delimited. The only species that does not appear to be a species complex is the yellowline arrow crab *S. seticornis*. Clearly, it cannot be taken for granted that even large, common, and reasonably well-studied invertebrates are not species complexes.

Future directions

Our work is now focused on using high throughput sequencing (RADseq) to add a genomic perspective to our species delimitation analyses, and provide a more rigorous test of putative cryptic species delimited by our barcode data. We are also using these data to reconstruct the phylogeographic histories of each species in our focal symbiosis across the Tropical Western Atlantic. Specifically, we are interested in the interplay between specialist and generalist host specificities and how, or if, these crustacean symbionts co-diversify with *B. annulata*.

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Climate Change in a Stable Thermal Environment: Effects on the Performance and Life History of Coral Reef Fish

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Introduction

Species living close to the equator are expected to be especially vulnerable to the effects of climate change related ocean warming, due to the narrow thermal range naturally experienced in these locations (Janzen 1967; Deutsch et al. 2008; Tewksbury et al. 2008; Burrows et al. 2011). For this reason, the ability to acclimate to higher temperatures is both extremely important and theoretically less likely for these populations. Studies show that elevated environmental temperatures can negatively affect the reproductive output, growth rates and physiological performance of coral reef fishes (Munday et al. 2008; Johansen & Jones 2011; Donelson et al. 2012; Donelson & Munday 2015); however the majority of research to date has been undertaken on fish populations from the middle and southern sections of Australia's Great Barrier Reef (GBR). Because many species span large geographical ranges and therefore naturally experience different local environmental conditions, this may limit our ability to make generalized predictions related to the impacts of climate change on marine organisms.

Figure 1. Juvenile *Acanthochromis polyacanthus* and *Pomacentrus moluccensis* damselfish school on a coral head.

During my PhD I examined how near-equatorial populations of coral reef fishes may respond to increases in ocean temperatures consistent with climate change projections for the end of this century. My research has demonstrated that chronic increases in temperature can have significant effects on the metabolic performance, cell structure, blood chemistry and survival of near equatorial populations of coral reef fish. My findings indicate an extremely narrow thermal performance range for these fish. For this reason, a capacity for plasticity or acclimation to increased temperatures will be essential if near-equatorial coral reef fish populations are to persist under future climatic conditions. Understanding these non-genetic modifications is particularly important, as they are capable of operating over climate change relevant time scales.

Torres Strait Damselfishes

In 2015, I received an ISRS student research award to investigate the capacity for developmental acclimation (acclimation that occurs during early life stages) in near equatorial populations of three common coral reef damselfish species; the spiny chromis damselfish (*Acanthochromis polyacanthus*), the lemon damselfish (*Pomacentrus moluccensis*) (see Fig. 1) and Ward's damselfish (*Pomacentrus wardi*). The study aimed to determine the extent to which these populations are able to maintain their aerobic performance at higher temperatures, depending on the thermal conditions under which individuals developed.

Damselfish were collected for this study from two reefs, Dugong and Kagar, in Southern Torres Strait. For all fish the smallest size class possible was collected in order to maximise the likelihood of collecting fish capable of undergoing developmental acclimation. This was expected to occur within the first three months of life, based on previous studies (Donelson et al. 2011). All fish were collected during a three day field expedition aboard a charter boat, and then transported by plane to research aquarium facilities in Townsville, Australia. Collecting and transporting live fish (approximately 600 of them) over such a short time period was a huge logistical challenge, particularly as the Torres Strait is an extremely remote location.

Figure 2. Thursday Island, Torres Strait, the study site for this near equatorial research.

To determine each species' potential capacity for acclimation, I conducted an analysis of their aerobic fitness after three months of developmental exposure to either the current-day summer average temperatures (30 ˚C; control), or to 1 or 2 ˚C above that average. If acclimation had occurred, it was expected that metabolic performance would be significantly improved in fish when tested at their own developmental temperature, when compared with the performance of acutely exposed fish from one of the other developmental groups.

Although this work has not yet been published, preliminary results suggest that there may indeed be some scope for these populations to cope with temperature increases relevant to climate change. The ability to acclimate metabolic rate to increased temperatures differed among species, with the greatest potential capacity observed for *P. wardi*.

For *A. polyacanthus* and *P. moluccensis* acclimation appeared to occur at a similar temperature to that which has been observed for the same species in more southern locations (Donelson et al. 2011; Donelson et al. 2012; Grenchik et al. 2013). However, when considered in relation to the summer average temperature for each location, acclimation was found to occur over a much more limited range for near-equatorial populations. This indicates that although there may be some scope to deal with climate change relevant temperature increases in the more northern populations, they are still more vulnerable to temperature increases than their southern counterparts. The life history and habitat choice of each species appeared to have a strong influence on their capacity for developmental acclimation, leading to the conclusion that scientists should consider the ecological niche of their own study species when making generalisations about the effects of climate change based on even closely related species.

Next Steps

The next step in this research will be to investigate the function of key metabolic enzymes that control functions such as oxygen usage and locomotion. The level to which enzyme performance is linked to whole organism aerobic performance, and differences across latitudes and between species will be investigated. This multi-level approach aims to deliver a more comprehensive look at acclimation capacity than previous single measure studies. This study, supported by the ISRS, provided me with the opportunity to conduct research in a remote and beautiful study location where very little previous research has been conducted. I have now completed my doctoral research and have gone on to work in fisheries management.

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Hong Kong: Ecosystem Functioning across Water Quality and Coral Species Richness Gradients

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Introduction

Of the many changes underway in the world today, one of the most striking is the decline and homogenization of marine biodiversity through overexploitation, climate change, habitat loss, nutrient pollution and species invasions (Meyer et al. 2016). This raises considerable concern, since human society depends on the ocean for its natural services. Marine environments are significant contributors to both local and global economies, providing ecosystem services and jobs to local people on the one hand, and representing a great bank of undiscovered species, including many of potential importance for human health, on the other. Recently Gamfeldt et al. (2015) concluded that loss of marine biodiversity likely decreases ecosystem function and impacts habitat resilience. However, the methods that have been employed to infer this are typically prohibitively time-consuming and difficult. As a result, data on ecosystem functioning of marine ecosystems are limited, despite the fact that such information could help inform the effective management of crucial environments.

In Hong Kong eutrophication (nutrient-driven marine pollution) has contributed to the loss of foundational species like hard corals and thus reduced the complexity, diversity and function of benthic ecosystems since at least 1975, giving rise to environmental economic losses (Scott and Cope 1982; Scott 1990; McCorry and Blackmore 2000). A fine example of this is Tolo Harbour, in northeast Hong Kong (see Fig. 1), which was once a pristine, coral-fringed bay, home to various coral communities and vibrant fisheries (Yim et al. 1982; Scott and Cope 1982). The progressive decline of water quality and marine life in the harbour as a result of coastal development has led scientists to refer to it as "*Hong Kong's first marine disaster*" (Morton 1988). In 2015 we utilized stable isotope analysis to understand nitrogen source dynamics in both wastewater effluents and receiving seawaters in the Tolo channel. We found that sewage is the dominant source of pollution in coastal seawater (Archana et al. 2016). This indicates an ecosystem out of balance; yet we have little understanding of how these eutrophic conditions affect the ecosystem function of such benthic marine communities as those found in Hong Kong.

In this study I have been using a set of novel yet simple assays to characterize quickly and efficiently ecosystem processes such as primary productivity, herbivory, predation and decomposition, along a water quality gradient. These methods have been developed with support from and to complement the Smithsonian Institution's Marine Global Earth Observatories (MarineGEO) program.

Methods and Study Area

Study Area. Hong Kong's marine environment is characterized by punctuated water quality gradients that correspond with foundational species diversity of taxa such as corals, seagrasses, mangroves, oyster reefs, etc. Further, the marine environment is almost entirely dominated by human-derived nutrient inputs, making it a "natural experiment". The study was undertaken over a period of one year across four field sites within Tolo Harbour, Hong Kong (Fig. 1); from inshore to open ocean these were: Centre Island – CT, Che Lei Pai – CLP, Port Island – TWP, and Tung Ping Chau – TPC. These sites represent a water quality gradient whereby concentrations of nitrate and ammonia decrease from inshore to the open ocean, CT>CLP>CLP>TWP (Archana et al., 2016), while the opposite trend is observed for coral species richness, CT<CLP<CLP<TWP (Duprey *et al*. 2016; Wong *et al.* 2016). These sites were chosen not only because of Tolo channel's pollution history, but because in 2015 we deployed 12 Autonomous Reef Monitoring Structures (ARMS) (3 replicates in each site) as part of the MarineGEO program. The

ARMS will provide biodiversity data, to which the ecosystem function data will be complementary. The study used a simple toolkit to allow the quantification of key ecosystem functions.

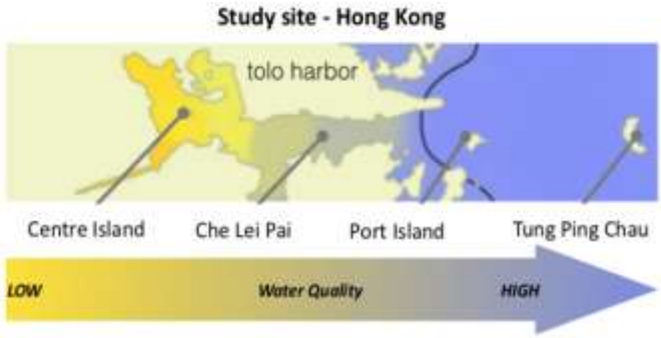

Figure 1. Left: Tolo Harbour, viewed from near Hong Kong Chinese University (photo by Citobun - commons.wikimedia.org). Right: Location of study sites - Centre Island – CT, Che Lei Pai – CLP, Port Island – TWP, and Tung Ping Chau – TPC.

Primary Productivity. Primary productivity is essentially the rate at which energy is stored as organic matter (Gaitain-Espitia, 2011). Historically there has been debate over whether nitrogen (N) or phosphorus (P) limits primary productivity in the marine environment (Howarth, 1988). More recently it has been concluded that typically N limits seaweed productivity in temperate latitudes, while P limits seaweed productivity in the tropics (Falkowski and Woodhead 1992). In this study, primary production was measured as net mass gain (%) on substrata protected from grazers, with the macroalgae (*Ulva*) being deployed in equal mass within plastic bottles. We deployed four replicates at each site, 4 m from the ocean floor (to standardize light availability). Treatment ropes were attached to bricks and deployed on the substratum at 5-10 m intervals. After 48 hours, we collected the macroalgae, returned them to the laboratory and assessed their mass loss/gain (Rasher et al. 2013; Fig. 2).

Herbivory / Grazing Intensity. Studies have shown that herbivores play a vital role in maintaining a healthy coral-dominated community through intense feeding and grazing of unwanted macroalgae that indirectly interfere with the growth, reproduction and survivorship of corals (Burkepile and Hay, 2008). To estimate herbivory we exposed samples of macroalgae (referred to as “algal pops”) to determine their susceptibility to grazing. The macroalgae was deployed on 90 cm lengths of three-stranded nylon rope, on which the alagae had been grown for two weeks prior to use (Fig. 2). At each site four replicates were deployed spaced 5-10 m apart on the sea bed. Following exposure for 48 hours, loss of biomass was calculated as $[H_i x(PC_i/PC_f)]–H_f$, with i,f, referring to initial and final wet weights (Rasher et al., 2013).

Predation. A simple assay was used to assess predation - “the squid pop”. This refers to a piece of dried squid deployed at the end of a tether tied to a stake as bait for fish. Squid pops were deployed at three sites (25 replicates per site) during each of two seasons (Dry and Wet). One hour after deployment, we returned to observe whether or not fish have consumed the bait. The degree to which the squid pops were consumed was used to indicate the level of predation in the marine ecosystem (Duffy et al., 2015; Fig. 2).

Decomposition. The decay of organic material (i.e. decomposition) is a critical ecosystem function. In this study we used commercially available tea bags (both green tea and Rooibos!) as a standardized unit of organic matter (Keuskamp et al. 2013). Their decomposition rate (the rate of organic matter loss over the deployment period) and their stabilization factor (how much organic matter remained following exposure) were determined at all four sites over periods of 1 month, 3 months and 6 months (Fig. 2).

Statistical Analyses. Data were screened for normality using a Shapiro-Wilk W test and for homoscedasticity using Levene's test. One-way ANOVA was used to evaluate the effect of site on primary productivity (% mass gain), herbivory (% mass consumed), predation (% bait loss) and decomposition rate. *Post hoc* comparisons to test for significant differences between sites were conducted using Student's *t*-test and Tukey's test. Pearson's correlation (α = 0.05) was used to understand variability with reference to nutrient enrichment (nitrate-NO_3 concentrations) and coral species richness. All statistical analyses were conducted in JMP12.0 (SAS Institute) and results reported with ± standard deviation.

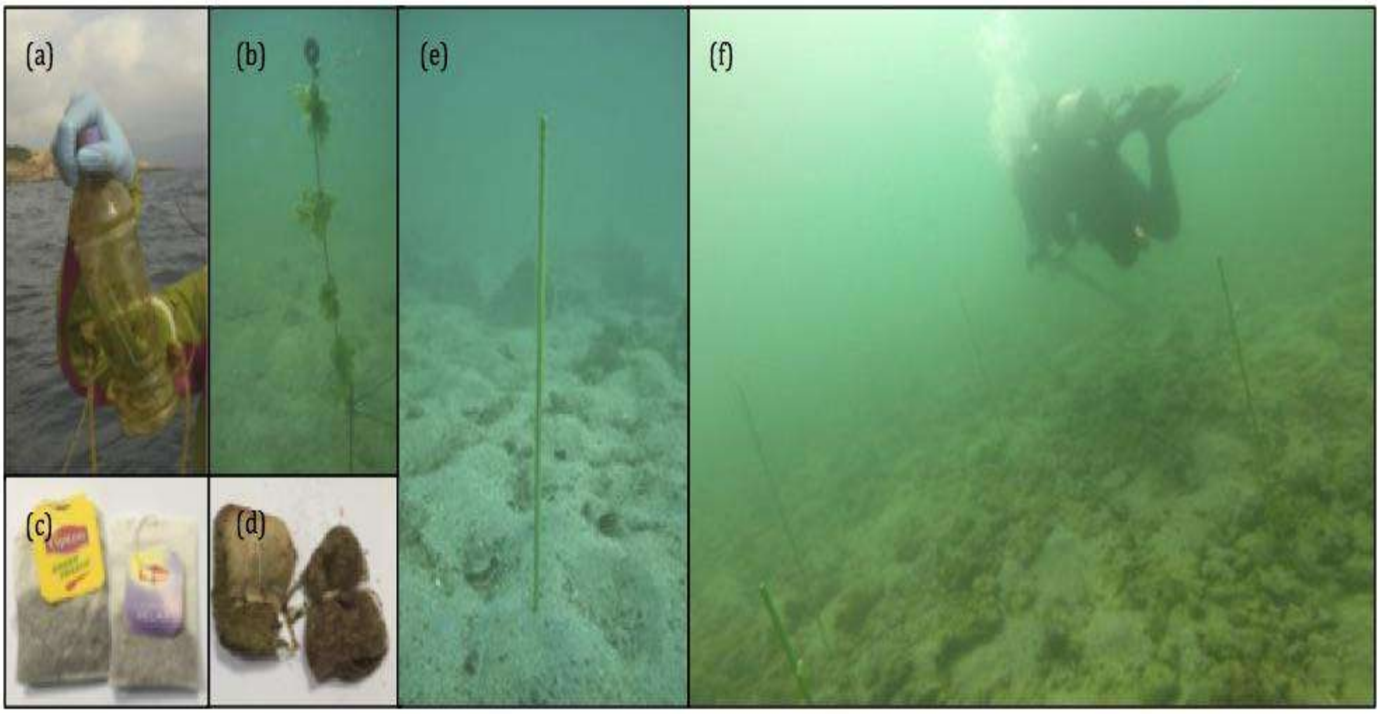

Figure 2. Design and deployment of ecosystem function assays in Tolo Harbour. (a) a primary productivity assay bottle after retrieval, (b) an algae pop set out at Port Island to assay for herbivory, (c) tea bags ready for deployment and (d) after retrieval, (e) a squid pop deployed at Port Island and (f) a diver deploying squid pops at Tung Ping Chau.

Results and Discussion

Net mass gained by protected *Ulva* varied significantly among the four habitats with mass gain increasing from inshore (Centre Island) to the open ocean (Tung Ping Chau) (Fig. 3). Seawater nitrate concentrations followed the opposite trend, being significantly negatively correlated with algal mass gain (R=-0.90; p<0.05; Fig.3). Coral richness in contrast was significantly positively correlated with algal gain in mass (R=0.83; p<0.05). *In situ* consumption of *Ulva* varied significantly among sites (one-way ANOVA, p<0.0001; Fig. 3) but did not show any significant correlation with nutrient concentration or coral species richness. We observed herbivorous rabbit fish and puffer fish at Che Lei Pai and Tung Ping Chau, sites that recorded relatively more loss of *Ulva*. We also noted that there were other types of algae, such as *Sargassum*, present at some sites, where *Ulva* could be less preferred than some other available species.

Loss of squid pop mass to predators varied dramatically among the three habitats being significantly greater at Port Island (48%) compared to Che Lei Pai (35%) and Centre Island (2%; p<0.05; Fig. 3). A recent study that employed this technique (Duffy et al. 2015) found increased feeding intensity (increased bait loss) to be directly correlated with fish abundance. This pattern could therefore reflect a higher level of predation (from generalist carnivores) in Port Island, a site where visual observations have also recorded more fish compared to inshore sites. On a linear random effects model, site helped explain 34.1% (R^2 = 0.31; p<0.05) of bait lost variability after 1 hour.

In addition, there was a significant negative correlation between seawater nitrate concentrations and percentage bait loss across habitats (R = -0.96; $p<0.05$) and a significant positive correlation between coral species richness and bait loss (R=0.89; $p<0.05$). This suggests predation rates are higher at sites with lower nutrient concentrations and higher foundational species richness. We were unable to observe directly the predators involved, although we suspect they include invertebrates and fish; we intend to deploy some underwater video cameras to capture predator diversity and abundance information.

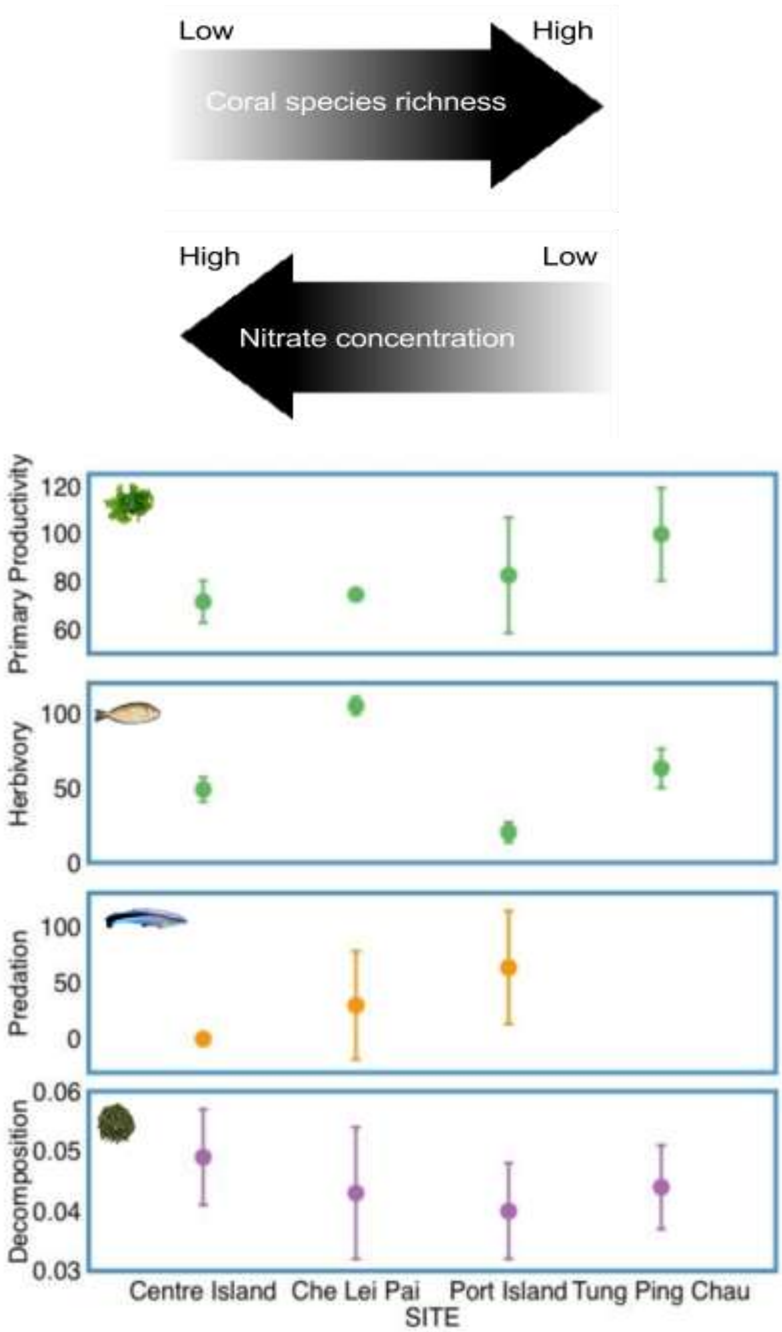

Figure 3. Coral richness, water chemistry and four ecosystem functions across the four sites in Tolo Harbour. Mass gain and loss of *Ulva* were used to determine primary productivity and herbivory. Percentage bait loss was used as a proxy for predator abundance/activity, and mass loss from tea bags to assess decomposition and stabilization.

The teabag assay found a clear effect of deployment period (1 month, 3 months and 6 months) for both tea types used - tea (One-Way ANOVA; $p<0.0001$). Three months appeared to be optimum deployment period for obtaining reliable discrimination between sites. The study also found significant variation between habitats (Fig. 3) that was more significant for Rooibos tea than green tea, with stabilisation values decreasing from the open sea (Tung Ping Chau) to inshore waters (Centre Island). Higher stabilisation values are believed to indicate increased carbon sequestration potential as defined by Keuskampf et al. (2013). This would imply that sites with poorer water quality, as indicated by higher inorganic nitrogen concentrations, and with lower coral species richness, sequester less carbon when compared to other sites. This could have significant environment management and policy implications in the context of global climate change.

Conclusions

In summary, the ecosystem function assay toolkit appears to provide a promising methodology for monitoring essential ecosystem functions in locations such as Tolo Harbour. Stark variation of all ecosystem function variables by habitat was observed. Notably nutrient concentration (CT>CLP>TWP>TPC) and coral species richness (CT<CLP<TWP<TPC) showing the same trend across sites.

Acknowledgements

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REEF CURRENTS

General articles and overviews of reef science and management

Ding, Dong, The Witch is Dead (?)— Three Years of Global Coral Bleaching 2014-2017

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In 2016, we wrote in *Reef Encounter* about the ongoing Third Global Coral Bleaching Event, which was forecast to continue into 2017 (Eakin et al. 2016). As predicted, the 2015-16 strong El Niño formed, worsening the bleaching, and was followed by a La Niña event. Despite the end of the La Niña, high temperatures persisted into 2017. At least half of the world's coral reef areas bleached in two or all three years of the event, and many suffered the worst bleaching ever documented. As of June 2017, the three-year-long, Third Global Coral Bleaching Event has most likely ended (National Oceanic and Atmospheric Administration, NOAA 2017) but remains the longest, most widespread, and probably the most destructive ever recorded.

Recap: Bleaching in 2014
In June 2014 coral bleaching began in Guam and the Commonwealth of the Northern Mariana Islands (CNMI, Heron et al. 2016) and an El Niño was predicted to form, but never did. Papahānaumokuākea Marine National Monument, the Main Hawaiian Islands (DAR 2014, Bahr et al. 2015), southeastern Florida and the Florida Keys (FRRP 2015a) saw bleaching in August and September, while the Republic of the Marshall Islands (Fellenius 2014, Eakin et al. 2016) saw bleaching from September-November.

Recap: Bleaching in 2015
Bleaching worsened as heat stress moved into the southern hemisphere in late 2014/early 2015, striking in the South Pacific, large areas of the Indian Ocean, and parts of Southeast Asia – including severe localized bleaching in Dongsha Atoll in June 2015 (DeCarlo et al. 2017). With the onset of the 2015-16 El Niño, the heat stress focused on the central and eastern Tropical Pacific. The heat stress spread northward, causing the worst bleaching on record in the Main Hawaiian Islands in October 2015 (TNC 2015, Eakin et al. 2016, Kramer et al. 2016, Rodgers et al. 2017, Rosinski et al. 2017). In the Atlantic, September-October brought moderate to severe coral bleaching (and disease) and low to moderate mortality to Florida's coral reefs for the second year in a row (FRRP 2015b, FRRP 2016a); bleaching at varying severities and scales was then reported from multiple locations across the eastern and western Caribbean through October. As of October 2015, with widespread bleaching in each of the Indian, Pacific, and Atlantic basins, NOAA declared that the Third Global Coral Bleaching Event was underway. By the end of 2015, 41% of global coral reefs had been exposed to heat stress of 4°C-weeks or more (measured by NOAA Coral Reef Watch's Daily Global 5km Degree Heating Week version 3 - DHW) and almost all of the world's reefs had exceeded their normal warm-season temperatures.

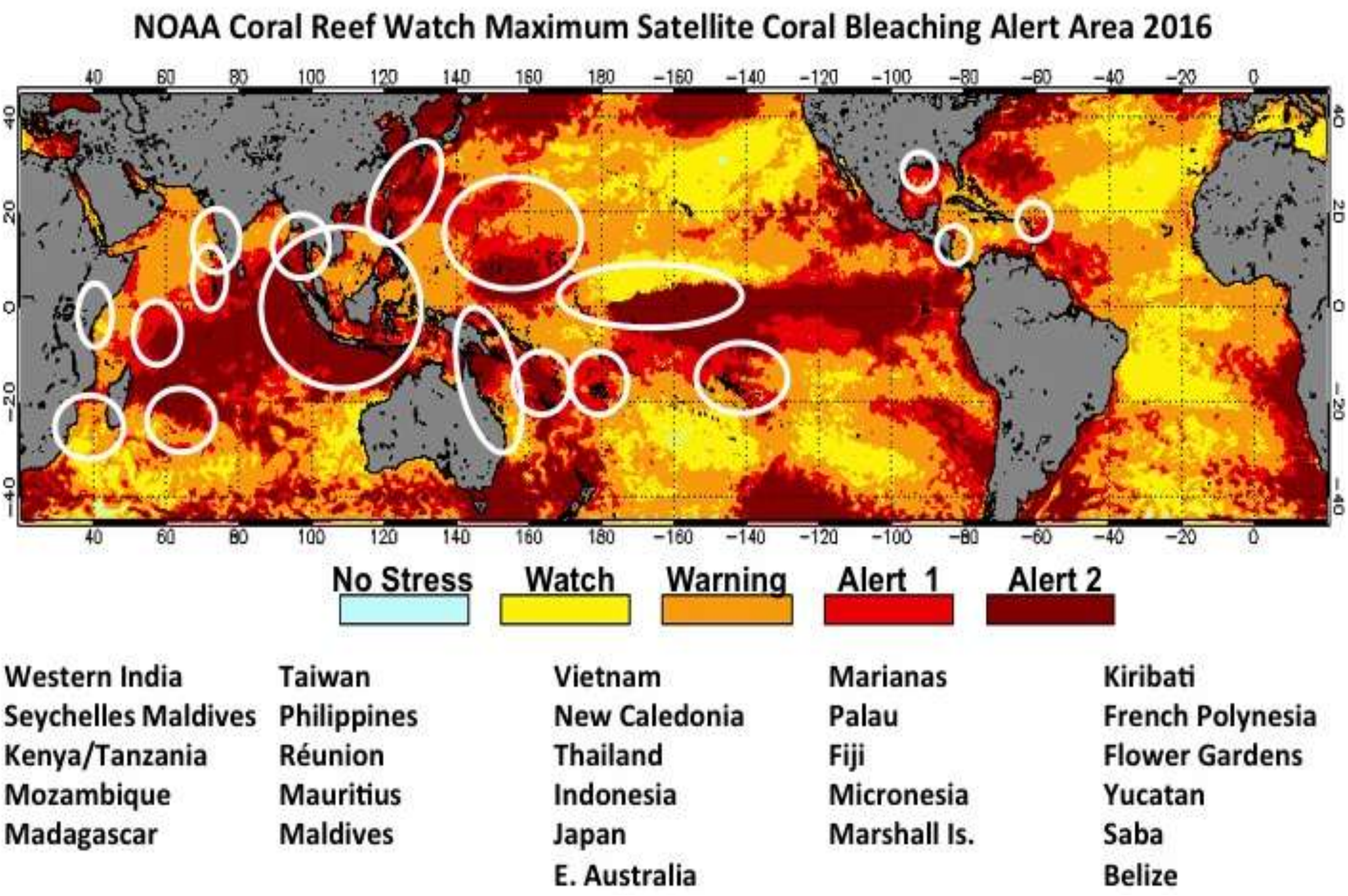

Figure 1. NOAA Coral Reef Watch Maximum Bleaching Alert Area map for January-December 2016. Severe coral bleaching was reported in all areas circled in white on map and listed below the map. Data from Coral Reef Watch Daily Global 5km Coral Bleaching Heat Stress Monitoring Product Suite version 3 (Liu et al. 2017)

Bleaching in 2016

As the El Niño continued to strengthen, heat stress and bleaching returned to the Southern Hemisphere. Heat stress in 2016 was much more widespread than in 2015, encompassing 51% of global coral reefs (as measured by CRW's DHW). Even more important was the severity. The El Niño resulted in continuous heat stress in the Central Pacific from April 2015 to May 2016. The Northern Line Islands heat stress values were the highest Coral Reef Watch has ever documented (DHW > 25°C-weeks) and caused the worst bleaching-related mortality ever reported. By May 2016, this included 80% of total coral cover dead and an additional 15% bleached in Kiritimati (Harvey 2016), as well as 98% total coral cover dead at Jarvis Island with substantial reduction to reef structural complexity (investigation into the mechanism of this rapid erosion is underway). Severe heat stress in Fiji's lagoons caused sudden and widespread coral death in February just weeks before Cyclone Winston cooled ocean temperatures. Bleaching in New Caledonia in March caused wide swaths of lagoon corals, especially *Acropora*, to fluoresce in multi-colored pastels. The first major bleaching ever documented on the Northern and Far Northern sectors of the Great Barrier Reef (GBR) peaked in March (Hughes et al. 2017). This was the worst bleaching ever seen in the GBR resulting in 29% mortality of shallow-water corals across the entire reef (GBRMPA 2017). Coral bleaching started in the Western Indian Ocean in January and peaked by May (CORDIO-EA), with bleaching in the Seychelles ranging from 69-99% resulting in a subsequent 50% reduction in hard coral cover (SIF 2017). Bleaching in Southeast Asia caused Thailand in May to close many of its coral reefs to recreational diving activities (AFP 2016). Bleaching in Guam, especially Tumon Bay, returned for the fourth year in a row.

In the boreal summer, bleaching returned to the Northern Hemisphere, with extensive (over 90%) bleaching observed in the largest coral reef in the Ryukyu Islands, Japan starting in July, resulting in 70% mortality (Harvey 2017). The heat stress then brought bleaching back to the western Atlantic, Gulf of Mexico, and Caribbean from September through November, with the western Caribbean hit hardest. Florida suffered only mild to moderate bleaching in summer 2016 but was struck by another round of coral disease, including the loss of 95% of pillar coral (*Dendrogyra cylindrus*) across the state (FRRP 2016b). October brought the worst bleaching ever to the Flower Garden Banks, while patchy bleaching was reported from the eastern Caribbean. Moderate to severe bleaching (generally more severe than in 2015) also was reported in parts of the Mesoamerican Barrier Reef in October and November, with deeper reefs being impacted more so than shallow. The year culminated in a return of bleaching to the Republic of the Marshall Islands by November 2016. Figure 1 shows the total extent of heat stress in 2016 and regions with confirmed coral bleaching reports.

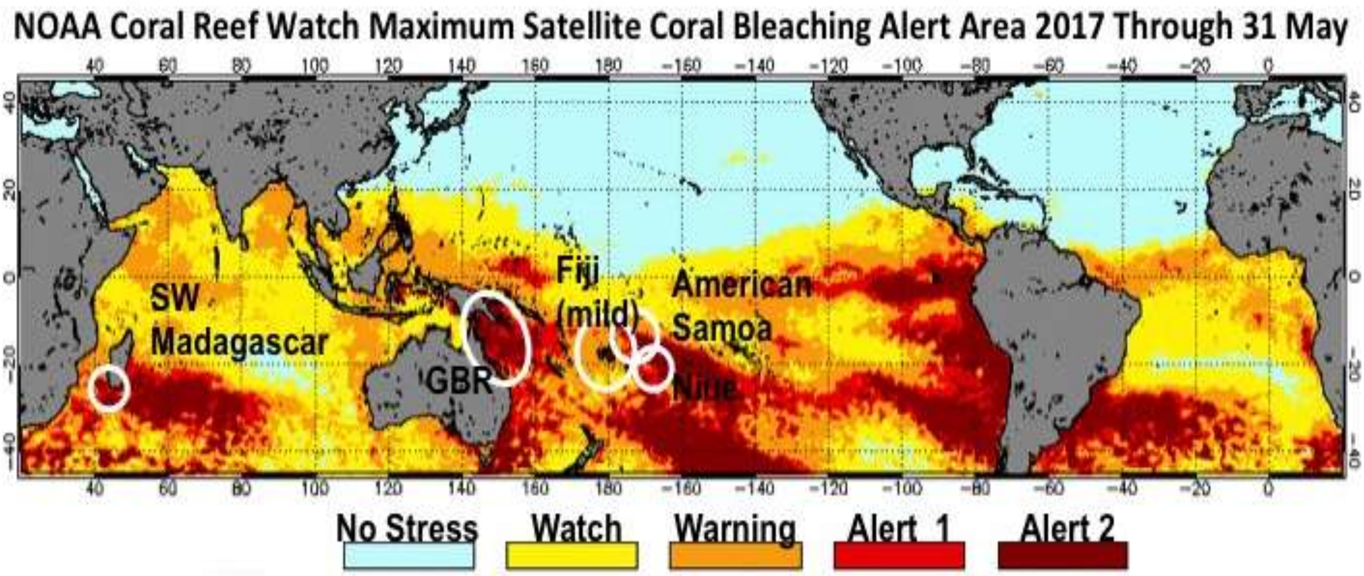

Figure 2. NOAA Coral Reef Watch Maximum Bleaching Alert Area map for January-May 2017, with coral reef areas with reports of bleaching circled in white. Data from Coral Reef Watch Daily Global 5km Coral Bleaching Heat Stress Monitoring Product Suite version 3 (Liu et al. 2017)

Bleaching in the First Half of 2017

Mild coral bleaching started in Fiji in January 2017, but stormy conditions cooled the water, averting severe thermal stress and bleaching. However, severe bleaching was reported in Niue in February and by March, bleaching returned to American Samoa and Samoa. This time, bleaching was much more extensive bleaching on the outer reefs than in 2015. The first-ever consecutive bleaching was confirmed on the GBR in March (Hughes and Kerry 2017). This time, the Northern (again) and Central sectors were most impacted in what would have been the worst bleaching of the GBR, if not for the mortality from 2016. Heat stress was limited in the Indian Ocean, with the only pocket of moderate bleaching reported from southwestern Madagascar in April (CORDIO-EA). Reports indicate that bleaching elsewhere in the Indian Ocean has been mild. Figure 2 shows the total extent of heat stress in 2017 and regions with confirmed bleaching reports.

As of September 2017, NOAA's El Niño-Southern Oscillation Alert System has issued a La Niña Watch, with a 55-60% chance of La Niña formation during late 2017. NOAA Coral Reef Watch's Four-Month Coral Bleaching Heat Stress Outlook indicates that bleaching is much less likely in most of the Northern Hemisphere this summer (Figure 3). However, the Outlook through December 2017 does indicate a potential for significant bleaching and potential coral mortality in the western Pacific Ocean (from the Guam through Micronesia); in the eastern portion of the Papahānaumokuākea Marine National Monument; and in the Caribbean Sea. We anticipate a similar level of risk to the rest of the western Atlantic and Caribbean after August and through the end of the year. While more coral bleaching may still occur in 2017, the absence of widespread coral bleaching in the Indian Ocean appears to signal that the three-year-long global event has ended.

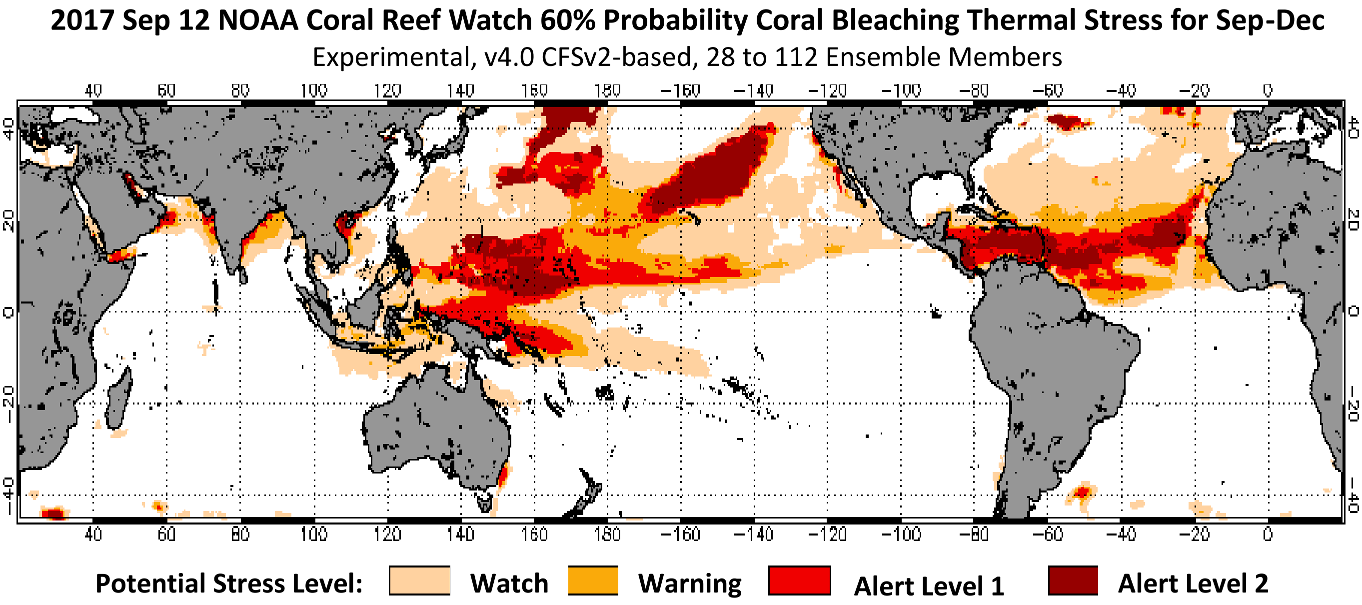

Figure 3. Map of areas where 60% or more of the model ensemble members were predicting heat stress at each of NOAA Coral Reef Watch's bleaching heat stress alert levels through December 2017 (as of 12 September 2017). Data from Coral Reef Watch Four-Month Coral Bleaching Heat Stress Outlook version 4 (Liu et al. 2017)

Documenting the 2014-2017 Global Bleaching Event

With the Third Global Coral Bleaching Event apparently coming to a close, NOAA Coral Reef Watch is now working in earnest to collate reports on the global extent of this event. We are planning a follow-on global summary paper similar to our 2005 Caribbean Bleaching Event paper (Eakin et al. 2010). We truly appreciate all reports we have received so far, many of which contributed to this brief review of the global event. Please assist us further by continuing to report coral bleaching and disease observations to your existing regional programs such as the Global Coral Reef Monitoring Network nodes, ReefCheck, CORDIO-EA, AGRRA, etc. Also, please send a brief email to coralreefwatch@noaa.gov to let us know where you submitted them. If you aren't involved in one of these monitoring programs, please submit your reports directly to the Coral Reef Watch Report Bleaching web page. Coral Reef Watch needs both bleaching and non-bleaching observations to document the spatial extent and timing of the event and to continue to improve its satellite and climate model-based products. Contributing your observations ensures that your site's data are considered in global analyses; gives context to how bleaching patterns at your sites compare with global patterns; and provides access to the latest global coral bleaching data analyses to communicate climate impacts to decision makers. All contributors will have the opportunity to co-author peer-reviewed publication(s) on global and/or regional bleaching.

A special issue or portion of an issue of the ISRS journal *Coral Reefs* will focus on this event. This will be an opportunity for you to publish more detailed studies on coral health, bleaching, disease, and mortality in your country or region associated with the Third Global Coral Bleaching Event.

Since our last update (Eakin et al. 2016), filmmakers at Exposure Labs completed an 89-minute documentary on their efforts to capture time-lapse imagery of coral bleaching during the Third Global Coral Bleaching Event. The film includes many of your contributions to their global call for bleaching reports and part was shot at the 13th International Coral Reef Symposium in Honolulu, Hawaii. The resulting film, *Chasing Coral*, premiered on Netflix on July 14, 2017 (see the two more detailed articles about the film on pages 46 - 50).

Final Thoughts

With the end of the Third Global Coral Bleaching Event, it is more essential than ever that coral reef ecosystem scientists, managers, and other stakeholders, including the public, work together to increase our collective knowledge as we continue toward a future with a changed climate. While continuing and expanding efforts to reduce local stressors, we all must work to address the cause of global warming through reducing atmospheric carbon dioxide concentrations and emissions.

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Coral Bleaching at Heron Island, Great Barrier Reef, Australia (Photo credit - courtesy of The Ocean Agency / XL Catlin Seaview Survey / Richard Vevers).

REEF ENCOUNTER
The News Journal of the International Society for Reef Studies
Reef Currents: Coral Reef Watch's Latest Products

NOAA Coral Reef Watch's 5km Satellite Coral Bleaching Heat Stress Monitoring Product Suite Version 3 and Four-Month Outlook Version 4

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In May 2017, the U.S. National Oceanic and Atmospheric Administration (NOAA) Coral Reef Watch (CRW) program launched version 3 of its near-real-time daily global 5km Satellite Coral Bleaching Heat Stress Monitoring Product Suite and version 4 of its global Four-Month Coral Bleaching Heat Stress Outlook. New products provide significant improvements over previous versions (Liu et al. 2014a; Eakin et al. 2012) in pinpointing and predicting areas around the globe where reefs are, or soon will be, at risk of coral bleaching (https://coralreefwatch.noaa.gov).

1. Daily Global 5km Satellite Monitoring Product Suite Version 3

As with prior versions of the satellite monitoring products, the version 3 (v3) daily global ~5km (exactly 0.05°) satellite coral bleaching heat stress monitoring product suite (released on May 4, 2017) includes sea surface temperature (SST), SST Anomaly, Coral Bleaching HotSpot, Degree Heating Week (DHW), a 7-day maximum Bleaching Alert Area, and a 7-day SST Trend (Fig. 1). These near-real-time satellite products are available currently from March 12, 2013 to the present. Reprocessed data to 1985 will be added shortly.

The Coral Bleaching HotSpot product (Fig. 1c) measures the occurrence and magnitude of current heat stress that can lead to bleaching. It is calculated as the difference between the nighttime SST value and the average nighttime temperature of the warmest month of the year (the maximum of the monthly mean SST climatology, or MMM) at the same location. The Degree Heating Week (DHW) product (Fig. 1d), which measures accumulated heat stress experienced by corals, sums the HotSpots of 1°C or greater over a rolling 12-week period. The 7-day maximum Bleaching Alert Area product (Fig. 1e) identifies areas where bleaching heat stress meets or exceeds predefined levels, based on the HotSpot and DHW values during the most recent seven-day time period. The 7-day SST Trend (Fig. 1f) provides information on the near-term pace and direction of the SST variation and, hence, coral bleaching heat stress over the preceding seven days. All products are updated daily and posted on CRW's website and FTP site. Detailed descriptions are provided on CRW's website (https://coralreefwatch.noaa.gov/satellite/bleaching5km) and in Liu et al. (2014b). CRW's 5km satellite monitoring provides service at or near reef-scales, allowing direct monitoring of heat stress on at least 95% of the world's coral reefs. A set of enhanced color schemes, developed to improve graphic presentation of the data and implemented in the version 2 (v2) products after their official release in May 2014, continues to be used in v3.

The v3 5km satellite monitoring continues to use the NOAA/National Environmental Satellite, Data, and Information Service's (NESDIS) operational daily global 5km geostationary-polar-orbiting (Geo-Polar) Blended Night-only SST Analysis (Maturi et al., 2017) as the near-real-time input data. The products use the same algorithms as the v2 products (Liu et al., 2014b) but use a significantly improved climatology. The new climatology was derived from a combination of the recently completed NOAA/NESDIS 2002-2015 reprocessed daily global 5km Geo-Polar Blended Night-only SST Analysis, and the 1985-2002 portion of the daily global 5km SST reanalysis of the Operational SST and Sea Ice Analysis (OSTIA) system, produced by the United Kingdom Met Office. The near-real-time OSTIA SST was

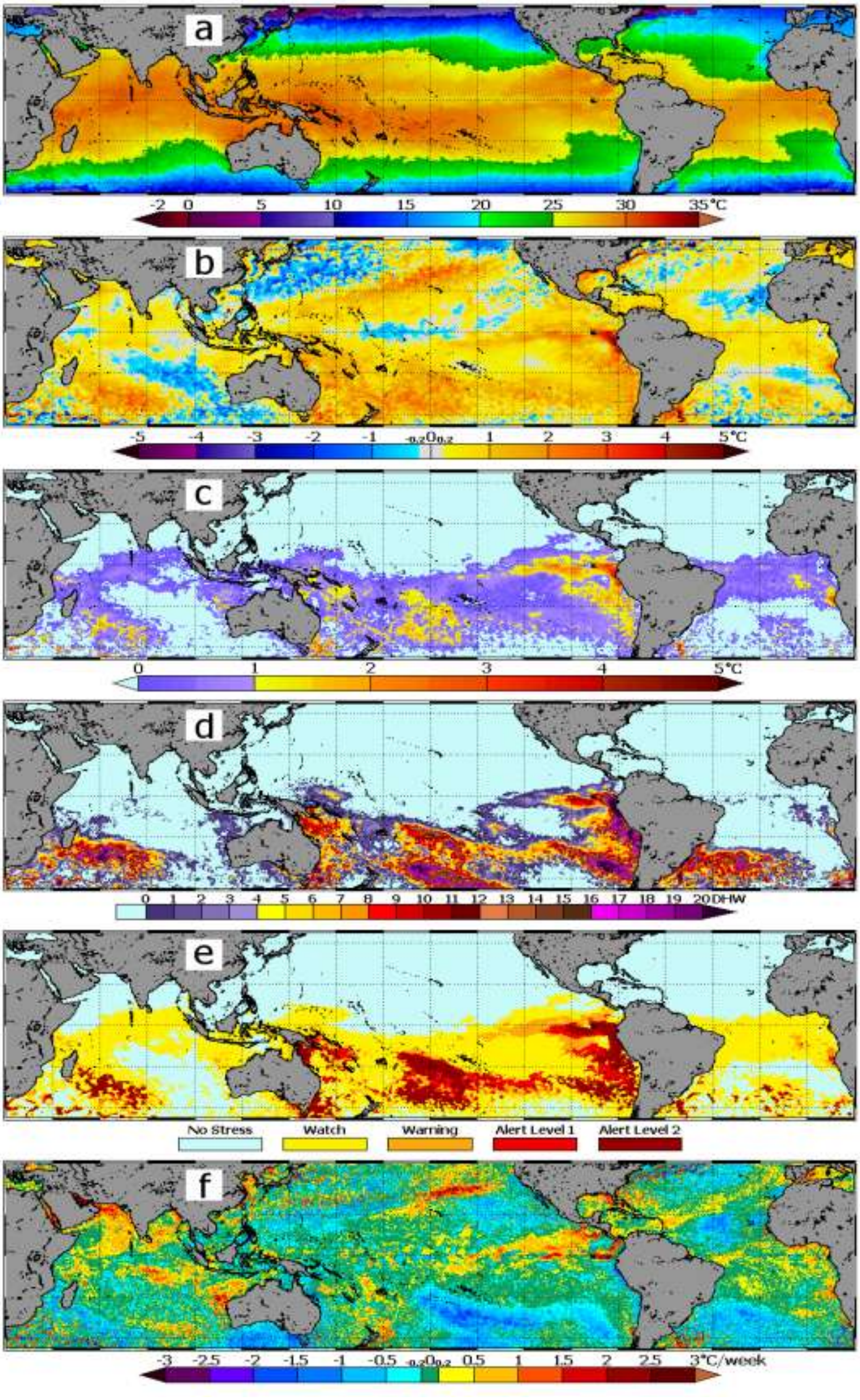

Figure 1. NOAA CRW's version 3 daily global 5km satellite (a) sea surface temperature (SST), (b) SST Anomaly, (c) Coral Bleaching HotSpot, (d) Degree Heating Week, (e) 7-day maximum Bleaching Alert Area, and (f) 7-day SST Trend maps issued on April 1, 2017. Note that the Bleaching Alert Area map (e) shows Alert Levels 1 and 2 heat stress in the Great Barrier Reef, Australia and in the region covering Samoa and American Samoa, where bleaching was being reported at that time.

recently (September 21, 2015) adopted by NESDIS to provide the bias correction in the latest generation of NESDIS' operational daily 5km Geo-Polar Blended Night-only SST Analysis, upon which CRW's 5km coral bleaching heat stress monitoring product suite is based. Hence, the combined 1985-2015 5km SST analysis has become the best historical global SST analysis available for deriving a climatology that is internally consistent with the near-real-time SST used in CRW's near-real-time 5km monitoring.

The methodology employed to create the v3 climatology followed the relevant algorithms applied in deriving the v2 climatology and is described in Heron et al. (2015). The 2002-2015 reprocessed Blended SST became available in October 2016 and led to the development of the v3 products presented in this article. The long-lasting 2014-2017 global coral bleaching event (Eakin et al., 2017), which started in June 2014 right after the launch of the v2 products and has continued into 2017, provided a unique opportunity for testing CRW's v2 satellite products on a global scale in a relatively short time period. Discrepancies between the v2 monitoring products and reported bleaching in some reef regions provided by CRW's partners and collaborators helped to confirm some of the problems CRW anticipated in the climatology of the v2 satellite monitoring products, further necessitating the improved climatology in the v3 products. Further analysis is ongoing, but the v3 products appear to have resolved most of the discrepancies between the v2 products and bleaching observations.

A reanalysis of the CRW 5km product suite spanning 1985-2015 will soon be produced, based on the combined 5km reprocessed Blended SST and OSTIA SST Reanalysis, and posted on CRW's website. This will be merged with our near-real-time products to provide a single dataset spanning 1985-date.

2. Four-Month Outlook Version 4

CRW released a new version (v4) of its subseasonal-to-seasonal-scale global ~50km (exactly 0.5°) probabilistic Four-Month Coral Bleaching Heat Stress Outlook on May 16, 2017. The Outlook predicts the likelihood of coral bleaching heat stress up to four months into the future. The predictions are derived using the daily SST forecast from the NOAA/National Weather Service/National Centers for Environmental Prediction's (NCEP) Climate Forecast System Version 2 (CFSv2), an operational, global, fully coupled, atmosphere-ocean-sea ice-land, dynamical, seasonal climate prediction system. The Outlooks are generated by applying the detection algorithm used in CRW's global 5km satellite coral bleaching heat stress monitoring (described in the last section; Liu et al., 2014b), with slight modifications (Eakin et al., 2012; Liu et al., 2017), to the SST predictions from the CFSv2.

The CFSv2 system provides sixteen forecast runs per day: nine runs out to 45-days, three runs out to three months, and four runs out to nine months. Each week, CRW probabilistic outputs from the v4 Outlook use between 28 and 112 ensemble members for each predicted week (112 members for Weeks 1-5 in the future, 49 members for Weeks 6-12, and 28 members for Week 13 and longer). The v4 Outlook utilizes all daily CFSv2 runs, with various predicted temporal lengths, to maximize the number of ensemble members for shorter lead-times (one to 12 weeks in the future); the v3 Outlook used only 28 members to provide predictions out to nine months. Initial analysis indicates that the v4 Outlook has a more robust dataset; however, the accuracy does not seem to be significantly different from the v3.

The v4 Outlook updates once a week, usually on Tuesday morning, U.S. Eastern Time. The Four-Month Outlooks, predicting Bleaching Alert Areas with 90% and 60% probabilities (Fig. 2), can be found at https://coralreefwatch.noaa.gov. Each probability has a four-month composite Outlook map (Fig. 2a-b) and a weekly Outlook map (not shown) for each week of the four-month time period. Taking the 60% probability as an example, at any given data grid, for a specified lead-time (i.e., a predicted week), the heat stress level depicted is the stress level predicted by at least 60% of the forecast ensemble members that correspond to that lead-time. Global probability distribution maps, one for each of the four specified stress ranges (Bleaching Watch and higher, Bleaching Warning and higher, Alert Level 1 and higher, and Alert Level 2), are also provided so that the probability of the occurrence of corresponding stress ranges can be identified for any reef location (Fig. 2c-f). A detailed description of CRW's CFS-based Bleaching Outlook product is provided in Liu et al. (2017) and Eakin et al. (2012), and online at https://coralreefwatch.noaa.gov/satellite/bleachingoutlook_cfs/outlook_cfs.php.

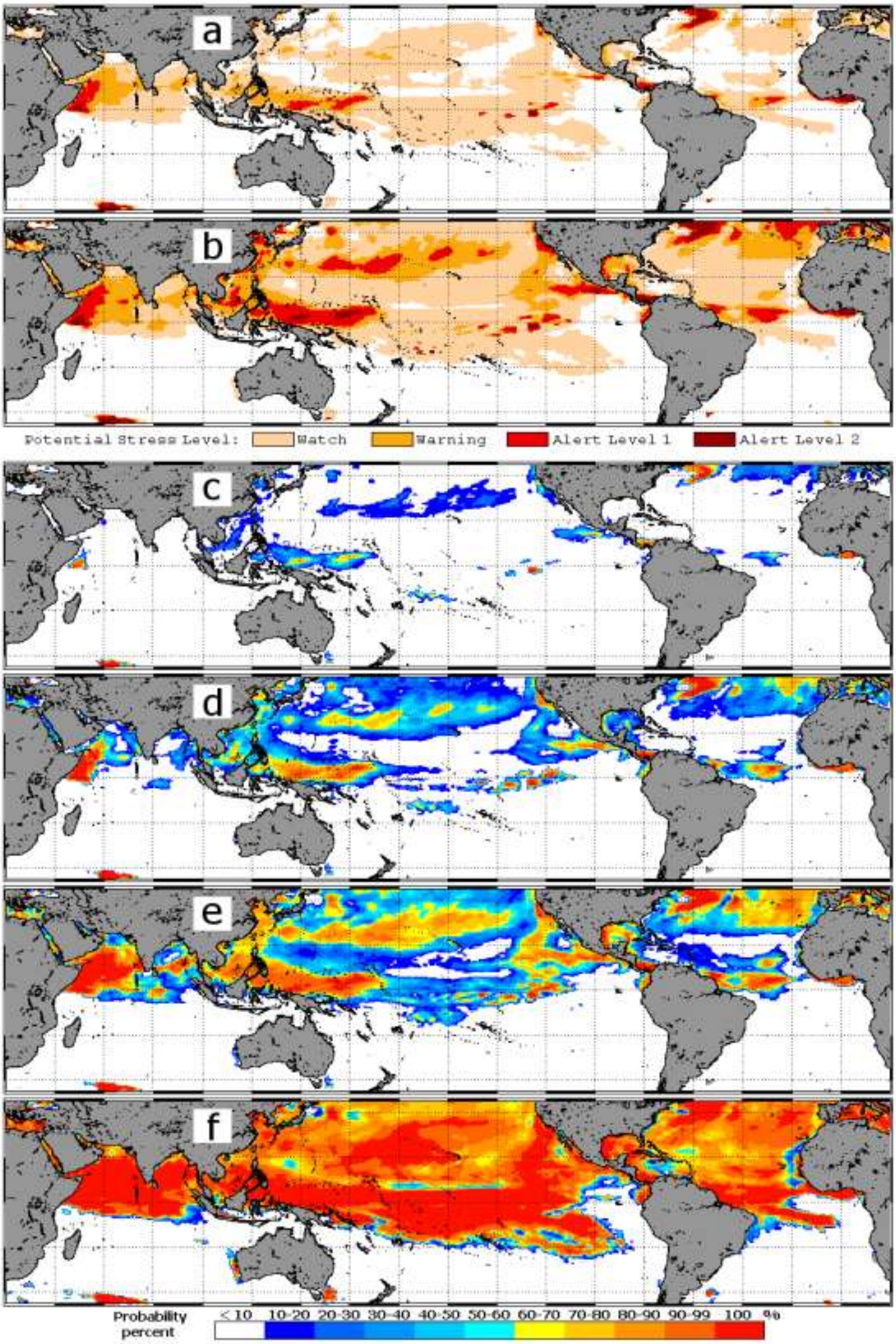

Figure 2. NOAA CRW's version 4 (a) 90% and (b) 60% probabilistic Four-Month Coral Bleaching Heat Stress Outlook maps, and probabilistic maps for the four predicted heat stress ranges: (c) Alert Level 2, (d) Alert Level 1 and higher, (e) Warning and higher, and (f) Watch and higher, issued on May 9, 2017 for May-August 2017.

3. Regional Virtual Stations and Bleaching Alert Email System

With the release of new versions of CRW's 5km global satellite monitoring and modeled Outlook described above, CRW updated its 5km satellite Regional Virtual Stations and Regional Bleaching Heat Stress Gauges product as well, as that product is based on the 5km global satellite monitoring products and associated climatology. The 5km satellite Regional Virtual Stations and Regional Bleaching Heat Stress Gauges product (https://coralreefwatch.noaa.gov/vs) includes 212 Stations intended to cover most coral reefs globally (Fig. 3). The free, automated Bleaching Alert Email System associated with the Regional Stations was also updated (http://coralreefwatch-satops.noaa.gov/).

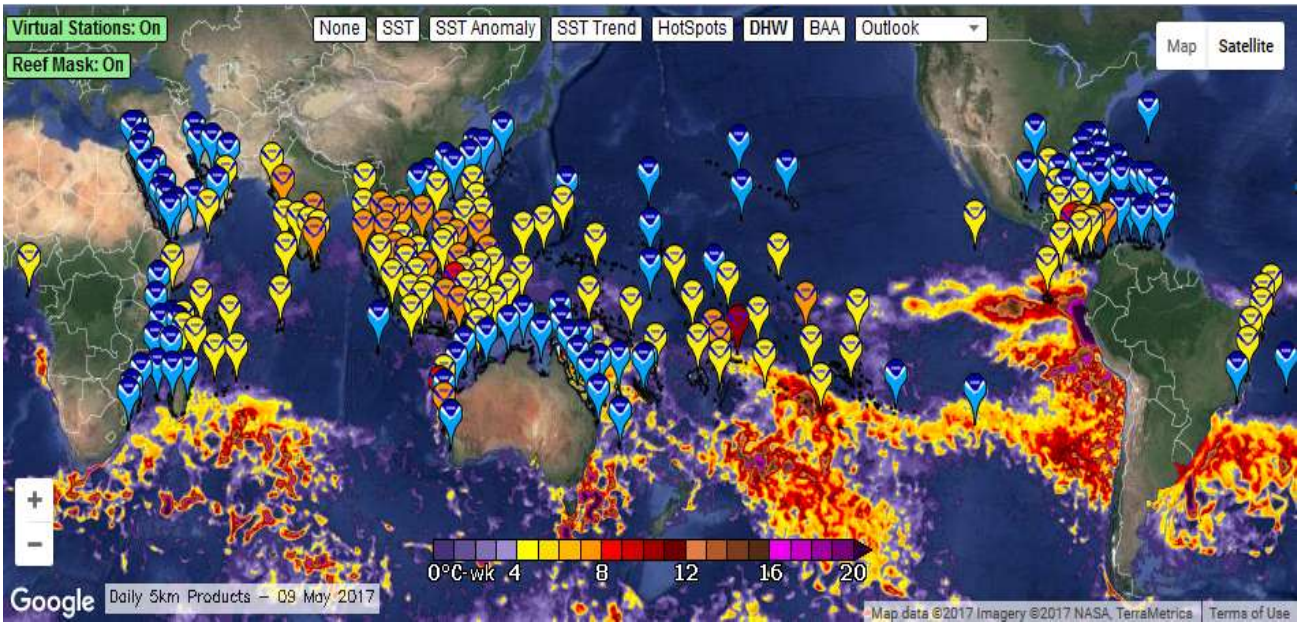

Figure 3. NOAA CRW's 5km Regional Virtual Stations (212 Stations across the global tropical oceans) presented in Google Maps and overlaid on CRW's 5km Degree Heating Week product of May 9, 2017. The color of each Station balloon indicates the level of heat stress experienced on that day (see the Bleaching Alert Area color legend of Fig. 1e).

A Regional Virtual Station includes all coral reefs in a jurisdiction or predetermined sub-region, providing local bleaching heat stress maps and analyses of 5km SST, SST Anomaly, HotSpot, DHW, and Bleaching Alert Area values. When a user receives an email alert for a pre-selected reef region, it indicates that there is change in the status of heat stress within the Station's boundary and guides the user to CRW's online information pertaining to the Station.

Daily-updated Coral Bleaching Heat Stress Gauges (Fig. 4) and time series data and graphs (Fig. 5) are provided for each 5km Regional Virtual Station. While the time series data and graphs contain temporal heat stress information based only on the 5km satellite monitoring, the Gauges provide both the current Station warning level and spatial distribution of heat stress, using the 5km satellite products, and the 60% probability Outlook for the upcoming 1-4, 5-8, and 9-12 weeks. Their detailed description and algorithm can be found at the Regional Virtual Stations website.

The global 5km satellite monitoring and Four-Month Outlook, along with the 5km satellite Regional Virtual Stations and Regional Bleaching Heat Stress Gauges, form the core components of CRW's next-generation decision support system (DSS) informing management and communication about the status of tropical coral reef ecosystems and other coastal marine ecosystems worldwide. These products will undergo continuous improvements as they are tested and ultimately transitioned to full operational support. The 5km satellite Regional Virtual Stations product was developed to help facilitate timely and effective jurisdiction-level management actions pertaining to mass coral bleaching.

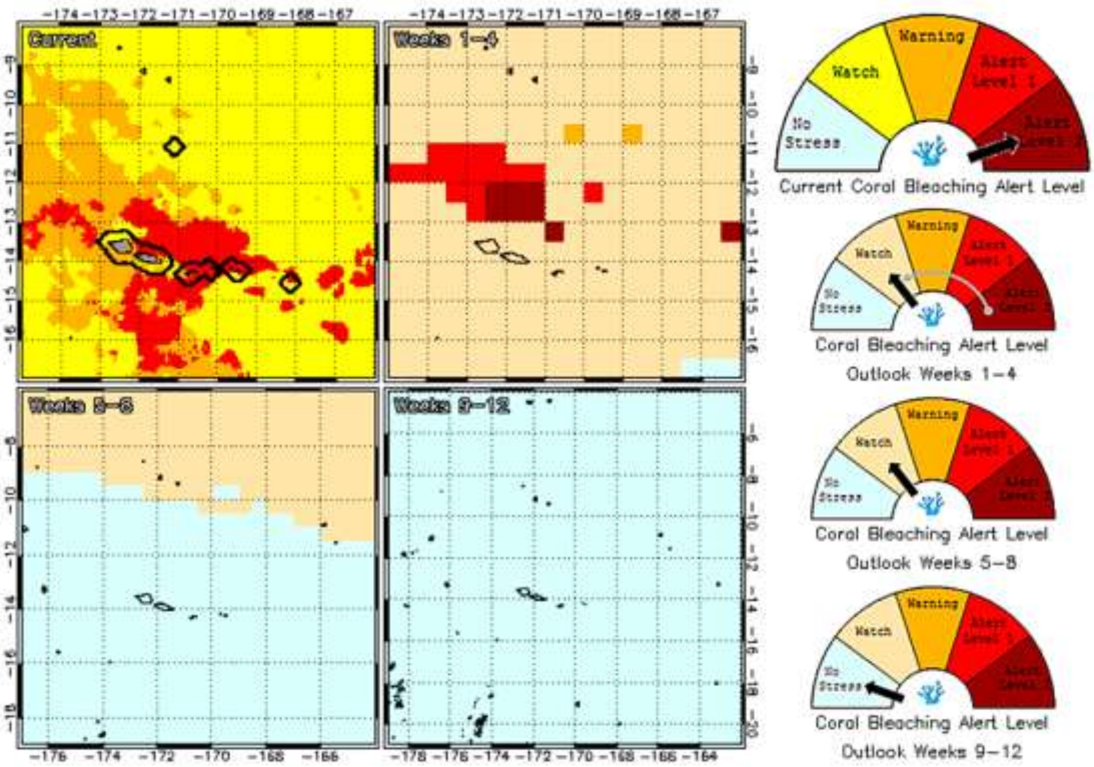

Figure 4. Example NOAA CRW Bleaching Heat Stress Gauge for the 5km Regional Virtual Station at the Samoas, issued on May 12, 2017. The top dial (gauge) and the top left map provide the current Station warning level and spatial distribution of heat stress in the Samoas, as monitored by CRW's 5km satellite products. The other three pairs of maps and corresponding dials (gauges) provide CRW's model-projected bleaching heat stress conditions (Outlook) with 60% probability at the Samoas Station for the upcoming 1-4, 5-8, and 9-12 weeks.

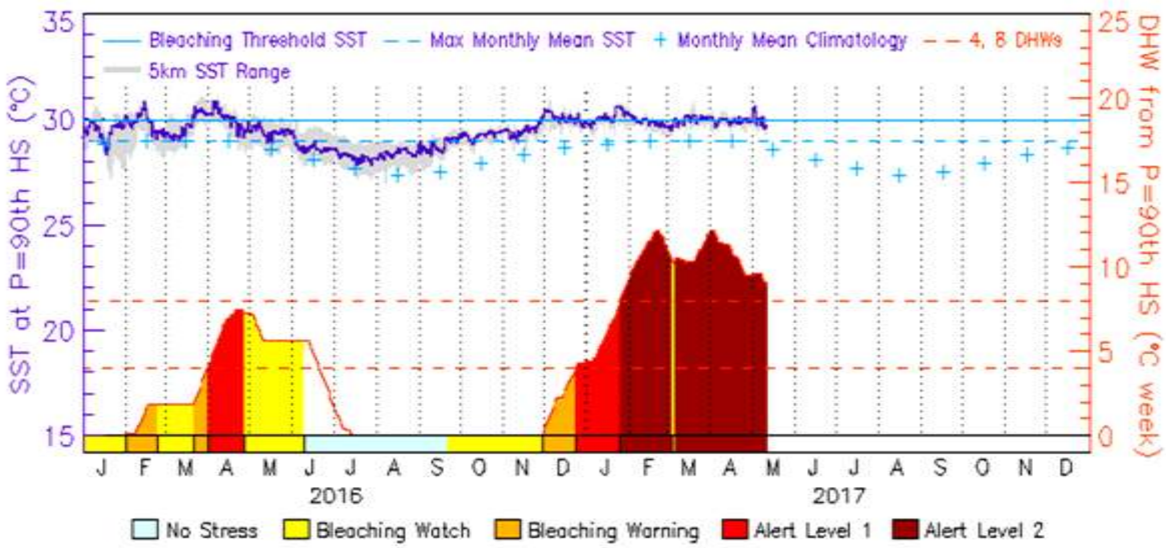

Figure 5. NOAA CRW's 2016-2017 coral bleaching heat stress time series (SST, DHW, and Bleaching Alert Level) for the 5km Regional Virtual Station at the Samoas, issued on May 12, 2017.

We encourage users worldwide to report episodes of coral bleaching and non-bleaching to help us calibrate and validate the new DSS products. Please email observations to coralreefwatch@noaa.gov and/or enter them online at https://coralreefwatch.noaa.gov/satellite/research/coral_bleaching_report.php. Your feedback is important for us to improve our products. Please send your comments and suggestions to coralreefwatch@noaa.gov.

Acknowledgements:
Development of CRW's version 3 5km suite of global and regional satellite products and the associated climatology was made possible through funding from the NOAA Coral Reef Conservation Program and NOAA's Ocean Remote Sensing Program. CRW's Outlooks were made possible through collaboration between NOAA's NCEP and CRW, with funding support from NOAA's NCEP, Climate Program Office, and Coral Reef Conservation Program. The contents in this manuscript are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government.

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Coral bleaching in New Caledonia (Photo credit - courtesy of The Ocean Agency / XL Catlin Seaview Survey / Richard Vevers).

Chasing Coral[1]: The Meeting of Filmmaking and Advancements in Coral Bleaching Image Technology

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In 2013, following his award-winning critically-acclaimed film *Chasing Ice*, director Jeff Orlowski launched a new quest to investigate the unprecedented disappearance of the world's coral reefs, while sharing the beauty and mysteries of the underwater world. *Chasing Ice* was groundbreaking in the filmmaking world, capturing long-term time lapse images to document the effects of global warming on polar climates. Orlowski hoped to do the same for *Chasing Coral*, but collecting long-term underwater footage proved to be a challenge.

Chasing Coral Director Jeff Orlowski, with drone custom - built by Falkor Aerials .

Unaware of Orlowski's new film, and having just completed undergraduate studies at the University of Colorado, Zackery Rago began working for an underwater imagery company called View Into the Blue in Boulder, Colorado. "[We] were on the forefront of creative solutions for collecting long-term imagery in the marine environment," Rago explains. "The foundation of the technology was the patented Clean Sweep System." Simply put, View Into the Blue had designed a vacuum-sealed glass dome to house camera equipment, and this dome was automatically wiped clean by a wiper arm, driven by sets of neodymium magnetic rings and motorized gears.

Essentially a windshield wiper for a camera housing, the Clean Sweep System was the leading technology to combat the obstacles in underwater filming. Rago points out, "When a clean surface, such as a glass dome, is introduced, underwater organisms immediately begin inhabiting the new space. In as short as 12 hours, organisms foul the images we want to capture."

View Into the Blue was using their developing technology to live stream underwater footage to the Internet and caught Orlowski's attention, as he hoped to capture mass coral bleaching events on film. "He was running into the very issue our team had been working to solve," says Rago. "Taking usable [underwater] images over a long period of time without human intervention is actually impossible." It became clear, however, that View Into the Blue's technology was the least invasive option and could be the solution that would take *Chasing Coral* from vision to reality.

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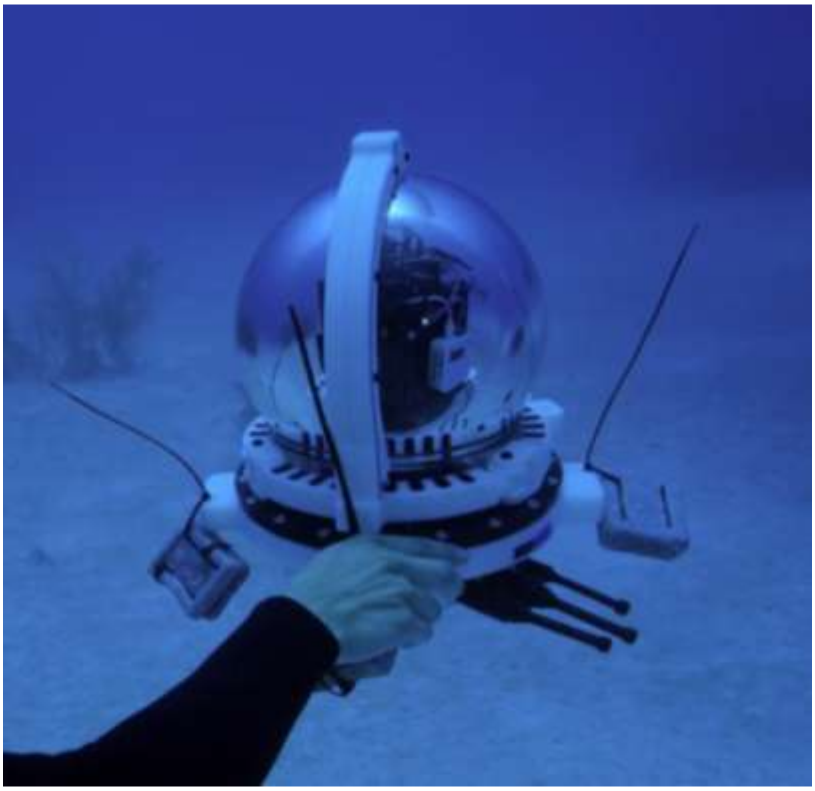
[1] *Chasing Coral premiered on Netflix on July 14th as a Netflix Original Documentary. Watch now! And urge family, friends and colleagues to do likewise!! For more information go to www.chasingcoral.com.*

Of course, adjustments needed to be made to reach the cinematic quality for which Orlowski and Exposure Labs are known. Rago and View Into the Blue were up for the challenge, and immediately launched new research and development for the project. Rago noted, "We began working with the Lumix GH4 camera. Then we had to design how to place the camera inside the [glass dome]. We also had to determine how to program the camera to do exactly as we wanted over its time in the field, then solve the problem of making the system completely autonomous and installable in the remote corners of the planet."



"Clean Sweep System" showing how the cleaning arm, just above the divers hand, wraps around the housing (Photo credit - courtesy Netflix / Chasing Coral).

Though complicated on the front-end, the solutions and systems began to reveal themselves through research. The team used a 3D printer to customize a more elaborate structure that housed the camera and other electronics, but allowed for precise placement and control. The Raspberry Pi was a general user interface (GUI) for accessing the Arduino Board, which Rago says was the real brains behind the operation. "In terms of becoming the brain of the camera, it was actually quite simple. There were really only four pieces at the core of the process—a Raspberry Pi, an Arduino Board, a solenoid and a custom-circuit to act as a shutter button," Rago explains.

"Our team wrote software that allowed us to schedule the camera to wake up and how many photos to shoot. In short, the camera would be asleep, but always powered. When the scheduled time occurred, the Arduino would fire the solenoid to wake the camera by pressing the manual shutter button." Once the camera was awake, the Arduino would ping the camera with two precise electrical signals—one to autofocus the images and another to take the photograph. "This repeated 30 times, then the camera could go back to sleep until the next scheduled shoot." The whole system was powered by a custom Pelican case that contained ten solid state batteries, wired with enough energy to power the whole system for two months minimum.

It took Rago and View Into the Blue six months to design and test the systems, and by that time, a third global mass bleaching event began. "At that point," Rago says, "We had no choice but to get them into the field. Orlowski's team hired me as the installing technician." Rago setup cameras in the Bahamas, Bermuda and Hawaii, before discovering the camera lenses were flawed. "We replaced the lenses, but also had time between working in the northern hemisphere and the southern (we knew the bleaching likely wouldn't start in Australia until Feb or March) to simplify the system as a whole - less underwater connections, less software actions, less electronics." It was the silver lining on a lesson learned the hard way.

With the systems operational, it was a matter of being in the right place at the right time to capture the bleaching events. At the approach of 2016, El Niño caused the water temperatures around the Great Barrier Reef to skyrocket. Rago and his team had five cameras set up, two systems around Heron Island and three more in the Keppel Islands. All five systems were in the water by mid February. They would continue to wait to capture a bleaching event on film.

"I'm a self-proclaimed coral nerd," Rago says. He, like other members on the team, felt a connection to the *Chasing Coral* project, beyond just scientific development. It was a passion project. Despite these challenges, Rago was deeply invested in capturing these unprecedented images that he believed the public needed to see.. "I am truly loyal to coral, and I have spent my entire life and career doing anything I can to work in their world. I think everyone began to realize I was deeply moved to have a part in this project."

Time lapse cameras from the film *Chasing Corals*., with Jeff and Zack.

The Northern Great Barrier Reef was still heating up in early March 2016. "We knew the corals had begun to bleach," Rago remembers. "We didn't have time or resources to move all the way up the Australian East Coast. But we did have the manpower and the commitment." Rago and the team left in place the cameras they had spent months developing and on March 15th 2016 they headed for Lizard Island in the far north. "We were going to do manual time lapse, every single day on the reef."

Lizard Island became the bullseye of the largest coral bleaching to ever occur on the planet. Rago and the team filmed every day at the same 60 sites while water temperatures climbed to 35 degrees centigrade. "We watched one of the most diverse, beautiful ecosystems die before our eyes. It was excruciating. But despite my personal frustrations, we accomplished a larger goal. This story, the reality of what is happening beneath the surface, can now be shown to the world."

Chasing Coral: A wonderfully told story and a new opportunity for conservation outreach

C. Mark Eakin[1] and Ove Hoegh-Guldberg[2]
Chief Scientific Advisors, *Chasing Coral*

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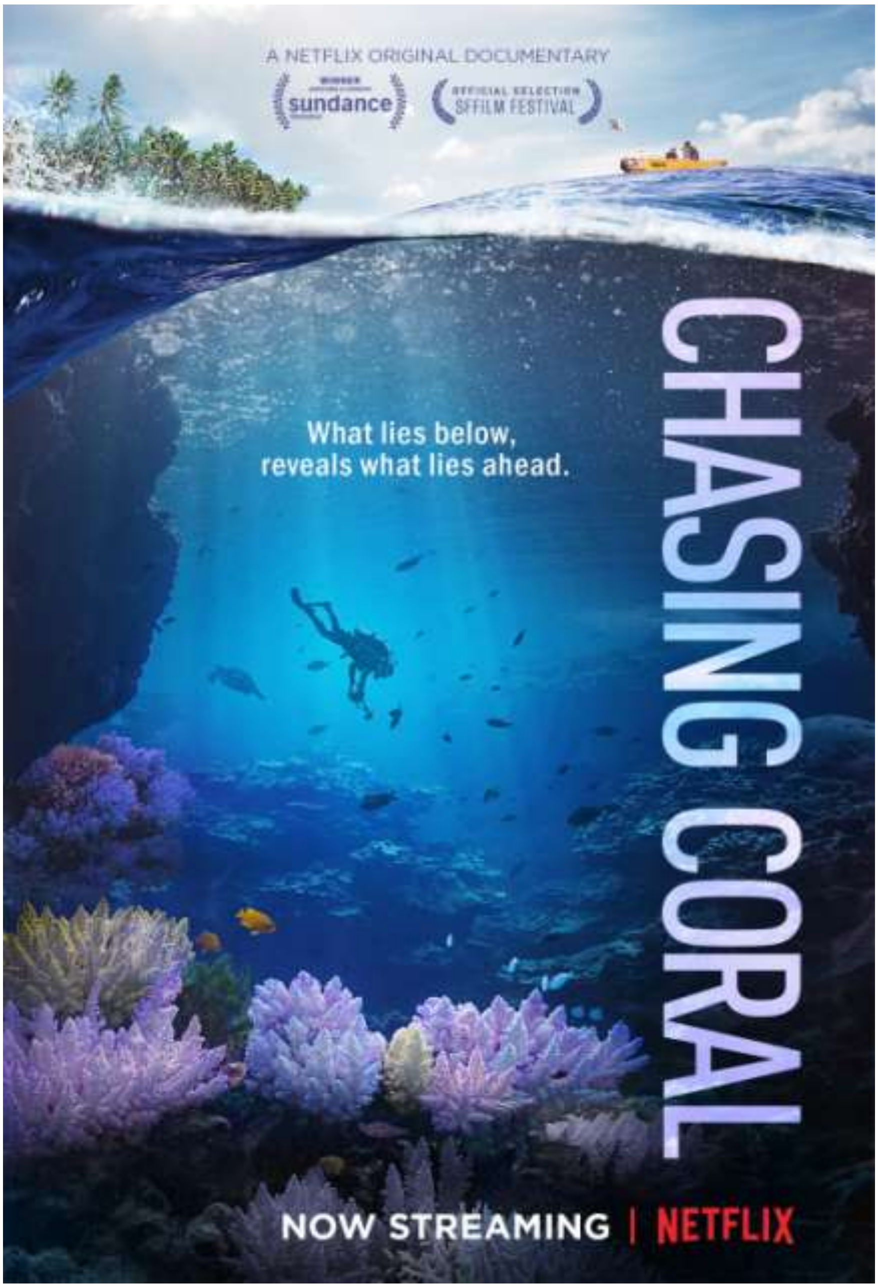
Chasing Coral, a new documentary film, begins following Richard Vevers, a former London advertising executive, whose passion for the ocean and expertise as an underwater photographer and communication specialist lead him to pursue a new goal – communicating the plight of the ocean and marine ecosystems to a broad audience. Coincidentally, Richard begins this adventure and his newly founded XL Catlin Seaview Survey just before the Third Global Coral Bleaching Event began to unfold (see article elsewhere in this issue). After documenting bleaching on a particularly hard hit reef, he saw the film *Chasing Ice* on a plane and a light bulb went off. The loss of corals was an unfortunately fitting undersea parallel to the loss of ice in Greenland. Working with the director of *Chasing Ice*, Jeff Orlowski, the filming of *Chasing Coral* began and the team began the pursuit to document coral bleaching as it happened around the world, using time-lapse videography. Along the way, Jeff met the film's surprise co-star, Zack Rago, a self-proclaimed coral nerd not long out of college and working for the Colorado company whose underwater video systems would soon play a major role in the film. The team planned to venture to reefs expected to soon bleach to capture the process first-hand. Easy, right?



As the two Chief Scientific Advisors Prof. Hoegh-Guldberg (Director of the Global Change Institute, University of Queensland and Chief Scientist of the XL Catlin Seaview Survey) provided Exposure Labs (the production team for

Chasing Coral) overall guidance on the increasing of impact climate change on coral reef ecosystems, and particularly the Great Barrier Reef; while Dr. Eakin (Coordinator of Coral Reef Watch, US National Oceanic and Atmospheric Administration) provided Exposure Labs and the XL Catlin Seaview Survey with the best guidance NOAA Coral Reef Watch's satellite and climate model-based products could offer on where and when the most severe coral bleaching would occur. Of course, the production team then had to factor in logistics, permits, equipment, and other constraints to decide where they could feasibly go. Unfortunately, problems with equipment, vagaries of weather, and other factors made this harder than the filmmakers first realized, but also a more exciting story to tell.

The film marries an exciting adventure with breathtaking imagery to bring the plight of coral reefs to life. It helps viewers fall in love with this astounding ecosystem we know well. It shows the threats climate change is posing to coral reefs without preaching or being heavy-handed. It shows the brutal loss of corals and reefs before the viewers' eyes and the impact it has on those of us who work with reefs daily. Finally, it uplifts the viewer with hope for the future. Be sure to stay through the credits – there is one part that, without fail, raises the delighted applause of audiences.

Many other top coral reef scientists appear throughout the film and were advisers to *Chasing Coral*, ensuring that the science is as accurate as possible. Many of you and your bleaching reports are in the film thanks to your responses to their appeal for underwater imagery. The film also contains scenes from the special Coral Bleaching Town Hall from the 13th International Coral Reef Symposium in Honolulu, Hawaii in June 2016. *Chasing Coral* won the US Documentary Audience Award at the 2017 Sundance Film Festival in January. Since then it has garnered several other awards, especially audience choice awards, from film festivals around the world. The official trailer is available on YouTube, while the film itself had its Netflix premiere on 14 July 2017. It is easily found on Netflix using the search function and you can arrange to host a screening from their website.

SVII in action during Seaview Survey in the Coral Triangle (Photo credit – courtesy XL Catlin Seaview Survey / The Ocean Agency / Aaron Spence).

This film is an excellent outreach tool that you can use to use in your communities to show off the wonders of coral reefs, the threats they face, and the need for both conservation and action to address global warming. At a time when bleaching has become more frequent and severe, and global warming continues to threaten coral reefs and other ecosystems around the globe, *Chasing Coral* provides a way we can all take this message to audiences who don't yet understand the need for action.

Sponges and Environment

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Sponges never stop surprising marine ecologists because of their ability to survive adverse environmental conditions. How do sponges become resilient and flexible? How do they survive and cope with continual environmental change? The answer from any sponge ecologist would be “don’t know” or “research ongoing” or “more research needs to be done”. The relationships between sponges and biophysical factors are complex, and globally several research projects are ongoing to “unwind” the ‘sponge-sturdiness’ secret. A detailed account of environmental parameters and their impacts on sponge communities has been provided by Rützler (2004). This short article is intended to highlight and outline recent advances in environmental research on this insufficiently understood group.

Sponges, phylum Porifera have several unique characteristics. Despite being the first multi-celled organisms with a complex skeletal system and structure (involving varying reliance on silica and carbonate spicules) and no true tissues or organs, they enhance nutrient cycling and bentho-pelagic coupling because of their filter-feeding nature and become efficient vacuum cleaners of our ocean. Sponges dominate, next to corals, the reef ecosystem because of their wider habitat distribution from shallow to the deep seas of both the tropics and temperate zones (Van Soest et al. 2012). They also possess varied functional roles like supporting corals and reefs through bioerosion, reef consolidation (mineralization and cementation), primary production and interaction with other organisms (Bell 2008).

Sponge biology is interrelated to hydrodynamic biophysical environmental parameters such as light intensity (Wilkinson & Trott 1985), depth, water movement (Kaandrop 1999), sedimentation (Pineda et al. 2016), nutrients (Wilkinson 1987), and angle of substrate (Powell et al. 2010). The other factors that impact sponge distribution are predation, habitat, larval dispersal and recruitment patterns (Duckworth 2015). These biophysical factors can influence the distribution patterns and species richness of sponges (Duckworth & Wolff 2007), as well as their morphology (Bell 2017). However, research on the apparent adaptability of sponges to adverse environmental changes and other competing biota is paramount, yet still in its infancy. Currently there are several environmental research projects on sponges that focus on their population connectivity, ocean acidification, eutrophication, bleaching events/ocean temperature rise, and turbidity. In this article, only a few examples mainly from the Great Barrier Reef (GBR) of the influence on sponge associations on substrate and depth, water flow, water quality, light, faunal associations and sponges as ecological indicators will be considered in detail.

Substrate and depth

Sponge larval settlement is highly related to the type of seabed and factors like sediment (Bell et al. 2015), currents, phytoplankton and depth can affect the settlement of sponge larvae. The GBR, on the north-eastern Australian coast, encompasses different reef types, communities, sediments, habitats and biophysical processes. The GBR has a complex seabed with a silty and siliceous inshore zone, coarser sandy areas across the shelf, carbonate sediments offshore and a rubbly region in the central-southern GBR (Mather & Bennett 1993). An interaction of the sponge, *Coscinoderma matthewsi* with substrate type and depth (6 to 12m), showed sponge cover greater at 12 m and three times less common in 6 m because of substrate stability effects by water flow (Duckworth 2015). Apart from the finding that there is greater sponge larval settlement in higher wave heights (Abdul Wahab et al. 2014), more studies are needed to understand if the broad and gently sloping continental shelves of the GBR are highly favourable to sponges, permitting larval settlement and adult survival in the face of changes in environmental conditions and food availability.

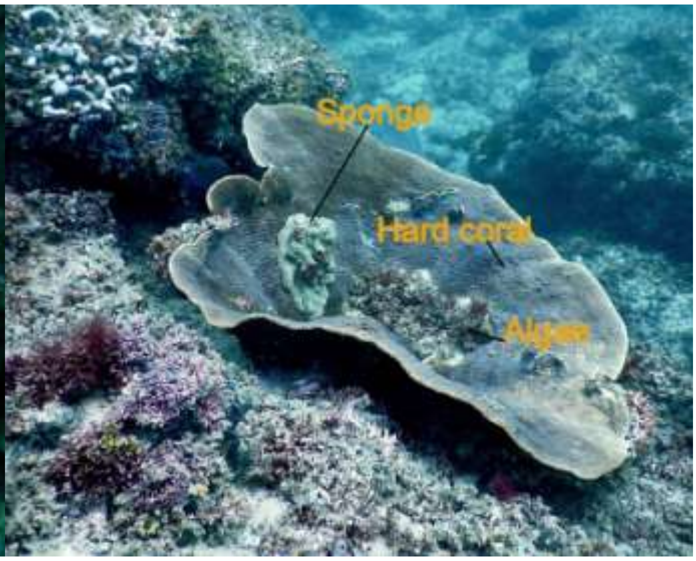


Figure 1 (left). A common sponge, *Xestospongia* sp. competing for space with hard coral, *Porites* sp. (Great Barrier Reef, Australia). **Figure 2** (right) Sponges trying to grow on a plate form coral (GBR, Australia).

Water flow

The rates of water flow and sponge growth rate are correlated, water flow being vital for dispersal of larvae as well the supply of food. Sponges also react widely to water movement, which has an impact on their morphology, physical stability, food supply and reproduction. A study on the effects of different water flow rates on sponges from two different taxonomic groups found this provoked them to react in a similar way, by changing thin-branching forms in to more compact shapes (Kaandorp 1999). Some sponges can adapt to live in greater currents or high wave exposed areas. This increases their functional ability yet decreases their growth rates because of the energy used in the constant filtering required (Palumbi 1986). However, if sponges are on unstable substratum, water flow at a higher rate can dislodge them and disrupt their morphology (Fenner 1991). The growth form of the sponge (e.g. upright or branching) can influence its risk of getting dislodged by strong currents. Turbulent and rapid water flow would affect sponge diversity and richness because of their slower growth, increased stiffness and lower colony profiles that result in wave exposed areas while moderate to high sedimentation rates would increase sponge diversity (Bell & Barnes, 2000). In the GBR, currents on the inner-shelf are mostly from south to north during the southeast wind regime, while on the outer-shelf the East Australian current flows to the south and the Hiri current flows to the north (Brinkman et al. 2002); these currents can have a dramatic impact on sponge morphology. Apart from current flow, there are other physical variables (storms, cyclones, temperature, wave height, tides) that have impacts on sponge morphology in ways that need to be better understood.

Water quality

Land run-off and organic pollution in moderate concentrations are beneficial to sponges as they favour their filtering capacity and provide them with nutrition. Water quality on the GBR has continued to be negatively affected by the discharge of excess nutrients, fine sediments and pesticides from the adjacent catchments (Brodie et al. 2012). Chlorophyll-a (chl-a) levels on the GBR are highly controlled by physical conditions, disturbance, grazers and nutrients and as a result vary significantly with space and time (Brodie et al. 2007). Increased levels of chl-a occur during the wet season due to the increased nutrient input from the adjoining catchments into the GBR lagoon (Devlin et al. 2013). Hence, it can be assumed, sponges obtain high levels of nutrition both for themselves and for their symbiotic communities if moderate input from river run-off is available.

Light

Phototrophic sponges hosting symbiotic green bacteria also derive nutrition from their symbionts, just like zooxanthellae and their coral hosts (Wilkinson 1987). These phototrophic sponges are found concentrated in the oligotrophic zones of the GBR, whereas they are rare or absent in the inner nearshore reefs (Van Soest, Marine Species Identification Portal, *accessed on 6 July 2017 12.01 pm*). The nearshore habitats of the GBR are characterised by suspended sediments which make it harder for the available light to reach the symbiotic bacteria in sponges. By contrast, where there is less suspended matter or calmer waters (e.g. at depths >40m), sponge biomass is considerably higher (Wilkinson & Trott 1985). Chl-a can act as an indicator of increased phytoplankton biomass (Spencer 1985) which again favours the abundance of sponges.

Figure 3. Sponges growing over a dead coral reef (GBR, Australia).

Faunal associations

Sponges are known for hosting a wide variety of endo and ectofauna, including microbes (Astudillo-Garcia et al. 2017). In a recent study of endofauna from three different sponges of the Great Barrier Reef, several new and rare associations were found (George et al., unpublished). The reason for why sponges are content to host so many of these animals remains something of a mystery. There are various hypotheses: that the associated faunae may give strength and stability to sponges, or that symbiotic or mutualistic associations may provide them with additional nutrition, or that the endofauna may contribute bioactive compounds which make some sponges toxic (to predators) or provide them with antimicrobial activity (hence the search for "wonder drugs" in sponges).

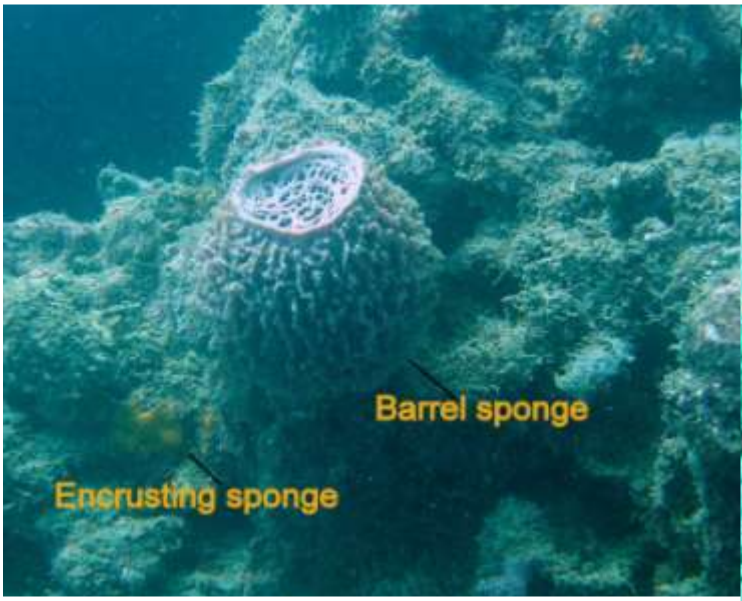
Ecological stress indicators

As sponges are strongly associated with abiotic environmental factors, they can provide valuable information on the temporal behaviour of any environmental stress, yet the use of sponges in monitoring studies is limited. Though sponges are happy to feed on suspended and dissolved organic matter at a moderate level, when there is a constant high sediment load, sponges are forced to use energy to clear their canals and oscules; hence their pumping rate can be reduced and may stop filtration (Reiswig 1971). Moreover, sponges are species-specific by active morphological adaptation to high silt conditions while some are highly sensitive (Carballo et al. 1996). In biomonitoring, based on the degree of stenotopy if sponges are used as indicator species, then it must be considered in a regional context (Carbello et al. 1996).

A preliminary investigation on sponges and selected environmental variables in the GBR showed morphological transformations can be used as stress indicators and study ecological trends (George et al. unpublished). It is suggested that, in areas prone to both anthropogenic activities (e.g. dredging, civil constructions, coastal developments and urban and industrial wastes) and other stresses (e.g. temperature rise, ocean acidification, cyclones, floods/river run-offs), studies should include both periodic sponge monitoring and studies on the impacts of biotic and abiotic factors (e.g. suspended dissolved organic matter, turbidity, water movement, heavy metals, currents, sedimentation, depth) to enable us to understand the 'sponge-sturdiness' secret.

Conclusions

In sum, when compared to other dominant marine organisms such as corals, sponge populations have been found to be surprisingly stable in the face of adverse environmental conditions. Sponge species tend to outcompete other benthic groups if there is high availability of particulate organic matter in spite of predation and competition. Being in a simple and primitive group, the complex skeletal system and presence of a cornucopia of symbionts and bioactive compounds, sponges tend to withstand both anthropogenic impacts and other environmental stressors to some extent and so maintain their abundance.



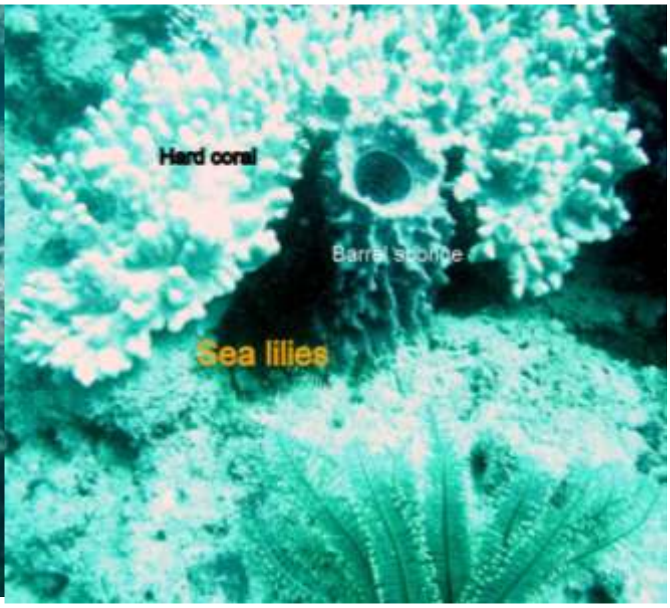


Figure 4 (left). Encrusting and barrel, *Xestospongia,* sponges competing with algae on a coral reef (GBR, Australia). **Figure 5** (right) Another *Xestospongia* sponge interacting with a digitate coral and sea lilies.

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PROGRAMMES & PROJECTS

Overviews of Ongoing Programmes and Projects

The International Coral Reef Initiative (ICRI)

www.icriforum.org

In the last issue of *Reef Encounter*, we gave any overview of ICRI, ISRS having just become a member. Here, ICRI Co-ordinator Francis Staub provides an update on recent ICRI activities.

The ICRI P**lan of Action 2016-2018** was adopted at the ICRI General Meeting in November 2016, and has the following 5 objectives:

1. **To raise awareness on the importance of coral reefs and related ecosystems to help mitigate the impacts of climate change.** **COP21, t**he twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) held in December 2015, highlighted for the first time the importance of the oceans in the context of climate change. The oceans and their role are specifically written into the Paris Agreement, the Agenda for Action, and the "Because the Ocean" declaration which was endorsed by many States. As follow up, the ICRI Secretariat and its Members are taking or encouraging the following actions:

   - ✓ highlighting the contribution of coral reefs, mangroves and seagrasses to mitigate and adapt to climate change and its impacts,
   - ✓ encouraging financing for projects and initiatives which help to protect and restore coral reefs, mangroves and seagrasses,
   - ✓ increasing knowledge on the role of coral reefs, mangroves and seagrasses in interactions with the climate and the ocean, as well as knowledge of the effects of these interactions on these ecosystems.

2. **To contribute to the implementation of relevant international agreements** – Many Multilateral Environmental Agreements (MEAs), including the Convention on Biological Diversity's Aichi Biodiversity Targets and Action Plan, are relevant to coral reefs. The ICRI Action Plan promotes implementation of these international commitments as well as efforts to develop new commitments as needed. For example, a resolution on the sustainable management of coral reefs was adopted at the second session of the United Nations Environment Assembly (UNEA-2) in May 2016 which calls for initiatives, cooperation and commitments to conserve and sustainably manage coral reefs; recognizes that education, capacity building and knowledge transfer is crucial; and encourages integrated, ecosystem-based and comprehensive approaches including partnerships with industry. The resolution also requests UN Environment to pursue a number of specific actions and helps to provide direction for coral reef policy and management in the context of the 2030 development agenda.

3. **To help reduce human threats to coral reefs and related ecosystems.** At the 2016 annual ICRI meeting, a recommendation to reduce plastic micro-beads pollution in the marine environment was adopted. Recommendations are being developed to address particular threats, including one in relation to dredging in coral areas for the purpose of creating or extending marine and coastal infrastructure and another on the deployment of environmentally friendly mooring devices. A review of the impacts of sunscreens and other endocrine disruptors on coral reefs will be produced.

4. **To monitor the state of coral reefs** - Through the Global Coral Reef Monitoring Network (GCRMN), regional reports on the status and trends of coral reefs will be released for the Pacific and for the Indian Ocean, the latter in collaboration with the Indian Ocean Commission.

5. **To raise awareness about the importance of coral reefs and related ecosystems** – This objective will be met through the activities to be carried out under the banner of the third International Year of the Reef (IYOR 2018) – see separate article.

ICRI is an informal group and decisions are not binding on its members. However, its activities have been pivotal in drawing global attention to the importance of coral reefs and related ecosystems in environmental sustainability, food security and social and cultural wellbeing. ICRI is regularly acknowledged in UN documents, highlighting it key role in cooperation, collaboration and advocacy role within the international arena.

Financial support to date has been provided by the governments of France, the United States of America and the principality of Monaco. In addition to the plan of action, a small projects scheme has been established for initiatives that contribute to meeting one or more of the ICRI Action plan objectives. Projects must be participatory and partnership-based and activities must be concrete and sustainable, with measurable results.

ICRI's objectives are also implemented through UNEP's Global Coral Reef Partnership (https://sustainabledevelopment.un.org/partnership/?p=7450) which helps relevant Regional Seas achieve key international commitments relevant to coral reefs through the provision of tools and guidance to implement best practice.

For more information, contact Francis Staub (fstaub@icriforum.org) or visit www.icriforum.org

Save the date

The next ICRI General Meeting will be held in Nairobi, Kenya (December 7 to 9), immediately after the 3rd meeting of the UN Environment Assembly (UNEA 3 http://www.unep.org/environmentassembly) which is the world's highest-level decision-making body on the environment.

REEF EDGE

Scientific letters or notes describing observations or data

"The wheels are falling off"

Reefs of the Chagos atolls in 2017

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The shallow parts of all ocean facing and lagoon reefs of the northern Chagos atolls looked, in 2017, like nothing so much as a vast bone yard of skeletons (Fig. 1). At most sites, it was hard to find even a few percent of living corals, and even fewer soft corals. This disastrous scene extended down to about 15 m depth, after which coral cover became more like, well, like a badly damaged coral reef, but a reef at least. Sometimes there might be a band in the 2-3 m depth range where there were still small massive *Porites*, but otherwise, coelenterates had largely gone.

Figure 1. Dead and tumbled table corals, Ile Anglais, Salomon atoll.

There were differences between reefs of course. Areas which formerly had a lot of *Acropora* tables still had them, though they were dead and tumbled. Other areas which previously had been dominated by soft corals were simply vast bare and relatively low profile expanses – soft corals don't leave a skeleton behind (Fig. 2).

We counted juveniles, and in the killed span their numbers had more or less collapsed, which was unsurprising given the state their parents were in. Curiously, most juveniles were growing on the dead and disintegrating *Acropora* tables, which seemed a foolish strategy in the circumstances, but then, this was pretty much an unprecedented set of conditions in coral evolutionary terms. We had noted the same after the 1998 warming too (Sheppard et al. 2002).

Figure 2. Exposed slope previously with soft coral dominating, Ile Yeye, Peros Banhos atoll

Some species groups were completely absent. Almost no *Stylophora, Seriatopora* or *Pocillopora* were to be found in the top 15 metres zone, nor any of the stubby finger *Acroporas* such as *A. humilis*. Skeletons of all these were now covered by calcareous red algae. The shallow part of the reef was formerly the habitat for these, so the likelihood of a strong and swift recovery was not good. Sadly too, not one live colony was seen of the iconic Chagos brain coral, *Ctenella chagius*, which is largely endemic to the archipelago (it has also been spotted on shoals to the west). As it too is a fairly shallow species, its recovery will be slow if it happens at all. If not, a local extinction might also be a global one.

Seaweeds were much more common, with *Halimeda* especially dominating now in several sites - something not seen before. There were still huge schools of fishes, and it was the presence of these grazers that we think helped ensure the relatively fast recovery after 1998. So, there is some hope.

Without corals to deposit limestone and provide framework, and with huge bare expanses for bioeroders to get stuck in to, reefs will erode rather than accrete, and the effects of coral mortalities must be considered in conjunction with sea level rise too. On the southern atoll Diego Garcia there is a tide gauge, whose data shows an accelerating rise which is now >6 mm per year. This is more than double the oceanic rise, but atolls subside too – that is how they are formed – and while vertical accretion of a healthy reef can easily match such rates of relative sea level rise, a reef without corals cannot. The tide gauge is a top-of-the-range model occupying a small building, not a stick in the sand, so while some deniers have misapplied some ludicrous statistics to show sea level isn't rising, I am afraid the truth is clear to see. I wrote one short piece about a school of small sharks foraging on a grass verge after one high spring tide (Sheppard 2012) and could just as easily have done another on rays cruising across a flooded car park the following year. The US Navy certainly knows what is happening – they spend a fortune on shoreline armouring now. The total land area in that atoll was shown (Purkis et al. 2016) to be stable over a few decades, but the mature eroding parts supported 100 year old trees while the accreting bits are largely deposits of young, soft sediment in embayments – not quite the same thing.

A prognosis is difficult. After 1998 the situation seemed dire, yet coral recovery was rapid because there were no local impacts to impede it. But in 2003 I wrote about extinction dates for Indian Ocean reefs (Sheppard 2003) based on the frequencies of recurrence of these warming spells, and my prediction for Chagos reef 'extinction' was the early 2020s. This was supported recently (van Hooidonk et al. 2016) using different methods, when a very similar answer came up. If corals are indeed killed repeatedly to the extent predicted, then the prognosis cannot be good.

On a final, rather quirky point, we have revised our OUP text *Biology of Coral Reefs* (Sheppard et al. 2009).

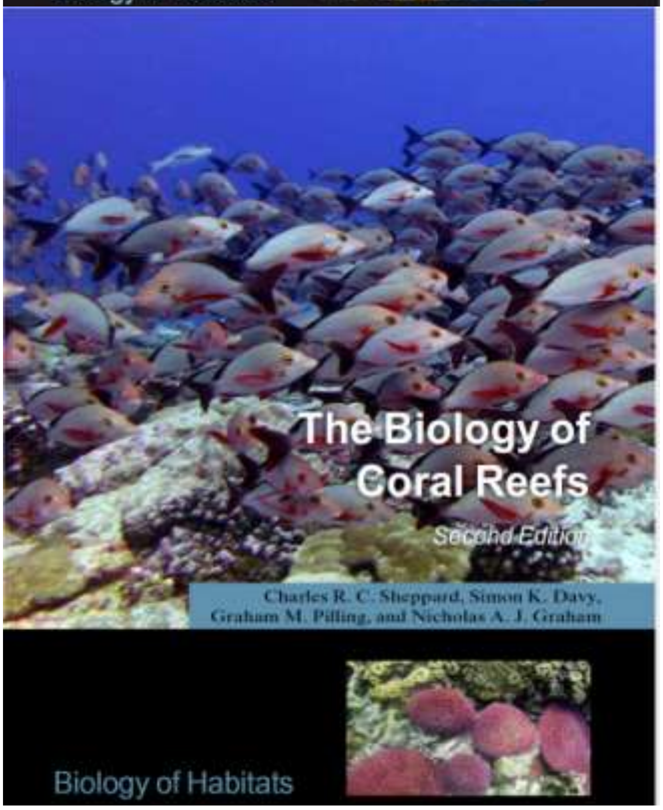

Figure 3 (above)**.** Book cover with photo of same site as figure 1, taken in 2009. **Figure 4** (below). Cover of revised edition, with substantial schools of fish on dead reef (Ile Fouquet Salomon atoll).

The cover photograph of the 2009 edition was of Salomon atoll in Chagos at 10 m depth (figure 3), surely one of the most spectacular dive sites that exist. It showed very good recovery of corals in the years following the 1998 wipe-out. This book revision was finished last year but we visited the same site in April 2017. The scene in Figure 1 is of exactly the same site now! What to do? A revised edition is an update, but quite clearly a photograph of a bone yard would not make a good cover picture. A compromise was reached: although coral cover had collapsed, huge schools of reef fishes still occur throughout this archipelago, this being one of the characteristics of these atolls (there is no fishing there). So, we chose a 2017 photograph of one of these schools, nicely obscuring the fact that coral cover at this site (Fig. 4) was also only 4%. Is that cheating?

In Chagos now (to borrow a colleague's phrase): "It looks like the wheels are falling off".

Acknowledgements. I gratefully acknowledge the Bertarelli Foundation for funding the 2017 expedition to the Chagos Archipelago.

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Gran Banco de Buena Esperanza: unique Caribbean coral reef system

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Gran Banco de Buena Esperanza (GBBE) is a lagoonal coral reef system in the Golfo de Guacanayabo, SE Cuba (Fig. 1), in the middle of the Caribbean reefs, but is among the last unexplored such reefs.

Figure 1. Map of Cuba to show the location of the Golfo de Guacanayobo.

Geomorphology. The senior author still feels the shock of the first touch of the reef front in 1972. His hands began vibrating, a sensation that qualified GBBE reefs as gelatinous (Zlatarski 1982). GBBE has complex irregular reticulated contours (Fig. 2) (Spalding et al. 2001) delineated by 20-25 m high biogenic dams with very steep to vertical external and internal escarpments surrounding deep patios and forming a maze offering refuge for many organisms. The reef tops are flat.

Geology. The real reef building height is approx. 75 m because it is embedded 50 m in grey clay. It stands not on solid substratum but compact red clay dated Late Pleistocene (Fig. 3). GBBE is in tectonic scenario with faults of Cauto depression. The GBBE reefs are approx. 10k years old (Avello Suárez and Pavlidis 1986; Cabrera Castellanos and Batista González 2009). Presumably, hydrodynamic conditions cause the vibration of reef tops because two-thirds of the reef height are embedded in clay but the remaining one-third is vertically reaching toward the water surface.

Figure 2. A satellite image of the Gran Banco de Buena Esperanza (GBBE).

Scleractinia. The predominant reef builders appeared to be corals and sponges. *Acropora palmata* was never found in the GBBE area. At the margins of the maze, slopes show the usual coral diversity for Cuba (Hernández-Fernández et al. 2013). In contrast, the dams' tops exhibited an impressively dense population of delicate branching and miniature coral colonies, with the hybrid *A. prolifera* predominating, along with frequent representatives of *A. cervicornis, Cladocora arbuscula*, *Oculina* spp. and branching *Porites*, and the presence of other species. *Eusmilia fastigiata* forma *guacanayabensis* (Fig. 4) was uniquely found here (Zlatarski 1982; Gonzáles Ferrer 2004; Anonymous 2009).

Origin. Usually, the formation of lagoonal reefs with such a geomorphic shape is expected to be predestinated by antecedent karst terrain (Blanchon 2011). In Golfo de Guacanayabo, this origin is unfeasible because GBBE is on a clay substratum. Most likely, after fragmentation, caused by intense hurricanes, branching Scleractinians constituted the reef base, as observed on soft bottom in the next bay. After this, GBBE grew vertically by keeping up with the sea level during active tectonic faults and the submergence of the Cauto depression sea floor (Zlatarski 1982; Zlatarski 2002; Cabrera Castellanos and Batista González 2009; Zlatarski 2010).

Discussion. In the early 1970's, conventional Caribbean coral taxonomy classified specimens in to discrete species. However, since the first attempt to identify Cuban Scleractinia, it was evident that many specimens don't "fit" within described species but demonstrate intermediate characters. In order to deal with this rich variation of coralla morphology, massive sampling was applied and led to the *phenoide* concept and a revision of taxonomy using the infrasubspecific category *forma*. The species could no longer be considered static (Zlatarski 1982). In time, phenotypic variability, hybridization and chimerism justified this taxonomic "heresy." Two decades before genetics proved the hybrid nature of *A. prolifera*, the Cuban material questioned its species status. Recently, in Cuba, the hybrid is expanding its habitat, forming densely populated areas, and fragments of its branches form the base of build-ups (Zlatarski 2010).

In the original study, and since then*, A. palmata* was not found in GBBE, astonishing in light of the hybrid's presence together with the other of the parental species, *A. cervicornis*. Presumably, the hybrid is fertile, which was confirmed by the presence of more than the F1 generation (Dr. N. Fogarty, oral communication). For four decades one parent and a hybrid successfully co-existed as proof of the evolutionary benefit of coral hybridization for reef survival.

Figure 3. Section of reef dam.

The abundance of small bushy delicate coralla and the existence of endemic phenotypes (Fig. 4) (Zlatarski 1982; Anonymous 2009) make GBBE very promising for the study of coral colony morphogenesis.

GBBE demonstrates the opportunistic character of some coral-dominated settings and presents a rare actualistic model for understanding fossil bioconstructions upon unsolid substratum (Khrischev and Zlatarski 1968; Zlatarski 2002).

Two recent expeditions went around GBBE without visiting the maze reef of dams and patios (Hernández-Fernández et al. 2013). Insufficiency of knowledge about GBBE hinders its adequate protection. This area holds important data relevant to coral ecology, life history, hybridization and skeletal morphogenesis, for understanding the idiosyncrasy of the self - organized shape of reticulate coral reefs, for application of monitored hybridization in our efforts to save the reefs, for paleontological interpretations and for geological exploration, and should not be neglected any further.

Acknowledgments. We are grateful to Dr. N. Fogarty for consultation on *A. prolifera* and to Dr. E. Green for the satellite image.

Figure 4. *Eusmillia fastigiata* forma *guacanayabensis*, holotype, No. 996, X2, Acuario Nacional de Cuba: Photo: junior author.

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The Reef Fish Community of Obispos Reef, Campeche Bank Reefs, Gulf of Mexico: exploring poorly-know sites

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Where is Campeche Bank and Obispos Reef?

The Campeche Bank Reefs are located in the south central part of the Gulf of Mexico, forming an arc along the shelf edge of the Yucatan Peninsula. It is a group of submerged coral reef banks and emergent cays with a geological origin in the Late Cretaceous, beyond which lies the Campeche Canyon (Fig. 1). The reefs are at a distance of 100-200 km from the coast of Yucatan; that long distance has helped maintain the health of these reefs in comparison to coastal reefs, but had also limited the number of research studies undertaken there. The reefs of Campeche Bank have been divided into geomorphologic categories by Logan (1969) as: reef knolls, linear reef walls, crescent reef walls and complexes with multiple emergent walls. The reef at Obispos is a submerged reef forming an extended hard platform or biostrome with external walls over relict topography.

Numbers of cays are present on Campeche Bank having emerged over time as a result of coral sedimentation. These now host patches of flora (Fig. 2) and are used for nesting by sea birds such as the pajaro booby, Sula dactylatra, and hawksbill and green turtles, Eretmochelys imbricate and Chelonia mydas.

What we did there?

During the summer of 2013 we undertook two expeditions to Campeche Bank, in order to produce first descriptions of the coral and fish communities of Obispos Reef and investigate the degree of connectivity both among the reefs of Campeche Bank and between these and the other reefs of the adjacent Gulf of Mexico and Caribbean. Here we provide a preliminary ecological description of only the reef fish community.

Data collection included generating a general description of the reef communities, using visual observations, video and photography (Figure 3). In addition fish abundance data were collected through counts by pairs of divers along sets each of four 50 x 2 m transects established 10 m apart at each of five sampling sites at depths of 8-12m (a total of 20 transects). Reef fish abundance, density, average size and species richness were calculated for each transect and for the whole reef.

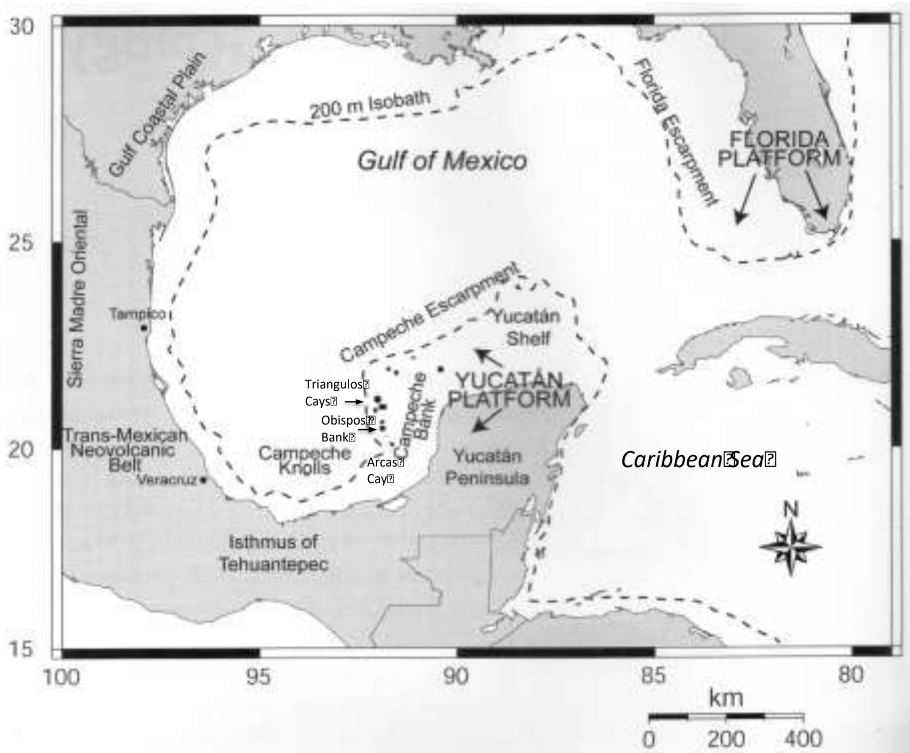

Figure 1. The Campeche Bank Reefs of the Gulf of Mexico (after Salvador).

What we found?
A total of 66 reef fish species were identified over the five sites, with an average of 16 species being recorded per transect. Overall mean density was 1.6 individual per m^2, and the average size of fishes was 19 cm (Table 1). Three species were dominant in terms of abundance: Chromis multilineata, Ocyurus chrysurus and Clepticus parrae, all planktivores. In terms of presence, the most frequently recorded species were the scarids, Sparisoma aurofrenatum, Sparisoma viride and Scarus vetula; the labrids, Halichoeres garnoti, Halichoeres bivittatus and Clepticus parrae, and the damselfishes, Chomis multilineata, Stegastes partitus and Stegastes diencaeus. Some other dominant species included the labrid Thalassoma bifasciatum, the grunt Haemulon flavolineatum and the snapper Ocyurus chrysurus.

Table 1. Ecological descriptors of the reef fish community of the Obispos Reef, Campeche Bank, Mexico.

	Mean per transect	SD	Reef Total
Species richness	15.36	3.81	66
Abundance	166.35	160.23	3327.00
Density per m^2	1.60	1.55	1.60
Mean fish size	18.96	3.21	19

Besides the fish a total of 19 species of coral were identified on the twenty transects performed on Obispos Reef, among them the most abundant (in terms of the number of colonies) were: Diploria strigosa (474), Siderastrea siderea (238), Montastrea cavernosa (183), Porites asteroides (157), Millepora complanata (138), Millepora alcicornis (128), Acropora palmata (120) and Diploria labyrinthiformis (106).

What's next?
It is believed that current flow coming from the Caribbean is the main source of larvae to the coastal and isolated reefs of the Gulf of Mexico, such as Obispos Reef and the Campeche Bank System. The current varies in temperature depending on latitude, but accordingly to recent images made available by NOAA (NOAA, 2013), that particular region of the Gulf of Mexico experiences some of the highest sea surface temperatures recorded in the Atlantic Ocean. One of the main reasons for continuing with monitoring of these reefs is to understand how the reef communities

Figure 2. Cayo Triangulos Oeste, Campeche Bank Reef (Photo: Gilberto Acosta-González)

may be influenced by sea surface temperature of these water bodies in the light of climate change.
It is also intended that further work will help elucidate the degree of connectivity between reefs of the Caribbean Sea and those in the Gulf of Mexico. Questions being investigated include: how similar are the two reef areas in species composition? are there endemic species whose distribution patterns may help indicate the extent of inter-regional recruitment, or in the form of low level artisanal fishing. Levels of fishing have been kept low due to the fact that the reef is submerged and so does not have a protected where boats can stay overnight. Accordingly there have been proposals for establishing Campeche Bank Reefs as a Marine Protected Area (MPA). These initiatives have been without success so far, due to lack of the scientific information required to justify the proposal and to support management plans. Accordingly our efforts will continue.

Meanwhile it was evident that for now Obispos reef is in relatively good condition, having been subjected to fairly low levels of anthropogenic disturbance, mainly are there significant rates of self-recruitment? And do current dynamics and geomorphology influence the biotic organization of the reef systems?

Figure 3. Araceli Pantoja filming a video transect at Obispos Reef.

Figure 4. On board our research boat, the "Lucky Star"; from left to right: Gilberto Acosta González, Carlos González-Salas, Maricarmen Pérez Lara, Julio Alcocer, Baltazar Dominguez, Nuria Saldivar, Aracely Pantoja, Enrique Núñez Lara and Miguel Ángel Ruíz-Zarate.

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Severe Coral Bleaching in the Gulf of Mannar, Southeastern India: a status update*

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The Gulf of Mannar (GoM) located on the southeastern coast is one of the four major coral reef areas in India. The most important reefs in the GoM are distributed around 21 islands within the Gulf of Mannar Marine National Park (8° 47' to 9° 15' N latitude, and 78° 12' to 79° 14' E longitude) between Tuticorin and Rameswaram, covering 160 km of coast. For management purposes, the 21 islands are grouped into the Tuticorin, Vembar, Kilakarai and Mandapam groups (Fig. 1). Their total reef area is 110 km^2 and the survey results in 2005 showed that about 32 km^2 of reef area had already been degraded, mainly due to coral mining and destructive fishing practices.

The reef areas are shallow, between 0.5 and 3 m depth, and a temperature of around 28-29 °C prevails through most of the year, with the corals seeming to be acclimatized to such a situation. However recently during summer (April - June), the temperature has varied between 31.0 and 33.5 °C (Patterson et al. 2008; Patterson 2009).

Since 2005 the Suganthi Devadason Marine Research Institute Reef Research Team (SDMRI RRT) has been regularly monitoring the reefs of the GoM. They recorded elevated Sea Surface Temperature (SST) and resultant coral bleaching during summer every year between 2005 and 2010. The average percentages of corals that were bleached each year during 2005, 2006, 2007, 2008 and 2009 were respectively 14.6, 15.6, 12.9, 10.5 and 8.93 (Patterson 2009), but no bleaching incidents were noticed during 2011 - 2015,

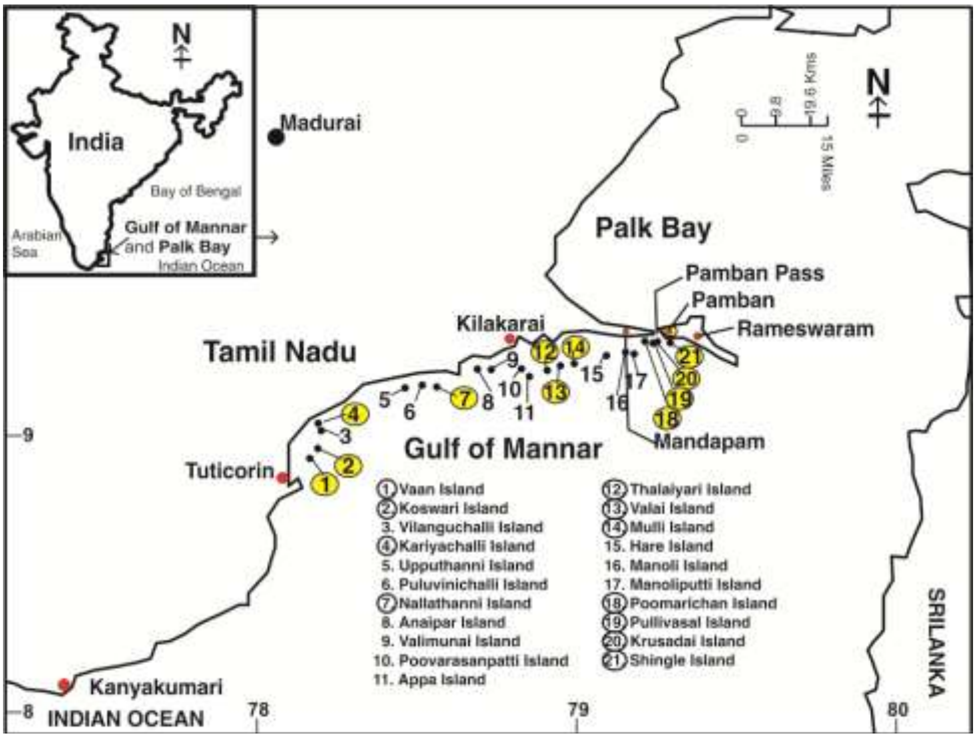

Figure 1. Map showing the 21 islands in Gulf of Mannar and Palk Bay and survey sites

except for a few colonies. During 2005-9 water temperature started increasing from March, and once it had reached 31°C, during mid April, coral bleaching was noticed. Massive corals like *Porites* sp., *Favia sp. Favites* sp. were the first to be affected, followed by branching corals like *Acropora* sp., *Montipora sp.* The incidence of bleaching, in terms of area and depth, was not uniform every year, but the pattern was same. Depending on the onset of rainfall and winds, recovery began during June-July and was completed in 1-4 months. The branched corals recovered quickly after the temperature drop, but massive corals took longer.

Previously in 1998 a significant rise in sea surface water temperatures across much of the Indian Ocean and elsewhere linked to an ENSO event seriously affected many reefs previously regarded as near pristine. Although some bleaching was experienced that year in the Gulf of Mannar, studies along the Tuticorin coast in the southern part of the Gulf, showed densely populated corals and no sign of bleaching (Patterson et al, 2007).

Coral bleaching and mortality in 2010

During 2010, elevated sea surface temperatures (32.2 to 33.2°C) persisted for four months from April and an estimated 10% of live coral colonies bleached among which there was more than 50% subsequent mortality. The species which mostly died include *Pocillopora damicornis*, *Acropora formosa*, *A. intermedia*, *A. nobilis*, *A. cytherea*, *Montipora digitata, M.foliosa, Favia* sp. and *Echinopora* sp. Recovery was primarily noted among partially bleached colonies of *P. damicornis, A. formosa*, *A. nobilis*, A. cytherea, *M. foliosa* and *M. divaricata* (Patterson et al., 2012). Previously the reefs of the GoM had exhibited signs of resilience, since after a halt to coral mining in 2005, live coral cover had increased from 37% in 2005 to 43.5% in 2009, but coral mortality in 2010 reduced live coral cover back to 34%. However even then mortality was observed only in the adult colonies, while coral recruits (0-10cm) and young adult colonies (11-40 cm) were relatively unaffected by bleaching, and this, in subsequent years, assisted recovery to 39% live coral cover by 2015. Also, following the 2010 coral mortality it was noticed that several reef fish species *(Lutjanus lutjanus, L. malabaricus, Siganus canaliculatus, Scarus ghibbus, Pterois russelii, Sargocentron rubrum*) had disappeared from the reefs, although they were seen in abundance in deeper areas (over 20 m depth) and around patch reefs about 15 km away from islands.

Coral bleaching in 2016

In 2016, the timing, intensity and pattern of coral bleaching warned of potentially severe loss of corals, since the same pattern prevailed as in 2010, with bleaching starting early i.e. in late March. Therefore over 12 - 16 April and 29 April - 02 May two rapid surveys were conducted to ascertain bleaching intensity and pattern over 11 islands: Vaan, Koswari and Kariyachalli islands in Tuticorin group, Nallathanni Island in Vembar group, Mulli, Valai and Thalaiyari islands in Kilakarai group and Single, Krusadai, Pullivasal and Poomarichan islands in Mandapam Group, and also at nearby Pamban in Palk Bay (Fig. 1). In each reef area (island), 6 separate 20 x 4 m belt transects (English *et al.,* 1997) were laid parallel to the reef face; these were distributed semi-randomly with at least 20 m between each transect.

The first survey showed that beaching was highest on reefs in the Tuticorin group of islands (10.7%) followed by Keelakarai (5%) and Mandapam (3.1%). Almost all massive corals were bleached (full or partial), and also branching and digitate corals. No coral recruits were affected, except of *Pocillopora* sp. in Mandapam. The average water temperatures were highest in Tuticorin with 32.6 ^{o}C, followed by Keelakarai with 31.8 ^{o}C and Mandapam with 32 ^{o}C. The bleaching was most severe between 0.5 and 3 m depth, especially below 2 m. In Palk Bay however bleaching was minimal (1.4%) with average water temperature at that time only 30.9 ^{o}C.

During the second survey however, after a 15 days interval, beaching intensity was much more extensive, being highest on the reefs of the Mandapam group (40.5%), followed by Tuticorin (37.7%), Vembar (32.5%) and Keelakarai (31.3%). By this time on all islands both massive and digitate corals were almost completely bleached. The average water temperatures were 33.5 ^{o}C in the Mandapam group, 33.0 ^{o}C in both Keelakarai and Vembar groups and 32.6 ^{o}C in the Tuticorin group. The recruits of *Pocillopora* sp. and *Montipora* sp. were now completely bleached, while those of other genera like *Acropora* sp. and massive corals had also started bleaching. In Palk Bay, 12% of the live corals were bleached and the water temperature was 33.5 ^{o}C.

The most affected coral species were *Montipora divaricata, M.digitata, M.foliosa Acropora formosa*, *A. intermdeia*, *A. nobilis*, *A. cytherea*, *Goniastrea retiformis*, *Porites lutea*, *Favites abdita* and *Favia favus* (Figs. 2a - c). At Koswari Island in the Tuticorin Group, soft corals like *Sacropohyton crassocaul, Sinularia polydactyla* and *Lobophytum crassum* were also affected (Fig. 3), and at Kariyachalli and Vaan Islands, the sea anemone, *Stichodactyla haddoni,* was affected. In Palk Bay, *Acropora cytherea, Porites solida*, *P. lichen*, *Platygyra lamellosa*, *Goniastrea retiformis*, *Symphyllia* recta, *Favites* sp., *Favia favus and F. pallida* were the most affected species.

Figure 2. a) (top) bleaching of Acropora in the Gulf of Mannar; b) (centre) bleaching of Porites at Kariyachilli Island in the Tuticorin Group; c) (bottom) bleaching of Montipora at Vaan Island, also in the Tuticorin Group.

Conclusions

The latest rapid survey conducted on reefs around 11 of the islands over 29 April - 02 May showed an average coral bleaching of 33%, a more than 5 fold increase since the prior survey, and higher than that seen in any previous year; likewise there had been a more than 8 fold increase in bleaching in Palk Bay over the 15 days interval. When 10% coral mortality was experienced due to elevated sea surface temperature in 2010, no impact was recorded on coral recruits, allowing recovery and a steady increase in live coral cover from 2011 onwards. On this most recent occasion however the recruits have been bleaching from the beginning, which is not a good sign for the future health of the reefs of the GoM. Further surveys by SDMRI RRT in association with the Forest Department will take place in order to monitor the situation.

Figure 3. Bleaching of soft corals at Koswari Island, in the Tuticorin Group.

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An encrusting p*eyssonnelid* preempts vacant space and overgrows corals in St. John, US Virgin Islands

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Increasing abundances of macroalgae have dominated studies of Caribbean coral reefs since at least 1994, when Terry P. Hughes described the rapid transition of Jamaican reefs from scleractinian- to macroalgal-dominance (Hughes 1994). Since this seminal contribution, similar transitions have been recorded on many reefs in both the Caribbean and the Indo-Pacific (e.g. Mumby 2009; Bruno et al. 2009), and in most cases they have involved increased dominance of foliose or stipitate algae in the genera *Dictyota, Halimeda, Sargassum, Turbinaria* and *Lobophora*. Increased cover of macroalgae has been widely observed on the shallow coral reefs of St. John, US Virgin Islands, where some reefs have underdone large declines in cover of scleractinian corals, and greatly increased cover of canopy-forming algae (Edmunds 2013).

In 2015, while conducting surveys on shallow reefs (< 5 m depth) along the south shore of St. John, US Virgin Islands, we found areas of high cover of macroalgae that were different from that frequently reported in the literature: large areas of hard substratum were densely coated by a brown crust. A portion of this crust was identified as *Peysonnelia stoechas* (Bourdouresque and Denizot 1975) based on the presence of hypobasal calcification and signs of a single-layered hypothallus (Fig. 1; R.S. Steneck pers. comm.), although the crust has a gross morphology and growth pattern similar to *Ramicrusta* sp. as described in Bonaire (Eckrich and Engel 2013). We measured the abundance of this algal crust using 50 m video transects (recorded with a GoPro Hero 3) at 3, 5,

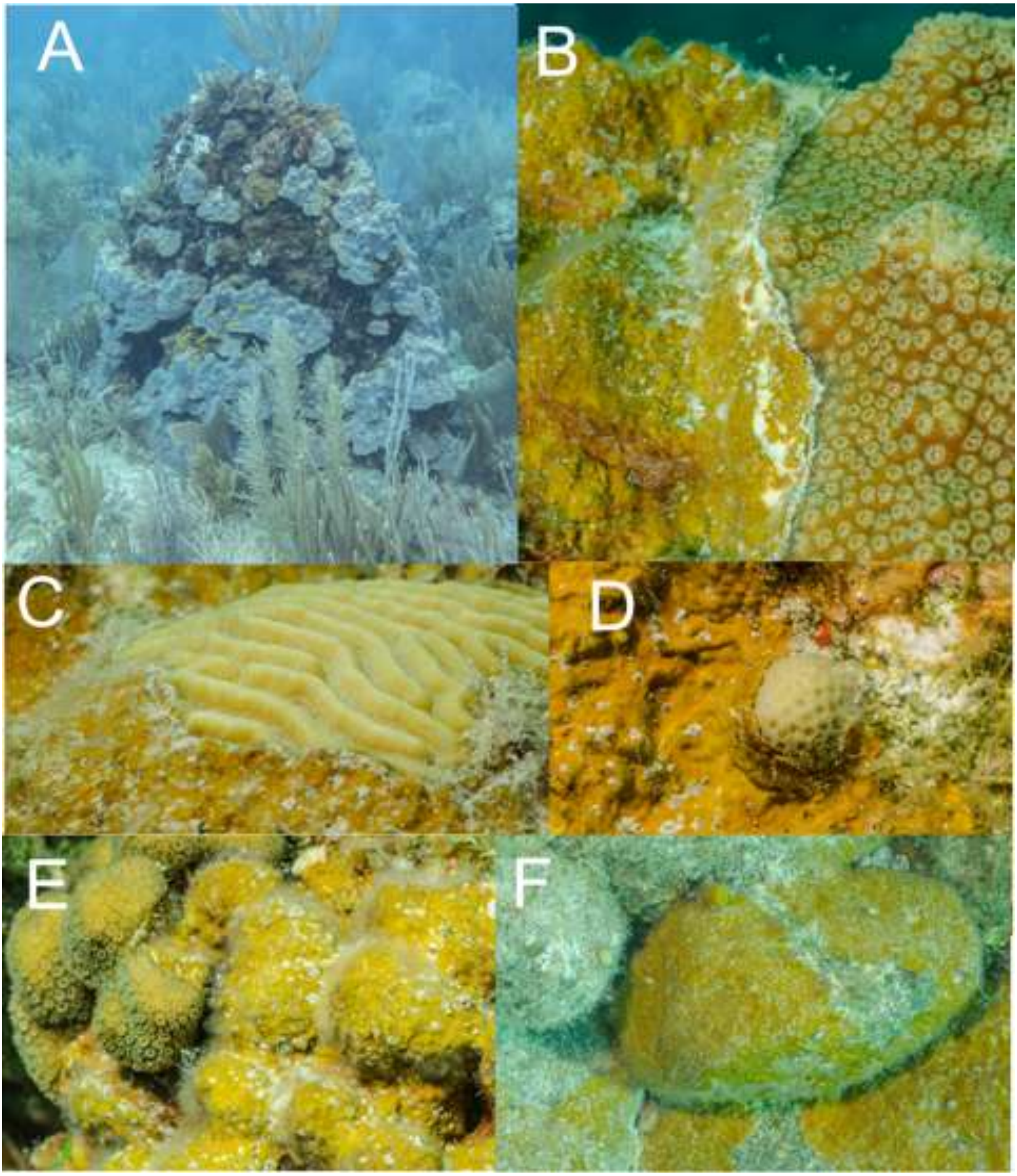

Figure 1. a) Peyssonnelid crust overgrowing *Orbicella faveolata* (photo credit HR Lasker). b) Peyssonnelid crust overgrowing *O. Annularis* (photo credit PJ Edmunds). c) Peyssonnelid crust overgrowing *Pseudodiploria strigosa* (photo credit PJ Edmunds). d) Peyssonnelid crust overgrowing *Porites astreoides* (photo credit PJ Edmunds). e) Peyssonnelid crust overgrowing *Madracis decactis* (photo credit PJ Edmunds). f) Peyssonnelid crust growing on igneous boulders, small *Porites astreoides* to the left is ~ 1 cm diameter for scale (photo credit PJ Edmunds).

and 7 m depth at five sites, haphazardly selected between Cabritte Horn and White Point on the south shore of St. John. Still images (n = 20 transect^{-1}, each ~ 250 cm^2) were randomly extracted and analyzed for percentage cover of peyssonnelids using a grid of 25 squares that were scored for dominance by this alga (i.e., 4% resolution). Mean cover was 8.5 ± 1.3% at 3 m, 3.4 ± 0.6% at 5 m, and 1.0 ± 0.2% at 7 m depth (± SE, n = 100 depth^{-1}). Cover varied significantly among depths ($F = 21.76$, $df = 2, 147$, $P < 0.001$), and was highest at 3 m (versus 5 and 7 m) depth (Tukey HSD: $P < 0.05$). At 3 m depth, the crust was commonly growing up to and over scleractinians (Fig. a - e) and on igneous boulders (Fig. 1f). The impact of this peyssonnelid crust on the reef community was at times greater than its mean planar cover suggested, as large colonies of ecologically important scleractinians (e.g. O*rbicella faveolata*) sometimes had large proportions of their surface covered by this peyssonnelid (Fig. 1a). Inspection of photographs and notes from surveys conducted since 1987, suggests that the crust began to occupy large areas of benthic substrate around 2011 and 2012, but overall such high cover of this crust is novel for St. John. Although we have not quantified its growth rates, its ability to spread rapidly is suggested by the overgrowth, within a year, of 20 × 20 cm settlement plates which were installed in August 2013 at 5 m depth, when the crust was not a conspicuous space occupier among the benthos. After three years, no scleractinian recruitment was recorded on these plates.

In the family Peyssonneliaceae (phylum Rhodophyta, subclass Rhodymeniophycidae), the genera *Peyssonnelia* and *Ramicrusta* both form calcified crusts and include 119 and 10 species, respectively (http://www.algaebase.org/) and have 25 and 10 species respectively recorded in the tropical and subtropical western Atlantic (Wynne 2011). Several peyssonnelids overgrow corals (e.g., Ballantine and Ruiz 2011; Pueschel and Saunders 2009; Eckrich et al. 2011), and recently *Ramicrusta* spp. has been reported to aggressively occupy hard substrata on shallow reefs in Bonaire (Eckrich and Engel 2013) and potentially in several locations in US Virgin Islands (T.B. Smith pers. comm.). Similar to that account of *Ramicrusta* spp. in Bonaire, surveys conducted for juvenile scleractinians in St. John (Edmunds 2013) have not revealed any scleractinians growing among the peyssonnelid crust, while cases were found where this crust had smothered juvenile corals.

Together, our findings from St. John suggest that not only is this peyssonnelid crust a strong competitor for space, but it is not a favored surface for recruitment by invertebrates including scleractinians (Arnold and Steneck 2011). Poor recruitment has been proposed as a leading cause of incomplete scleractinian population recovery after disturbances (Arnold et al. 2010; Gilmour et al. 2013), and the recent increase in cover of peyssonnelids on shallow reefs in St. John ultimately might affect scleractinian community resilience. An important next objective will be to identify the peyssonnelid(s) spreading over the shallow reefs in St. John, and to develop effective means to distinguish *Peyssonnelia* from *Ramicrusta.*

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BOOK & EQUIPMENT REVIEWS

Coral Reefs at the Crossroads

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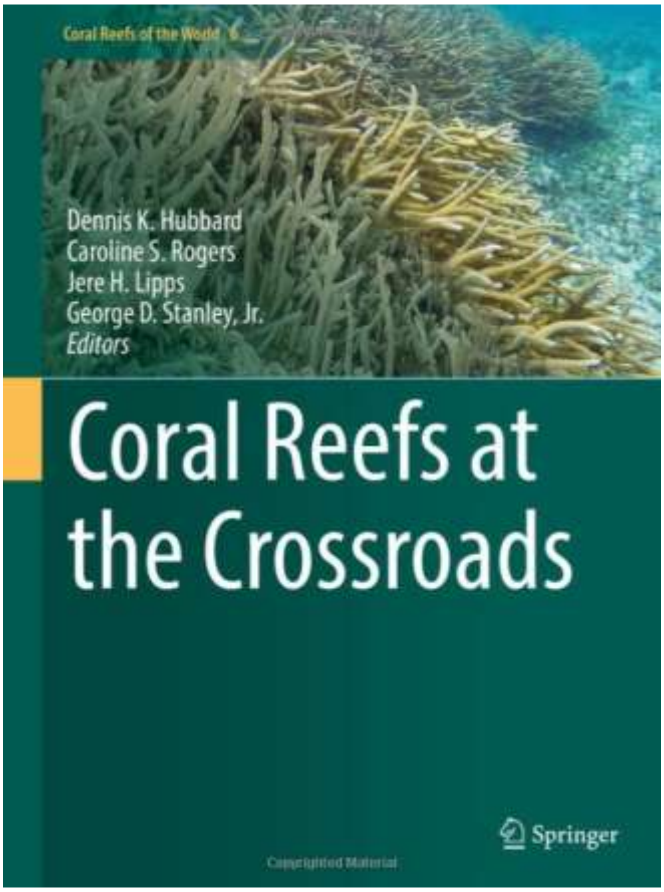

The lead editor of this new compendium of coral reef research, Dennis Hubbard, and I were faculty colleagues in the late 1970s to mid-80s at the West Indies Laboratory (WIL) of Fairleigh Dickinson University in St. Croix in the U.S. Virgin Islands. Dennis often complained about the isolation of reef geology and paleontology from biology in the education of students and at the coral reef symposia and other meetings. At WIL he worked hard to change this in our undergraduate teaching program in tropical marine science. In the present era of crisis of decline of global coral reefs, he and his co-editors pitch the book at the important goal of integration of these two key coral reef sciences to serve scientific understanding and reef management and conservation.

The book has 12 multi-authored chapters by 15 well-known reef scientists, a total of 6 geologists and 9 biologists. In the opening chapter, Hubbard looks at the history of coral reef research and laments the narrowing of focus and loss of the big picture at the same time that our analytical tools and imaging from space and underwater have broadened our capability to see the whole. He seeks to bring biology and geology together to encompass the true scales in time and space of threatened global coral reefs.
Each subsequent chapter highlights the importance of a geological/paleontological point of view. Chapter 2 (Jokiel, Jury and Kuffner) is a very thorough and well-illustrated discussion of coral calcification with emphasis on the potential impact of ocean acidification. It is notable for a state-of-the-art discussion of coral anatomy relative to calcification. The book is dedicated to Paul Jokiel and this chapter is a fitting memorial to a talented scientist. In Chapter 3, Lipps and Stanley discuss photosymbiosis by reef building organisms in past and present reefs, noting that encysted dinoflagellates in reef organisms were present in the Triassic and, by indirect evidence, as far back as the Cambrian. They develop the hypothesis that the major roles of photosymbiotic reef organisms explains both the successes and the failures of reefs over geologic time. Perry and Harborn (Chapter 4) examine the impacts and responses of reefs to bioerosion under changing ecological and environmental conditions. In spite of its acknowledged importance, there are few studies of erosion rates by well-known eroders. In Chapter 5, Wulff points out that the sponges of the Paleozoic and Mesozoic were important reef builders. While contemporary reef sponges live and then die without a trace, they are critical in reef building, stabilization and bioerosion.

Hubbard and Dullo (Chapter 6) look at reef building through geologic time and speculate about the future of reefs under climate change and sea level rise. They suggest that reversing the Doctrine of Uniformitarianism to "the past is the key to the present" may prove useful as we try to predict the many potential future scenarios of climate change. Important among these is the potential of reef accretion to pace anticipated sea level rise. Aronson and Precht (Chapter 7) discuss the persistence of reefs through huge environmental changes over geologic time. They reject the idea of many paleontologists that reef communities totally reorganize each time after a major disturbance and conclude that reefs across regions were able to track major and rapid environmental changes through time making reassembly unnecessary. Lipps and Stanley (Chapter 8) warn that while reefs have diversified, gone extinct and re-appeared numerous times since the early Paleozoic to Recent times, the present pace of environmental change, particularly increasing CO_2 in the atmosphere, may exceed the tolerance limits of reefs and reef organisms. Coming to a similar conclusion, Jury and Jokiel (Chapter 9) consider climate change, ocean chemistry and the evolution of reefs and conclude that the recovery of reefs numerous times in geological history does not necessarily mean that history will repeat itself today, largely because of the impact of unprecedented levels of CO_2 in the atmosphere. Lescinsky (Chapter 10) asks if living reefs can be equated with their fossilized mineral remains. He concludes that data from mineral reefs provides a baseline and a context to compare with changes to living reefs.

The final two chapters concentrate on contemporary reefs and discuss what actions will help their survival. Chapter 11 (Aronson and Precht) considers the anthropogenic stressors that operate locally, regionally and globally on the threatened reefs of the Caribbean Sea. Do local scale processes or global ones limit living reefs? They conclude that global scale changes of CO_2 into the atmosphere appear to be the strongest, but local scale processes are also influential. Management must address all the relevant scales to save coral reefs. In the last chapter, Rogers and Miller discuss the current state of coral reefs and the monitoring techniques that will track changes into the future. They briefly review various management goals including marine protected areas, managing for biodiversity and resilience and valuate their effectiveness. The chapter notably contains a detailed text box, lavishly illustrated with color photographs, on the evolving story of Elkhorn coral (*Acropora palmata*) a key Caribbean reef builder. They argue that geochemical techniques applied to cores could help determine the recent history of reefs as well as the future impact of management.

Comparing Birkeland (2015) *Coral Reefs in the Anthropocene* (Springer), also a multi-authored compendium of 12 chapters, to *Crossroads* and judging only from its table of contents, *Anthropocene* is more oriented to coral reef biology and ecology. The editors of *Crossroads* have achieved their goal of better integrating biology and geology in a state-of-the-art review of coral reef research. However, I have a few quibbles. There is considerable redundancy between the chapters which could have been more integrated had the authors met in advance to discuss the book, its goals and the individual chapters. I am also surprised that with the exception of the final chapter, only a few authors point out the management and conservation implications of the science. Perhaps this will inspire a companion volume.

As I finish this review, several papers in top journals and the media report a third successive year of widespread coral bleaching on the iconic Great Barrier Reef (GBR) and in other areas of the world. Prominent scientists have announced that unless there is an immediate change in the policy of the global industrialized societies to reduce the concentration of $C0_2$ and greenhouse gases the damage may be irreversible. There is a new urgency in the air, after years of largely frustrated attempts by reef scientists to draw attention to the sum of human disturbances to coral reefs and the need for local, regional and global management. We must support science, but we must also actively support on-going international efforts to convince policy makers to pay immediate and sustained attention to global policies that limit CO_2 and greenhouse gases. The clock is ticking.

Literature Cited
Birkeland, C. (Ed.). 2015. Coral Reefs in the Anthropocene. Springer, 271p. ISBN: 978-94-017-7248-8

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CONFERENCES & WORKSHOPS

Together for Continuity into the Second Century of a Coral Transect

Over a decade before the Great Barrier Reef Expedition of 1928-1929, Alfred Mayor of the Carnegie Institute did a number of studies from 1917 to 1920 of the growth, ecology and distribution of corals in American Samoa. One of his studies in Spring 1917 was to quantify the distribution and diversity of corals along a 267-m transect off the village of Aua in Pago Pago Harbor. His accurate description of the transect included photographs and a map which allowed locating the transect in the future. The U.S. Coast and Geodetic Survey placed permanent markers at the two ends of the transect which has been resurveyed 9 times over the past century. A summary of the first 90 years can be found online at http://micronesica.org/sites/default/files/2013-06_birkeland_et_al_aua_transects_screen_res.pdf

When Charles Birkeland and Alison Green came to American Samoa to repeat the survey on the 100th year, Alice Lawrence and her colleagues at the American Samoa Governor's Coral Reef Advisory Group (CRAG), in collaboration with the NOAA Pacific Island Regional Office, took advantage of this event to reach out to the American Samoan students and public by organizing events to develop their awareness of the value and their concern for the health of their coral reefs. They arranged for visiting scientists to give talks at two elementary schools and one high school and to a public gathering to highlight the importance of coral reefs to their standard of living and things that can be done locally to keep them healthy enough to persevere in the face of global changes. They arranged for a science fair in the village of Aua at which the government groups involved with managing coral reefs (American Samoa Community College (ASCC) Marine Science Program; University of Hawaii (UH) Sea Grant program; National Park Service of American Samoa; Department of Marine and Wildlife Resources; National Marine Sanctuary of American Samoa; NOAA Pacific Island Regional Office; American Samoa Coastal Zone Management Program; ASCC Land Grant, and the American Samoa NRCS office) maintained information booths. A student symposium on coral reefs took place at the National Marine Sanctuary of American Samoa Ocean Center. The visiting scientist spoke at a STEM (Science, Technology, Engineering and Mathematics) congress on how Samoan women were also needed to fill positions at American Samoan agencies that worked to manage the island resources wisely, and students should consider getting the training to follow such careers. All the above, including taking data along the transect, took place within one week.

For continuity into the future, Alice also arranged for three local scientists, Motusaga Vaeoso of CRAG, Mareike Sudek of National Marine Sanctuaries, and Kelley Anderson Tagarino of UH Sea Grant, to participate in taking data along the transect.

In American Samoa, the coral reefs are under the jurisdiction of the local village leaders. To obtain permission to resurvey the Aua transect, we got up at 4:30 am in order to be at Aua village before dawn and take part in the village council. The Chiefs gave short talks and then each of us drank a small bowl of kava in turn. It was an interesting experience and it is good because local authority probably provides more diligent management than open access.

Chuck Birkeland (email: charlesb@hawaii.edu)

Chiefs, representatives of government agencies, teachers and students come together to celebrate the science and management of their coral reefs

ISRS MEMBERSHIP

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

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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 services page at: https://www.sgmeet.com/isrs/membership/memberlogin.asp

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 relative 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