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REEF ENCOUNTER

ICRS 13, Honolulu, Hawaii – Conference Perspectives
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Conservation Committee & the South China Sea
Education Committee Initiatives
Don Kinsey and Paul Jokiel

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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: **Cultural blessing at the Opening Ceremony of the International Coral Reef Symposium (ICRS13) at the Hawaii Convention Centre, Honolulu, Hawaii, 20th June 2016 (photo R. Ormond).**

EDITORIAL

Again this edition of Reef Encounter is appearing a little later than anticipated. My excuse has been an exceptionally busy year, not least with involvement in ICRS13 in Honolulu, as well as three deserving research and conservation projects .

In this edition we offer a series of views of ICRS13; the diversity of experiences should interest those who were there, as well as members unable to attend. We have also chosen to highlight the work of two still relatively new ISRS committees - the Conservation Committee and the Education Committee. Any members interested in assisting their work are urged to contact the respective chair. Two other articles deserve special comment. We are grateful to Charlie Veron and co-authors for providing an introduction to their CORALS OF THE WORLD website. And I am also pleased to include in the Reef Perspectives an article by one of our youngest members , Austin Yeung, still a pupil at the American School in Shanghai, China. The views and commitments of his generation will be critical to the survival of coral reefs as we have known them.

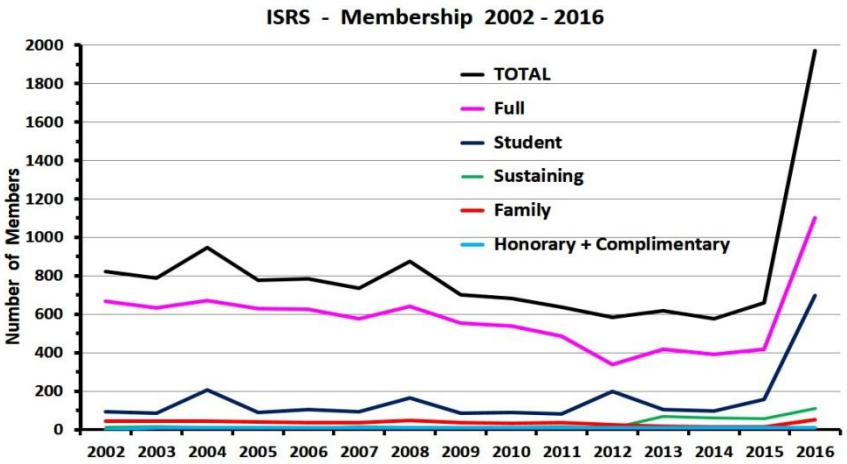
Rupert Ormond
Corresponding Secretary ISRS & Editor, Reef Encounter
Honorary Professor, Heriot-Watt University, Edinburgh, UK

RECORDING SECRETARY'S REPORT

During the second part of 2016, in addition to regular officers' conference calls, we held ISRS Council Meetings both on June 20th (at ICRS13 in Honolulu) and over 25th-29th October (by Skype). At these meetings Council considered a range of initiatives that should further raise the Society's profile. The very successful ICRS in Honolulu afforded us a measure of financial stability that allowed us to expand the number of student fellowships and to consider regional chapters. The Council is also developing a range of scientific statements and policy papers to highlight issues relevant to ISRS's mission. We welcome your suggestions for issues and involvement in this effort. Finally, we look forward to a new cohort of incoming officers and councilors and give our deepest thanks to those who have served the Society over the last four years.

Kiho Kim
ISRS Recording Secretary & Chair Website Committee
Associate Professor, American University, Washington DC, USA

TREASURER'S REPORT



2016 was a very positive year for the Society with both human (i.e., members) and financial resources reaching record levels. Over the last year, total ISRS membership tripled from 660 in mid 2015 to 1965 paid members at the end of November 2016, almost entirely due to the success of the 13th ICRS in Honolulu (see the above figure). While available funds have increased every year since 2012, dues from the membership surge mean that financial reserves are now approaching an all-time high that will enable the society to expand existing programs (e.g., fellowships) and develop new regional and global initiatives to support research, management and conservation of reefs. Particularly gratifying is the commitment to ISRS shown by increasing numbers selecting the higher dues of Sustaining membership (111 in 2016).

As of 11 December 2016, uncommitted funds totalled $US91,604. After repayment of the $41,530 advanced to the Schneider Group as "seed money" for the ICRS, plus additional ICRS income from registration fees that exceeded expenses, uncommitted funds available to ISRS are likely to exceed $150,000 early in 2017. This total does not include income from the ~1500 members whose membership expires at the end of 2016 - if most of these renew at current levels, their dues could generate another $50-75,000.

As my tenure as Treasurer draws to a close (2009-2016), I am happy to pass these healthy finances on to the incoming Treasurer. I also want to express my appreciation to all the other Officers and Councilors whose efforts and vision over the last eight years have revitalized the Society, and to the Schneider Group who have enabled us to realize that vision. I now look forward to furthering the mission of ISRS in other ways.

Donald Potts
ISRS Treasurer
Professor of Biology, University of California at Santa Cruz, California, USA

SOCIETY ANNOUNCEMENTS

SOCIETY AWARDS AND HONORS 2017

Call for nominations for the 2017 round of awards and honors

(Deadline for receipt of nominations January 15th, 2017)

The Society acknowledges the scholarship and work of members through the annual award of a number of honors including:

1. **A Young Scientist Award**: one awarded each year to a scientist under the age of 35, in recognition of a publication or series of publications.
2. **A Mid-Career Scientist Award**: one awarded each year in recognition of excellence in research during the preceding approximately 10 years by a mid-career scientist.
3. **An Eminence-in-Research Award:** up to two awarded per year to established scientists in recognition of an outstanding body of research over an extended period of time. (The award is seen as being second in status to the Darwin award of which only one is awarded every 4 years.)
4. **A World Reef Award:** one awarded per year in recognition of scientific or conservation achievement by an individual who is a member of a group under-represented in the field of reef science or management.
5. **ISRS Fellow:** the status of ISRS Fellow is awarded to members in recognition of scientific achievement and / or service to reef conservation or management and / or service to ISRS over a significant period of time. Up to 15% of full members may be recognised as Fellows.

Nominations should be sent, preferably as a single .pdf file by email, to the secretary of the Society's awards committee, Dr Andrea Grottoli, School of Earth Sciences, Ohio State University, 125 South Oval Mall, Columbus, Ohio 43210 USA, email: grottoli.1@osu.edu.
Nominations for any of the above awards and honors may be made by any existing active member of ISRS (although nominators are not eligible to themselves be separately nominated for the same award category in the same year). A nomination should consist of:

a) a completed ISRS Awards Nomination Form,
b) a one-page nomination letter (not to exceed 500 words)
c) two additional letters of support (not to exceed 500 words each) from other current ISRS members
d) a C.V. (up to 6 pages in length) of the nominee

Further information may be found on the Awards & Honors page of the ISRS website at: http://coralreefs.org/society-awards-and-grants/awards-fellowships/

Society Elections

Elections for two officers (Treasurer and Recording secretary) and six replacement Council members are ongoing. Members who have not yet voted on receipt of this issue, are urged to please do so by the end of the day on Monday January 16th (2017).

To vote please go to the following webpage: http://sgmeet.com/isrs/ballots/2016-2017/election.htm. There members will need to enter their member identification number which may be most easily found in the email sent to them by ISRS membership services (isrs@sgmeet.com) on 20th December 2016.

ISRS Graduate Fellowships / Research Grants

Call for applications

(Deadline for receipt of applications 31st January, 2017)

ISRS is committed to encouraging and supporting students interested in coral reefs, and, for 2017, will be offering six **Graduate Fellowships** for research on Coral Reef Ecosystems, three of which will be reserved for students coming from developing countries in different parts of the world. The deadline for the receipt of applications is 31st January 2017.

The fellowships are available to students who are either student or full members of ISRS, and are already admitted to a Research Masters or PhD program at an accredited University or College. The fellowships provide funding (currently US $2,500 per award) which may be used to cover the costs of fieldwork, or of visiting another laboratory, in order to obtain results that are to be included within a thesis submitted for a research degree (e.g. PhD, MPhil, or MSc). The funding is not available for use after a student has submitted their thesis, nor to cover the costs of attendance at a Conference.

In addition to providing funding, ISRS will assist the successful candidates in liaising with other members who may be in a position to assist their research, while in turn the holders are required to prepare reports on their progress for publication in Reef Encounter and on the society's website. The successful candidates are expected to be announced by the end of March 2017.

Further details can be downloaded from the society's website at: http://coralreefs.org/society-awards-and-grants/student-grants-and-awards/

Members' Directory

A reminder to members that the Society's Directory of Members is available in the Members' area of the Society's website. The Directory can be searched for example to find members living in different countries, or working in a specific ocean region or researching a particular subject area. To access the Directory log in to your account using your email address and ISRS password at: http://coralreefs.org/membership

European Coral Reef Symposium 2017

CALL FOR SESSIONS & WORKSHOPS

13-15th December 2017, Department of Zoology, University of Oxford, UK

The next European Coral Reef Symposium, sponsored by ISRS, will be held in association with the 20th Annual Reef Conservation UK Meeting, in the Department of Zoology, at the University of Oxford, Oxford, UK, from 13th-15th December, 2017.

The three day conference is planned as the European Inter-congress scheduled to take place approximately midway between ICRS13 and ICRS14. The meeting will consist of talks, poster sessions, social events and workshops.

The organisers are currently calling for proposals for thematic sessions and workshops. Proposal forms may be completed at or downloaded from the Conference web-page at:
http://www.reefconservationuk.co.uk/ecrs-2017.html
The deadline for receipt of proposals is February 15th, 2017.

A subsequent call for abstracts is anticipated during March. Further information about submission of abstracts, registration and accommodation is or will be available at the same site or on the conference pages of the ISRS website at: http://coralreefs.org/conferences-and-workshops/

COMMITTEE ACTIVITIES

The ISRS Conservation Committee

Sue Wells (chair)
email: suewells1212@gmail.com

Conservation was not seen as an aim for the Society when it was founded in 1980 – the original constitution stated that the purpose of ISRS was "to promote, for the benefit of the public, the production and dissemination of scientific knowledge and understanding concerning coral reefs, both living and fossil." At that time, of course, there was little indication that reefs would undergo the precipitous decline that we are now seeing.

Today, most scientific research on coral reefs is related to improving our understanding of how we can mitigate their decline and restore their health. A large proportion of the ISRS membership is involved in research that is critical to underpinning conservation efforts. The lack of a mechanism by which the Society could directly engage in such activities was particularly evident in the run up to the December 2015 UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21), when the Society was developing its position statement on climate change: the burden of work fell on the ISRS Corresponding Secretary and a few other committed members.

A proposal for a Conservation Committee was thus put to Council, and Terms of Reference were approved in April 2016. The purpose of the Committee is "*to consider what coral reef **conservation and management-related activities** it is appropriate for the Society to undertake, considering the Society's character and constitution, **prioritise** those activities and, subject to approval in principle by the Council, **pursue those activities** as energetically as is practicable*."

The scope of work of the Committee includes:

i. Promoting the publication and dissemination of scientific data and analysis resulting from the work of ISRS members to facilitate conservation; this includes production of briefing papers, policy responses and other statements;
ii. Reviewing materials submitted to *Coral Reefs* and *Reef Encounter* that address conservation issues;
iii. Ensuring that ICRS and other ISRS-supported coral reef meetings appropriately address conservation issues;
iv. Providing liaison between ISRS and global and regional conservation bodies such as ICRI (International Coral Reef Initiative) and the CBD (the Convention on Biological Diversity) Secretariat, and providing scientific evidence and expertise as needed;
v. Ensuring that ISRS provides scientific input into major administrative and legal processes that contribute to the health of reefs (such as the Climate Change Conferences, the decadal International Years of the Reef and the CBD's Sustainable Oceans Initiative).

The Committee is made up of volunteers, with at least three members who are on ISRS Council, two who are students, and two who are members or employees of international or significant national conservation organizations. The aim is that the Committee as a whole should have good geographical representation and a variety of research interests. We can also co-opt other people onto the Committee on a short-term basis for specific activities and to provide regional or thematic advice.

Since its establishment, the Committee has managed the application for ISRS to join ICRI – the International Coral Reef Initiative (see box on page 11) – and was accepted at the ICRI General Meeting in November 2016. It has also overseen the production of the briefing document on the South China Sea (see page 12), with the assistance of ISRS

members John McManus and Ed Gomez, and supported the motion put to ICRI that 2018 should be recognized as the third International Year of the Reef (IYOR3) (see box below).

ISRS does not intend to duplicate the work of or compete with existing conservation organizations and, to this end, we have developed some simple criteria that can be used, in combination with the scope of work defined in the TOR, for deciding which issues to engage with. Essentially, ISRS will become involved in a conservation issue if the reef(s):

i. Lie within a significant Marine Protected Area (e.g. within a World Heritage Site).
ii. If not protected, are among the two or three reef areas of the greatest scientific, socio-economic, cultural or conservation significance within a country.
iii. Span several countries, or stretch across a region of global importance; or
iv. If not meeting any of the above criteria constitutes, for other clearly documented reasons, a very special case.

Current members are:

Sue Wells (chair) – Consultant, Cambridge, UK
Stacy Jupiter (ISRS Council Member) - Wildlife Conservation Society, Fiji
Stephanie Norman (ISRS Council Member) - Marine-Med (Marine Research, Epidemiology & Veterinary Medicine), USA
Kazuo Nadaoka (ISRS Council Member), Japan
David Obura - CORDIO (Coastal Oceans Research & Development – Indian Oceans) East Africa, Kenya
Gal Eyal (student rep) - Tel-Aviv University & Interuniversity Institute for Marine Sciences, Israel
Jesse Bergman (student rep) - California State University Northridge (CSUN), USA

We would welcome additional volunteers, as well as suggestions from members on issues that the Committee should consider.

2018 – Third International Year of the Reef

IYOR3

Following a Palau motion at the ICRI General Meeting, 2018 has been designated the 3rd International Year of the Reef. English, French and Spanish language versions of the motion are available at:
www.icriforum.org/sites/default/files/ICRIGM31_Reco_IYOR2018_0.pdf
www.icriforum.org/sites/default/files/ICRIGM31_Reco_Annee_Internationale.pdf and
www.icriforum.org/sites/default/files/ICRIGM31_Reco_IYOR2018_SP.pdf
The previous IYORs took place in 1997 and 2008 and contributed significantly to raising public awareness and triggering a wide range of management, policy, research and conservation actions for reefs.

IYOR3 will provide an opportunity to create the critical mass of public attention needed to provide a tipping point that will activate the global, regional and national resources required for the fundamental policy and behavioural changes necessary to reverse current practices that are leading to coral reef loss. Awareness-raising will be the central goal of IYOR3 but activities will also extend to strategic outreach in order to challenge decision-makers, influence policies, and involve the private sector.

Co-ordination mechanisms for the initiative are still being discussed but it is hoped that government agencies, NGOs, community organizations, educators and others will start to plan activities that will contribute to IYOR3.

The International Coral Reef Initiative (ICRI)

ICRI is an informal partnership between governments and organizations which strives to preserve coral reefs and related ecosystems around the world. Its objectives are to: (a) encourage the adoption of best practice in sustainable management of coral reefs and associated ecosystems; (b) build capacity and (c) raise awareness at all levels on the plight of coral reefs around the world.

ICRI was initially set up by eight governments (Australia, France, Japan, Jamaica, the Philippines, Sweden, UK and USA) and was launched at the First Conference of the Parties of the Convention on Biological Diversity in 1994 when the threats to reefs began to become a global priority. It now has over 60 members. The **ICRI Secretariat** is hosted by State members, on a voluntary basis, usually for two years at a time; the current host is France. The Secretariat progresses ICRI's objectives through a **Plan of Action** and organizes **General Meetings** at least annually.

Current ICRI priorities, adopted at the 31st ICRI General Meeting (Paris, November 2016) include:

- *Helping to address the issue of pollution of the marine environment by plastic microbeads pollution*
- *Supporting the implementation of IYOR3*
- *Helping to develop a global network for reef monitoring*
- *Addressing the decline in coral reef health due to global bleaching events - ICRI has set up an ad hoc committee on climate change and organized a ministerial (France and Australia) press conference on coral reefs at the 22nd Conference of the Parties (COP 22) to the UN Framework Convention on Climate Change*
- *Contributing to the implementation of international commitments, especially of resolution 2/12 on sustainable coral reef management (UNEA-2).*

For more information please see the ICRI website at: www.icriforum.org
Or contact Francis Staub at the ICRI Secretariat (fstaub@biodiv-conseil.fr)

Coral Reefs of the South China Sea a Need for Action

Satellite photos of Fiery Cross Reef: (left) 2006: small military outpost and largely healthy reefs, (middle) 2014: reef flat has been dug up for giant clams, (right) 2015 during artificial island construction, with plumes of sand and silt spreading onto the reef (a. CSIS Asia Maritime Transparency Initiative / Digitalglobe, b and c Google Earth/Digital Globe 2016).

SUMMARY

The South China Sea (SCS), a marginal sea in the centre of Southeast Asia, is surrounded by ten of the most economically important Asian nations: People's Republic of China (PRC), the Republic of China (Taiwan), the Philippines, Malaysia, Brunei, Indonesia, Singapore, Vietnam, Thailand and Cambodia. It plays a central role in the economy and development of these countries, in terms of shipping, energy and fisheries. The SCS is also of critical ecological importance, abutting the western border of the Coral Triangle, a region of anomalously high marine species diversity. With nearly 600 known species of corals, the SCS rivals the Coral Triangle in coral diversity. It is also home to a plethora of marine life of both ecological and commercial value, including many species on the IUCN Red-List.

The SCS contains over 250 small islands, atolls, cays, shoals, reefs, and sandbars, most of which have no indigenous people. The principal archipelago and island features are the Spratly Islands, Paracel Islands, Dongsha Atoll, and Scarborough Reef. Each of these main reef systems is subject to overlapping sovereignty claims by two or more nations. With intensification of these interests in recent years, threats to the reefs such as overharvesting and pollution, which have been present for many years, have greatly increased. There is now clear evidence of significant damage which, if not halted, will have a long-term impact on the biological diversity of the SCS, the ecosystem services provided by the reefs, and the sustainable development and economic stability of the surrounding nations.

This document lays out the views of the International Society for Reef Studies (ISRS) and concerned coral reef scientists on the ecological importance of reefs of the SCS and the threats posed to them by the activities currently underway.

The United Nations Convention on Law of the Sea is clear on the need for international cooperation in the resource management of seas such as the SCS. There is therefore an urgent need for the public and all relevant governmental, intergovernmental and non-governmental agencies to step up efforts and accelerate international cooperation, in order to alleviate those stresses that are causing the rapid decline of coral reef and related ecosystem resources in the South China Sea. Appropriate, timely and effective action will ensure the recovery of fisheries and the reef and associated ecosystems on which they depend, and the protection of this significant portion of the common heritage of mankind for future generations.

ABOVE: Giant clam harvesting in the Paracel Islands using the propellers of 'cutter boats' to dig up the bottom. Available as of 10 July 2016: http://blog.sina.com.cn/s/blog_51460dc40102e5eq.html

RIGHT: Map of South Chna Sea with area of offshore reefs indicated in light blue. Approximately 122 surface-breaking reefs are marked in red.

INTRODUCTION

The South China Sea (SCS) is a marginal sea that is part of the Pacific Ocean, encompassing an area from the Singapore and Malacca Straits in the south to the Taiwan Strait of around 3,500,000 km^2. The SCS abuts the western border of the Coral Triangle, a region of anomalously high marine species diversity extending from the Solomon Islands to eastern Java, Indonesia and north to the Philippines, with some authors considering that part of the SCS lies within the boundaries of the Coral Triangle (*see map above right*).

The SCS contains over 250 small islands, atolls, cays, shoals, reefs, and sandbars, most of which have no indigenous people, many of which are naturally under water (5-10 m) at high tide, and many of which are reefs and banks that are permanently submerged, such as the Macclesfield Bank and Truro Shoal between the Paracels and Scarborough, the Reed Bank north of the Spratly area, and numerous reefs scattered across the Sunda Shelf. The principal archipelago and island features are the: Spratly Islands, Paracel Islands, Dongsha Atoll, and Scarborough Reef. Each of the main reef systems is subject to overlapping sovereignty claims by two or more nations.

The Spratly Islands, which are of particular concern, cover an area of 810 x 900 km and include some 175 identified islands and islets, the largest being Taiping Island (Itu Aba). The largest single feature in this area is a 100 km wide seamount called Reed Bank, in the northeast of the group, separated from Palawan Island (Philippines) by the Palawan Trench. Now completely covered, with a depth of 20 m, Reed Bank was an island until it became submerged about 7,000 years ago due to the increasing sea level after the last ice age. With an area of 8,866 km², it is one of the largest submerged atoll structures of the world.

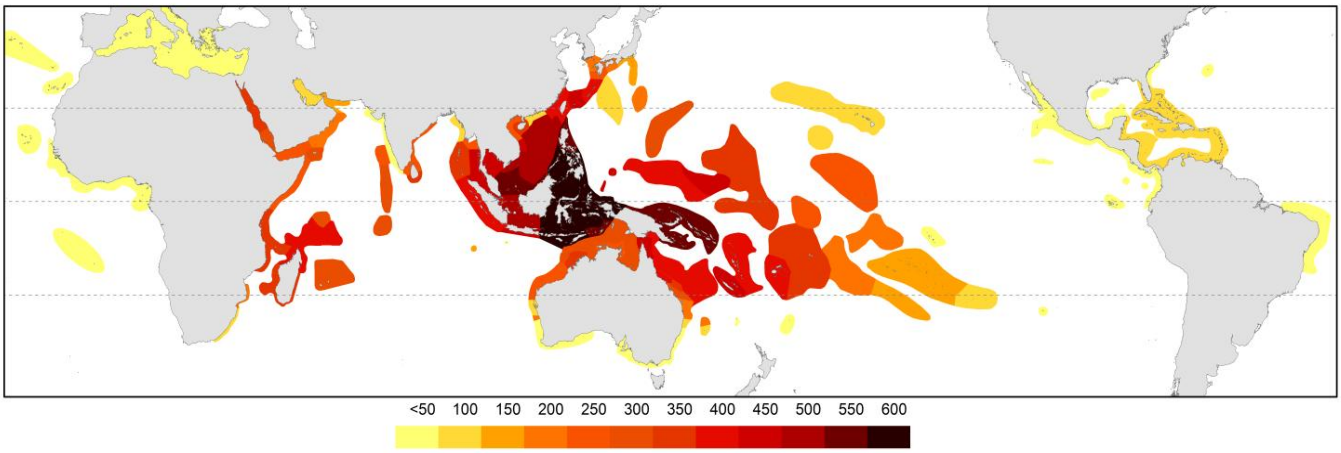


Figure 1. Numbers of shallow-water coral species found globally. The South China Sea has more than five times the numbers of species in most fish and invertebrate groups as in the Caribbean or Hawaii. Source: Veron et al. (2015).

Major rivers that flow into the SCS include the Pearl, Min, Jiulong, Red, Mekong, Rajang, Pahang, Pampanga, and Pasig Rivers.

ECOLOGICAL CHARACTERISTICS & SCIENTIFIC IMPORTANCE

The SCS rivals the Coral Triangle for the importance and diversity of its reefs. The total reef area is estimated at about 12,000 km^2, or 4.7% of the world's total reef surface area. Over 300,000 (multicellular) reef-associated species (some 37% of c. 800,000 known reef species in the world) are found on the southern reefs of the SCS, many of which have yet to be identified and probably many new to science (McManus, in review). The SCS is home to an estimated 571 known species of reef corals (Huang et al., 2015), with diversity ranging from 95 species on the northernmost reefs of the SCS in southeastern China to 433 species in western Luzon, Philippines. Of the 70 known coral genera, 50 have been found in the area (Vo et al. 2013). The SCS has some 17% less coral reef by area than the Coral Triangle, but only 5% fewer corals (the Coral Triangle has 605 species of reef corals; Huang et al., 2015). The high species richness is illustrated in Figure 1.

Studies on many groups of marine species, including annelids (Paxton and Chou 2000), molluscs (Norman and Lu 2000; Sachidhanandam et al. 2000; Tan 2000), crustaceans (Jones et al. 2000; Komai 2000; Lowry 2000; Moosa 2000; Rahayu 2000), echinoderms (Lane et al. 2000), sponges (Hooper et al. 2000) and fish (Randall and Lim 2000) document considerable proportions of global richness.

Records exist for 1,766 crustacean species (Pan 2010) and 7 of the 12 giant clam species (Vo et al. 2013; Neo et al. in press). Over 3,000 species of fish are known from the SCS (Randall and Lim 2000), comparable to 3,000-4,000 estimated from the Coral Triangle (Burke et al. 2011). The SCS is also home to 102 non-fish vertebrate species, of which 36% are marine mammals, 36% are seabirds, and 27% are reptiles (Sorongon and Palomares 2010). The SCS also has 20 of the 50 seagrass species and 45 of the 51 known mangrove species (Vo et al. 2013).

Currents of the SCS vary greatly over the year as a result of the reversing monsoons and other weather factors, and sometimes reverse directions themselves. This may partly explain why fish species targeted by fisheries here do not go extinct. Genetic studies of three reef fish species (the false Moorish idol *Heniochus acuminatus*, the six bar wrasse *Thallasoma hardwickii*, and the threespot dascyllus *Dascyllus trimaculatus*) in the SCS have shown that connectivity in the SCS is very high, but that there may be some population differences in some areas (Ablan et al. 2002; Chen et al. 2004).

ECONOMIC IMPORTANCE

This region is vitally important economically. South East Asia is home to more than half a billion people and, as of 1997, the Association of Southeast Asian Nations (ASEAN) has been the world's fourth largest trading bloc (Chandler et al. 2005). Countries with an influence on the SCS include oil-rich Brunei, the highly successful 'tiger economies' of Singapore, Hong Kong, and Taiwan, and the rapidly rising economies of Indonesia, Malaysia, the Philippines, Thailand and Vietnam (Glover 2013). To the north lies the PRC which may achieve economic dominance in Asia within the next two decades (Davies 2002). The maintenance of the national prosperity of these nations depends heavily on their location on important global shipping routes, and their abundant natural resources such as oil for energy and fish to feed the rising populations.

Shipping: The SCS contains the second most used sea lane in the world, and the area between the Spratly Islands and PRC is particularly important. About half of the world's shipping tonnage passes through the area annually, supplying roughly 60% of the energy needs of South Korea, Japan and Taiwan, as well as 80% of PRC's crude oil imports (Figure 2; Kaplan 2014). Some USD 5.3 trillion worth of international trade passes through each year, including up to half of the world's oil shipments (Cronk 2015), about 80% of the shipping trade with PRC, and a large part of the shipping trade connecting Europe, Africa and Asia with Japan, Hawaii and the Americas.

Oil and gas: The South China Sea has approximately 11 billion barrels of oil and 190 trillion cubic feet of natural gas in proven and probable reserves (EIA, 2013). However, these are to be found primarily along near-shore continental shelf areas, and not among the offshore reefs, perhaps because the porous carbonate sediments associated with coral reefs have prevented the build-up of oil and gas (Hayton 2014). The Spratly and Paracel Islands are believed to have negligible amounts of oil and less than 0.1% of the total natural gas found within the SCS (EIA 2013).

Fisheries: The SCS supports major fisheries, and many of the surrounding nations are expanding their fleets by providing subsidies and/or improved technology. The coral reefs provide critical habitats that support fisheries production. The Spratly Islands, in particular, are a source of larvae to replenish locally extirpated fish populations throughout much of the SCS (e.g. McManus 1994, Juinio-Meñez et al. 2003, Kool et al. 2011, Treml and Halpin 2012). The pelagic fisheries from the Kalayaan Island Group in the Spratly Islands are estimated to be worth about USD 47-105 million per km^2 annually, in addition to USD 39-60 million from commercial reef fisheries (Aliño et al. 1998). The capture fisheries contribute about 10 million tons a year, which is 12% of the world's landed catch (Sumaila and Cheung 2015). Fish contribute 28% of the protein to the area outside of the Gulf of Thailand and 38% within it. The protein is particularly important to the over 43,500,000 impoverished people living within 100 km of the coast (TWAP 2015a,b; Talaue-McManus and Estevanez 2016).

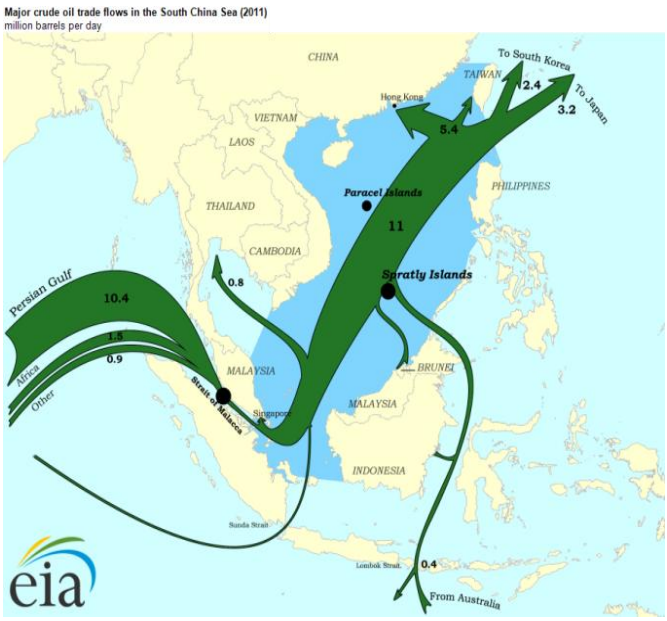


Figure 2. Major crude oil shipping routes through the South China Sea in millions of barrels per day in 2011. *Source US Energy Information Administration as of 10 July 2016: http://www.eia.gov/todayinenergy/detail.cfm?id=1067*.

Defence and military bases: There are now more than 40 military outposts (McManus, in review) and a wide range of associated infrastructure, facilities and activities (Morton 2016).

Potential for pharmaceuticals: The high level of species diversity indicates that the potential for new medical drugs from the sea from these offshore reefs is likely to be very high.

Figure 3 (left). Filling to extend Woody Island in the Paracel group. Source: Google Earth 2016 (Google Earth and DigitalGlobe 2016).

Figure 4 (above). Extensive coral mortality from giant clam 'cutter boat' activity observed on a reef east of Thitu Reef in the Spratly Islands, February 2016. Photo (c) John McManus

Potential tourism: There are at least a hundred reefs in the Greater Spratly Islands, and another twenty or so in the Paracel Islands with potential for world class tourist diving (McManus, in review). There has also been interest by some of the surrounding countries in other forms of tourism (Morton 2016). At present, the only tourist resort in the Spratly area is the Malaysian resort at Swallow Reef. The PRC base of Sansha (Woody Island) in the Paracels and Taiwanese-occupied Taiping Island in the northern Spratlys and the Dongsha Islands are being prepared for increasing tourism, with much emphasis on environmental protection.

THREATS TO THE REEFS OF THE SCS

Experts associated with the SCS Large Marine Ecosystem Assessment (Feary et al. 2014) rated much of the SCS and Gulf of Thailand as "poor" in terms of species biodiversity in nearshore ecosystems. Although ecosystem health was largely "good," most areas were also rated as "poor" in terms of human-induced pressures. Most of the parameters evaluated were stable or declining, and there was little indication that ecosystem health or biodiversity was improving. Three habitats (coral reefs, seagrass, and mangroves) and fourteen species groups were found to be in the poorest condition because of coastal development and exploitation. While there are national and international conservation actions to protect some of these species groups, such as groupers and giant clams in national waters, there is no significant coordination or extension of these efforts into offshore areas.

An earlier transboundary diagnostic analysis in 2000 identified coastal habitat degradation and loss in the surrounding countries, overexploitation, and marine pollution as the major threats to the SCS and adjacent Gulf of Thailand (Talaue-McManus 2000). In particular, many of the coral reefs fringing the major land masses are threatened by coastal development and overexploitation (McManus 1997; Burke et al. 2011).

Reefs of less inhabited island clusters, such as the Spratly and Paracel islands, previously under little threat, are now subject to major impacts. Surveys in February 2016 of the reef flat and lagoon at Thitu (Pag-asa) Reef in the east

Spratly Islands showed that these reefs had been overfished (piscivorous fish generally absent), but that there was good coral cover behind the breakers and on the outer reef flat: mostly small, dense, relatively fast growing *Acropora* and *Montipora* colonies interspersed with some low microatolls of various more storm-resistant and slow-growing species. The coral community is clearly adapted to rapid recovery following the frequent typhoons that affect the area, and is well-flushed with very clear oceanic water (McManus 2016).

Dredging and filling. Most of the nations claiming the Spratly Islands have engaged in some level of dredging and filling to expand and reinforce small islands, create access channels and obtain construction materials (Fig. 3). While PRC has done this in the Paracel Islands, it has primarily built new artificial islands in the Spratly area totalling at least 13 km^2. Prior to this construction, each of these areas was subject to extensive damage from giant clam extraction (McManus, in review). While focussed on a smaller total area than the widespread damage from clam extraction, the filling operations are of particular concern because reef recovery is impossible in such areas.

Overfishing. Most fish stocks of tuna, mackerel, jacks, and sharks subject to offshore commercial fishing underwent a reduction of more than 50% from 1960 to 2000 (Christensen et al. 2003). The impact of commercial fishing is compounded by fishing for consumption by military personnel stationed in the area. Most coastal waters, including reefs, are fished at estimated levels of at least twice that for optimal fisheries production, leading to low catches per hour fishing (McManus, in review), a problem compounded by widespread coastal reef degradation from a wide range of stressors (Chou 2013).

Use of destructive fishing methods. In prior decades, the Spratly islands were often fished using *muro-ami* methods, in which hundreds of fishers drove fish into nets anchored by weighted ropes which damaged coral. This practice is now rare. There have been apprehensions of fishers using blasting devices in shallow waters, which leads to wasteful depletion of fish populations and considerable damage to corals and other reef organisms (Akamine 2006).

Most recently, giant clam hunters have taken to digging up large areas of reef flat in search of shells. The boats are anchored and pulled laterally in arcs with the propeller spinning to dig up the bottom (Lee 2016). The combination of damage directly from the propellers and indirectly from the suspension of sand and silt is causing extensive mortality among bottom-dwelling species (Fig. 4). Over 100 km^2 of coral reef in the Paracel and Spratly areas has been estimated to have been severely damaged in this way (McManus, in review). Although corals in the SCS are typically adapted to recover within a few years from typhoon damage, the destabilization of substrates may extend this recovery time to more than a decade. Efforts are underway by relevant authorities to halt this destructive harvesting practice but need support and strengthening.

Harvesting of threatened species. Large fleets of boats ranging in size from small outriggers (often carried or towed in by larger vessels), to large, modern, well-equipped fishing craft collect a variety of marine wildlife from the offshore reefs of the SCS. Sea turtles, sharks, large groupers, wrasses, and giant clams are specifically targeted. Their populations are likely much lower now than they were a few decades ago. Giant clam shells can be worth around US$1000 per pair and are used to produce many products, including carvings worth far more (Fig. 5).

Figure 5. Carving produced from giant clam shell. Photo: www.taobao.com.

POTENTIAL MITIGATION & SOLUTIONS

There is a wide range of potential measures that could be used to manage the environmental issues that have arisen in the SCS, such as gear restrictions, spatial closures, seasonal closures and licensing systems. For example, the UNEP/GEF project "Reversing Environmental Degradation Trends in the South China Sea and the Gulf of Thailand" (http://www.unepscs.org), which ran from 2002-2009, initiated the establishment of a network of demonstration sites in the region for coastal habitat and land-based pollution management that integrates local government and community initiatives (Vo et al. 2013), but was unable to include the offshore reefs because of the issue of overlapping claims.

Regulation of any kind is difficult in a situation of overlapping claims. Should any one claimant declare a management measure, compliance by other claimants may be interpreted as recognition of another claimant's authority. Thus the annual ban on fishing in the Spratly area during summer months mandated by PRC (Xieyuan 2015) tends to be violated by other nations (Cabacungan et al. 2014). In the coastal waters of Brunei, fishing is prohibited around the numerous oil rigs and interconnecting pipes which thus act as no-fishing reserves; the high levels of fish populations in that area are a testament to the effectiveness of such spatial fishery management.

However, within areas subject to multiple claimants, any one claimant's declaration of a park or reserve tends to be met with official protests by others. Clearly, there must be multilateral coordination of fishery and environmental regulations, such that all regulations are declared by all claimants simultaneously.

Many international agreements call for multinational cooperation in fishery management and environmental protection, including the United National Convention on Law of the Sea, the Convention of Biological Diversity, Agenda 21, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the FAO Code of Conduct for Responsible Fisheries, the Convention on Wetlands and others.

Reasonable goals for natural resource management of the offshore reefs of the SCS include:

- Ecologically sustainable fishing
- Ecologically sustainable tourism
- Regionally coordinated management arrangements
- Standardized environmental impact assessment procedures

If sustainable management is introduced, there is potential for recovery of many of the reef systems. Recovery from local extinctions of the species that have been over-exploited has proved possible in other areas. For instance, giant clams have been restored on many reefs elsewhere in the region (Gomez and Mingoa-Licuanan 2006). Sea turtle populations in Hainan are recovering as a result of rescue and release practices (Ruggeri 2015). Large predatory fish have been shown to recover quite well when fishing pressures on them are alleviated for long periods of time (Russ and Alcala 2004).

The development of sustainable tourism among these offshore reefs could involve some combination of low-impact development on islands and a strong emphasis on keeping tourists on live-aboard dive boats. An example of the former is Taiping Island (Jennings 2015), where sustainability is being promoted via careful land-use and innovations such as solar power generation. The value of live-aboard tourism is exemplified at the Tubbataha Reefs World Heritage Site. This offshore Philippine reef system in the Sulu Sea due east of the Spratly Islands was previously over-fished and subject to a number of disturbances. Two-decades later, after a gradually improved system of park management and enforcement, the area teems with large predatory fish such as groupers, snappers, jacks and sharks (Dygico et al. 2006), a positive sign of a return towards a near-pristine state. A significant part of the management costs of this reef come from tourist entry fees (Subade 2007). The true economic value of the park includes a wide variety of financial benefits to the country, such as income from tourists in the course of their journey to the park, via airports, hotels, shops, restaurants, dive-tour operations, and a multitude of other activities.

A peaceful and environmentally well-managed SCS would lead to substantial growth in tourism across the region, and provide major boosts to industries such as yacht-building, in which the PRC is prominent primarily for the vessels it sells for use outside the region (Wilkinson 2015).

Figure 6. Reef flat, Thitu Island. Photo (c) John McManus

There have been several proposals for protecting the Spratly Islands area (White 1983; Valencia et al. 1999; Alcala 2011). Priority sites for protection have been identified in the Philippines (Aliño et al. 2006) and Taiwan (Shao and Lin 2014). It has also been recommended that the whole of the Spratly Islands group be designated as an international protected area or peace park (McManus 1992, 1994; McManus et al. 2010). Given the multi-decadal relative success of the Antarctic Treaty System, a similar model could be used for a Peace Park. For this, a time-limited, renewable treaty could be developed with a freeze on claims and claim supportive activities, and a plan for joint resource management. This idea has been supported by several authors (Hughes et al. 2010; Zhao et al. 2013; Mora et al 2016). The recent Arctic Ocean agreements (Tai et al. 2015) also provide a model, as does the Binational Red Sea Marine Peace Park in the Gulf of Aqaba (Toán and Đăng 2016).

Regardless of the approach, there is an urgent need for a system of coordinated, effective fishery management and environmental protection, in conjunction with programmes to restore key populations of giant clams and other regionally depleted species. This could ultimately lead to the recovery of many of the coral reef resources in the SCS to the benefit of all nations.

CONCLUSIONS

The United Nations Convention on Law of the Sea, to which all claimants in the SCS belong, is clear on the need for international cooperation in the resource management of seas such as the SCS. Article 123 on Cooperation of States bordering enclosed or semi-enclosed seas states that:

"States bordering an enclosed or semi-enclosed sea should cooperate with each other in the exercise of their rights and in the performance of their duties under this Convention. To this end they shall endeavour, directly or through an appropriate regional organization:

> to coordinate the management, conservation, exploration and exploitation of the living resources of the sea;
> to coordinate the implementation of their rights and duties with respect to the protection and preservation of the marine environment;
> to coordinate their scientific research policies and undertake where appropriate joint programmes of scientific research in the area;
> to invite, as appropriate, other interested States or international organizations to cooperate with them in furtherance of the provisions of this article."

There is, therefore, an urgent need for the public and all relevant governmental, intergovernmental and non-governmental agencies to step up efforts and accelerate international cooperation, in order to alleviate those stresses that are causing the rapid decline of coral reef and related ecosystem resources in this important region, the South China Sea. Appropriate, timely and effective action will ensure the recovery of fisheries and the reef and associated ecosystems on which they depend, and the protection of this significant portion of the common heritage of mankind for future generations.

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The ISRS Education Committee

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Since its inception at the ICRS meeting in Hawaii this year, the Education Committee has been developing its membership and its priorities and proposals for the future. We have an exciting and dynamic membership, including Erinn Muller (ISRS Council member), Judith Mendes (Lecturer in Coral Reef Ecology, UWI), Tom Sparke (Education Program Manager, Little Cayman Research Centre), Paul Burke (Marine Science Teacher, Cayman Prep and High School), Dan Bayley (PhD student at University College London), working with the Zoological Society of London and the Natural History Museum), Sean Russell (Youth Program Director, Mote Marine Laboratory), Heather Page (PhD student, Scripps Institute of Oceanography), Archana Anand (PhD student, University of Hong Kong), and Adrienne Correa (BioSciences at Rice University, Ecology and Evolutionary Biology Program, Martel College Associate). We have also benefitted from the knowledge and experience of Rupert Ormond (Corresponding Secretary, ISRS) as occasional observer and advisor. With such a panoply of stars, as Chairman, I am definitely a 'guide on the side' rather than the 'sage on the stage'.

PROPOSALS

Our virtual discussions over email have produced the following proposals:

1. An **up-to-date database of ISRS members with a list of their individual expertise**.
Many members of the committee have excellent experience in promoting public awareness of coral reefs. ISRS should encourage this for all members. Although there is already a directory of ISRS members including their details and interests accessible from the membership page of the ISRS website, it is somewhat outdated. Having a one stop hub for reef education resources, lesson plans, public engagement activities, service project ideas etc. should both prove valuable to ISRS members and help broaden the reach of ISRS out to educators/students looking for these types of resources, all in one place. We need to revise the data fields to reflect up-to-date priorities of importance in education. These could include:

Have you produced written teaching materials?
Have you produced video/other media teaching materials?
Would you be willing to act as mentor in coral reef studies?
Have you done outreach to Schools/Colleges?

In addition, we anticipate having an **"education and outreach"** page and links on the ISRS website.

2. The need to **share educational materials.**
The need to share educational materials, such as leaflets and lectures, is an important feature in our Terms of Reference. Reef scientists do not have the time to re-invent wheels when preparing educational materials for their own projects, yet education has never been so critical. So far we have the following (in no particular order):

a. **Web sites**:
(i) Using some of the recent 'big' surveys on video, including –
Catlin Seaview (who are behind the underwater google street view). They have produced a series of curriculum resources based on their expeditions as well as media to use: http://oceans.digitalexplorer.com/
Tara oceans expedition was good for this too (http://oceans.taraexpeditions.org/en/m/education/) and made an effort to get school children to come and see the boat and the science they do at each port stop.
(ii) The Natural History Museum in London have an interactive virtual reality exhibit where you can dive with David Attenborough on the GBR http://www.nhm.ac.uk/visit/whats-on/programs/nhm/david_attenborough's_great_barrier_reef_dive.html Researchers to do in-the-field posts from various reefs they are working on around the world to inspire people, and to try show what people are doing more effectively.

(iii)The UK Marine Biological Society's Bioblitzes are really popular and make people feel involved with the science – see: https://www.mba.ac.uk/learningzone/

(iv) The National Oceanic and Atmospheric Administration office in Galveston, TX does an Ocean Discovery Day that has some great activities: http://flowergarden.noaa.gov/newsevents/oddarticle.html.

(v) The Khaled bin Sultan Living Oceans Foundation has launched a Coral Reef Ecology Curriculum, which is a comprehensive digital resource freely available online. It includes award-winning videos, custom-built interactive exercises, games, quizzes, and lesson plans for teachers — all aligned to the latest education standards (Next Generation Science Standards, Common Core State Standards, and Ocean Literacy Principles). The Coral Reef Ecology Curriculum can be found online at: www.lof.org/CoralReefCurriculum.

b. **Educational lessons and materials**
(i) Scripps Community Outreach for Public Education program -The lesson plans can be found at the following link: https://earthref.org/SCC/activities.htm
Several of these lessons revolve around coral reefs and/or include reefs as examples of core concepts in biology.

(ii) Partially complete - The Caribbean Reef Education and Training Initiative (aka The CREATIve Project) was funded by the EU's Edulink programme. The project, which was completed in 2013, developed undergraduate Coral Reef Ecology courses in five Caribbean countries: Jamaica, Barbados, and Trinidad (the three campus territories of The University of the West Indies), Belize (University of Belize), and The Bahamas (College of the Bahamas). The course at the College of the Bahamas was never implemented. The project also trained 10 teachers (two from each country to deliver the course). With respect to teaching material there remains an unpublished draft of a textbook to accompany the course (minus the geology section which was never written). What is currently available could form the basis of a complete Caribbean Coral Reef course.

(iii) 2-D Reef Replicas to convey concepts and methods in coral reef ecology and conservation, even in locations where we can't access reefs easily. Essentially, the 2-D Reef Replicas involve printing high-resolution mosaic images of coral reefs at 1:1 scale (aka life size) on an outdoor advertising banner (i.e., vinyl that you'd see on a billboard). Here is a little blurb about them: Young children to adults in public outreach or students in courses can use these to 'become' marine scientists when they use quadrats to quantify metrics of reef health, such as percent live coral cover, from the 2-D Reef Replicas. In outreach programs, teams working on different reef swaths can ultimately come together and 'scale-up' the data from their individual plots to examine variance across reefs and perform basic statistical analyses. As a culmination of these exercises, program participants can compare their results to Caribbean-wide reef statistics, and assess the health status and likely trajectory of the reefs they have examined. See: https://www.youtube.com/watch?v=jeDJqP7IalQ Adrienne Correa at Rice University has some lessons for students to use with the 2-D Reef Replicas that she can share, and then students calculate the same metrics using a computer image analysis program (CPCe with excel extensions).

(iv) Tom Sparke can provide lessons for K-12 students on topics such as Caribbean fish ID, Caribbean coral ID, coral, seagrass and mangrove ecology, coral nurseries and also some very interactive workshops of lionfish management and ecotourism. All of the lessons have an interactive activity attached and he would gladly create them into succinct lesson plans for sharing with others.

(v) Sean Russell and Erinn Muller, with NSF support, have created a researched based afterschool programme for high school students in the Florida Keys and USVI. Details of the programme can be found at: https://mote.org/education/kids-families/research-based-after-school-program-for-students

3. Collaboration with the ISRS Conservation Committee
We are in contact with the ISRS Conservation Committee, and the chairs met at the annual Reef Conservation UK (RCUK) meeting at the Zoological Society of London (ZSL) at the end of November 2016 to discuss further links. In

particular, we anticipate collaboration over the proposal for a third International Year of the Reef (IYOR) to be held in 2018.

4. Cooperation with other organizations

Cooperation with other organizations should be encouraged. These could include Operation Wallacea, Blue Ventures, and Coral Cay. There is a global network of Youth Ocean Conservation Summit alumni. Using key events at zoos, aquariums, and museums, such as World Oceans Day celebrations, also provides an excellent opportunity to share coral conservation messaging and/or work to involve students in leadership roles teaching their peers about coral conservation and engaging them in conservation work. Also, the National Marine Educators Association and associated listservs/communication platforms have a wide reach to marine science educators working in both formal and informal settings around the world, making it an excellent avenue to share educational resources.

5. Possible Young Ambassador Award.

Applicants could be asked to create media as to how they could make or have made a difference to a country's reef or community. We could then explore the option of having the winner work at one of our organizations to gain work experience. A number of Programs have been identified that have helped elevate the outstanding work of many young conservationists over the years. Examples are:
Brower Youth Awards (http://www.broweryouthawards.org/),
International Young Eco-Hero Awards (http://actionfornature.org/eco-hero-awards/) and
SeaWorld & Busch Gardens Environmental Excellence Awards (https://seaworldcares.com/en/2016/07/Celebrating-Young-Conservation- Leaders/)

RECENT EXAMPLES OF EDUCATION AND OUTREACH

The committee has identified a number of recent examples of effective education and outreach activities that deserve mention here:

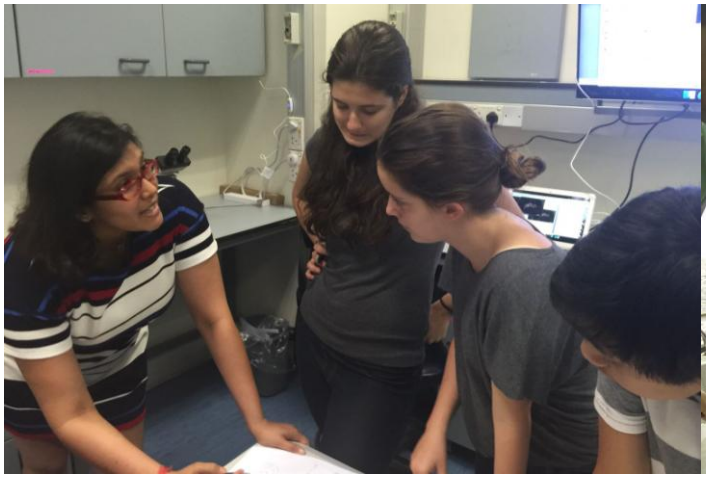
1. Sean Russell has been working with SeaWorld and Busch Gardens coordinating youth leadership programs, and directing the Youth Ocean Conservation Summit, an annual event held at Mote Marine Laboratory and replicated at aquariums/science centers across the U.S. This event trains students to launch conservation

projects, and equips them with the funds/resources to ensure their success. See: www.yocs.org or https://youtu.be/XoirNhQqjvw and photo below.

2. Ruth Gates' Laboratory has been very active in outreach activities. For example, in early September, PhD Candidate Christopher Wall completed a video in partnership with the STEM program at Nu'uanu Elementary School (Honolulu, HI) on marine biology and the ongoing research in the Gates Lab. The video has been shared with over 250 STEM educators in Hawaii and is available publicly at https://vimeo.com/183601976. Christopher and six other Gates Lab members taught 50 middle students and 12 chaperones from the School for Examining Essential Questions of Sustainability (SEEQS) in Honolulu, HI (see photos below). The students traveled to HIMB by boat to learn more about what coral is, the importance of coral reef ecosystems, the current threats to coral reefs, and solution-based science.

   Gates' Lab research students are also active in the community. For example: Several Gates Lab students have signed up recently to participate in "Nerd Nite Honolulu". Nerd Nite is an international event where "nerds" share their interests in a casual atmosphere. In early September, PhD Candidate Beth Lenz discussed coral reproduction with about 50 individuals including high school teachers, tourists, and graduate students (see photo below). PhD Candidate Ariana Huffmyer traveled to American Samoa in August to present a Climate Science Teacher Institute workshop. This week-long workshop focused on climate science, the impacts of climate change on local communities, and how these concepts align with their curriculum and standards. And earlier this summer Ruth, along with an interdisciplinary team, produced an article about coral bleaching in the Scholastic Magazine, *Science World*, which is an educational magazine for students in grades 6-10 (see photo below).

3. In June 2016 Archana Anand gave a talk to the Kai Tak Youth Rowing Club (KTYRC), a Hong Kong NGO aiming to teach rowing to economically underprivileged students between 12 and 14 years of age. Her talk educated them about Hong Kong waters, corals, sea life and how they can contribute to ocean conservation. She also shared a research project with the Hong Kong International School (HKIS), where students collect seawater samples and analyse them for *Enterococcus* (photo with students in class below with Archana on the left). Archana has also mentored a group of Hong Kong University students in macroalgae deployment for nitrogen isotope analysis (see images below).



4. Finally I myself was at the New Scientist Live exhibition for the public at Excel, London, on September 25th talking with the public about ' "Why are coral reefs so important for everyone?' 30,000 People attended the event, organised by New Scientist magazine in conjunction with the Royal Society of Biology over 4 days. The photos below were taken in the relaxed few moments before the doors opened! I spoke to many of the participants, of all ages- even a small girl in a pram wanted to hold a *Siderastrea*! Many school age students wanted to do some sort of biology at university, and they were fascinated by the corals and their environmental problems. They also liked the dive profiles I showed them on my dive computer. They left enthusiastic and I hope with some useful knowledge.

James Crabbe (second from right) at the New Scientist Live Exhibition

These are but a few examples of the educational outreach activities being undertaken by members. We would very much welcome hearing from members about similar activities in which they have been involved, especially if there are examples which may be borrowed by, or materials shared with, the wider ISRS community, for example via a dedicated page on the ISRS website. In addition we would welcome contact from those members who would be interested to join the committee or contribute to its work.

REEF ENCOUNTER
The News Journal of the International Society for Reef Studies
Reef Perspectives: Post-Truth in Reef Conservation

REEF PERSPECTIVES

Personal comment on reef science, policy and management

POST-TRUTH IN REEF CONSERVATION:
changing the narrative to focus on people through education and social media

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When I attended ICRS13 in Honolulu, as a high school student, it was like 'Alice in Wonderland'. Gleaming with delight, I absorbed new knowledge and had the experience of meeting researchers whose contributions to reef science have been legendary. True to the theme of 'bridging science with policy', the topics presented by scientists, managers and policymakers were fascinating, especially those on active restoration and assisted evolution. After attending the symposium and reading past issues of *Reef Encounter*, I realized a couple of things. First, many ideas presented at ICRS13 were quite inspiring and most identified viable solutions to arrest the decline of coral reefs. Second, the actions taken thus far were limited, or their outcomes had been mixed. Hence, here in *Reef Encounter*, I would like to contribute my thoughts to the conversation, and offer a voice from the millennial generation. I believe it would be helpful to reach out and build emotional connections with the millennial and future generations, especially through education and tools like social media.

Perspective on reef conservation.
There is little need here for us to revisit the reasons for reef conservation as the topics have been well covered in many journals, magazines, and prior issues of *Reef Encounter.* Yet, for starters, I do wish to offer my perspective on the conservation efforts as a student of reef science.

Corals have been around for millions of years. Ever since humans learned to efficiently harvest and use Earth's natural resources, coral reefs have been in decline (Jackson 1997). Now, 75% of the world's coral reefs are under threat (Burke et al. 2011). The human ecological footprint is pervasive. The Earth only had a billion people less than 2 centuries ago. Now there are 7 billion. Through explosive population growth, humans have become the 'greatest' ecological force that this world has seen. The ability of humans to affect the environment through consumption of natural resources and destruction of natural habitats is enormous. Through technological advances, humans have the capability of destroying habitats, altering climates, and harvesting species to extinction. Look around the world, and you'll see clear-cut forests, polluted rivers, and altered seashores. At many places, what used to be pristine ecosystems are left empty and desolate.

Science informs.
On the science front, we know the facts are there, and cost-benefit data are irrefutable. We know over-fishing happens. We know human population growth and rises in consumption are main causes for reef loss. We don't need science to tell us. But science can tell us the extent of coral coverage loss and quantify the causal factors. Major damages done to ecosystems are well documented (Barnosky et al. 2013). Before industrialization, anthropogenic impacts were local; for instance, remote reefs not easily accessible by humans remained healthy. Now, with ocean warming and acidification, it's no longer the case. Global changes are becoming more important causes of reef decline (Sheppard, 2015).

Started in the last century, international efforts to rescue corals have kicked into high gears in the new millennium. Yet, is it too little, too late? As early as

ICRS7 in 1992, ISRS recognized and started to document threats to coral reefs from growing human populations and their associated stresses (Wilkinson et al. 2015). Public awareness campaigns and improved communication among scientists, politicians and coral reef managers helped usher in the establishment of hundreds of new marine protected areas (MPAs). From an ecological standpoint, these MPAs are a good start as we try to keep areas off-limit for exploitation. From an evolutionary point, however, it is noteworthy that the current global MPAs can only secure about 1.7% of the Tree of Life for corals (Mouillot et al. 2016). We have a ways to go. Indeed, the establishment of MPAs hasn't been able to stem the tide. Extinction of coral reefs isn't too far around the corner, prompting the question: What aren't we focusing on that we should be?

In a previous issue of *Reef Encounter*, Sale (2014) described the folly of thinking that there was a single cause of coral decline and therefore expecting that 'saving the reefs' could be done with a single solution. We can't expect MPAs to solve all our problems. In fact, global problems need global-scale actions as mass bleaching is now taking place more frequently. Disappearance of coral reefs is no longer a 'what if' scenario, it's becoming reality. Prevention of reef extinction should be a top priority in this rapidly closing window for action. While there were doubts if conservation efforts could be implemented rapidly (Wilkinson et al. 2015), I learned that problems and solutions are known *and* available to us.

Why aren't things better?

If we know the problems and how to solve them, why haven't we? Despite all the efforts, why aren't we receiving better results? Why aren't enough actions being taken if the necessary actions to solve the problems are so obvious? Do we not have enough facts? Yes and no. I don't believe it's just about knowledge and facts. Are the costs too high, outweighing the benefits? Whose costs and whose benefits? I think these are big issues. I am not alone in asking these questions as many were posed by scientists in recent issues of *Reef Encounter*. For instance, Sheppard (2015) reiterated that we had measured and quantified reef declines, and debate had since turned into why we were unable to arrest the trend. We know that solutions such as marine spatial planning (Sale 2014) would work. We know carefully planned eco-tourism, where local reef communities are supported with food and energy shipped from afar, could minimize "ecological footprints" and help conserve reefs (Sheppard, 2015). We also know the essential points in maintaining "humanity's life support systems."

To me, what's puzzling is that our leaders, parents, teachers, and other elders talk about leaving a better future for the next generations. Why aren't they? Using corals as an example, reefs are on the verge of extinction, and the measures to protect them are known. Yet, we don't seem to be able to slow the decline, let alone reverse it. Maybe shifting baselines have us misinformed; maybe it's our diminishing expectations. Or maybe, it's a combination of both. To inform and raise expectations, I believe we must help bring awareness and shape public opinion. Population growth and other changes are global issues. It's not just about facts and data. The science is clear. The cost and benefits are clear. But do people and policymakers have the will to make the hard choices? Are people willing to make short-term sacrifices to reap long-term gains? Are policymakers willing to prioritize the environment over the economy? I argue they could, but the path to nirvana is not through their heads, but their hearts.

Hard choice and post-truth.

As Sale (2014) told us, we do recognize the problems, have the solutions, yet we are not applying the solutions well. The problem is: we are addressing the environment, not the people. We know ecologists study the relationships of organisms with their environment and with one another. So, the question and the answer may lie with the organisms, especially humans and their behavior. And humans are creatures with their own values, experiences and emotions. Sometimes, it is beyond the science and cost/benefit analyses.

Which brings us to the term "post-truth," the international word of the year 2016, according to OxfordDictionaries.com. Generally referred to as "circumstances in which objective facts are less influential in shaping public opinion than appeals to emotion and personal belief" (Flood, 2016), post-truth is a word that defines our time, finding its use in social media initially and now increasingly in the mainstream media and everyday banter.

We deal with emotions everyday. For conservation, it's about emotions when you ask the rhetorical question, "Can people live with nature and not destroy it?" It's not scientific anymore. It's philosophical. It's about our own personal beliefs. In our community, the narrative has been: "We must fight climate change, or slow it down." To a few, especially those beyond our scientific community, they don't understand climate change. Or climate change doesn't matter. To them, the climate always changes. It's either warming or cooling. Or staying the same – until it changes. That really shouldn't be the point if we care about the issues and their consequences. The point is: if we lose our natural resources and irreplaceable treasures like coral reefs, it would have been our generations who cause it and allow that to happen. If they are worth protecting, then we must address the people, not just the environment. It's like: if you ask me, "do you worry about the weather?" Not sure, maybe. But if you ask, "do you worry about catching a cold with the change of weather?" That's the driving question.

For the survival of corals, it is vital to put climate change into a perspective that people can identify, understand and relate to. Scientific facts and findings for reef conservation are important and essential to action in policymaking. But 'after the truth was known', the new implication is the need to involve people's emotions and personal beliefs. Policy makers and the general public are equally important and relevant here. Rather than trying to convince politicians and others to see the world through a scientist's lens, or through the arc of an environmentalist, we must appeal to and connect with them also. We must address post-truth in reef conservation. If they believe in protecting the ocean and have an emotional investment in it, backed by facts and scientific data, it's a lot easier to take actions – despite the costs and trade-offs, or short-term sacrifices, that come with it.

Education is key.

If we agree on the importance of post-truth in reef conservation, what can we do? I suggest public education is the key. Public awareness is not just about facts and figures, but about raising consciousness and shaping opinion and beliefs. Getting to people on climate change or disruption is hard. It's much easier to do it via education of the next generations and via outreach through the channels by which they communicate.

Seeing is believing. Visits to healthy coral reefs and active research centres have played a key role in developing the author's views and commitment.

According to Sale (2014), we have "far too little investment in public education" and must build a broad consensus. Our messaging must be directed to the public also via emotional attachment and involvement. People don't have protecting ocean and climate change as their top priorities, rather, they are worried about education and medical care. In fact, a clue into that question can be found in a United Nations global survey for citizens, MYWorld, taken to capture people's voices, priorities and views (United Nations 2016). The top priority for those who participated is education. Climate change comes *last* in people's priorities within this particular survey. It's a bit of a wake-up call. I think it's fair to say that people are not going to be concerned about protecting the ocean or fighting climate change when they're

constantly worried about food, health and personal safety. That's why developing nations do not see the importance or urgency for environmental protection. Developed nations do – but that's after we have degraded or have even destroyed our own environment while our economies grew. Now, we tell developing nations not to pollute – even though that was exactly what we did decades ago during our own economic booms. We know most reefs are in developing countries with people depending on reef resources for food and livelihoods. Thus, there is a need, as Wilkinson et al. (2015) put it, to increase awareness and implement co-management of coral reefs. Hence, education training for tour guides, diving staff, and hotel managers is important and should come before other initiatives.

Reaching out to the Millennial.

As Sheppard (2015) pointed out, "we have to make the case for conservation outside our own community of researchers." I believe K-12 education, with natural science, environmental science, and social sciences, is a golden opportunity for the scientific community, especially ISRS, to reach out and affect. So many reef researchers, professors, post-docs and graduate students are now undertaking cutting-edge research.; but can they not also promote outreach to high schools and middle schools. We can develop new champions and advocates for reef conservation, starting with school children and educators. But we need to build interest and change the narrative. To quote Prof. Steve Palumbi at Stanford University, on his visit to Shanghai American School in 2015, he told us, "We need to teach our children and future generations - the ocean is not just a place to catch seafood." We can provide opportunities to kids so that they can learn on their own – destroying natural habitats, polluting the environment and over-fishing are definitely not cool. As an example, Prof. Dave Baker, from the University of Hong Kong, along with many others, has allowed youngsters like myself to be part of his research team, to learn from experience first hand not just the science, but the beauty and bounty of the ocean. We learn about the shifting baseline and what it could have been. We further our love of the sea and our desire to protect and preserve.

In the past, we have succeeded in ocean conservation campaigns such as promoting Reef Check and slowing the killing of sharks for their fins. For coral conservation it's time we take that to a wider audience at schools, aquariums, museums, dive shops through education and outreach in research. Education is about experiential learning and deepening of knowledge, emotions, and personal beliefs. When we have deep personal beliefs and emotional connections with the ocean, we can have the wherewithal to make hard choices. Not just for my generation, but the ones that come after ours. They are the future generations of scientists, managers and policymakers whom we would like to reach. The ISRS has a role to play here. It can do more to reach out to schools, teachers and students – both in the U.S. and in developing countries like China. Start with high school, but also with elementary and secondary schools. Not everyone will become a reef scientist or resource manager, but everyone will enjoy the beauty and may do his part to conserve.

Social media may hold the key.

How should we go about doing this? I believe the Internet and especially social media hold the promise for reef conservation. Since the democratization of the Internet, social media holds the promise for revolutionizing digital communication. It will be a big help with the newer generations. As 'millennials', we are born with social media as one of our essential functioning tools. The growth of the user base across social media platforms, in the Americas, Europe or Asia, is exponential. In a recent issue of *The Eagle Review*, Marcel Gauthier, Head of School at Shanghai American School (SAS), lamented how things had changed so much between generations. A high school senior at SAS told him recently, "Middle-schoolers are a different generation," when asked to explain, he said, "Middle school kids use totally different apps than we do! We don't even speak the same language!" Such is the fast-changing world that we live in.

For many social causes, there have been numerous examples where social media are used to raise awareness and funding. Perhaps we can do the same, and raise awareness and bring actions to reef conservation. We could start to communicate via social media and educate by partnering with the likes of Ocean Portal (Smithsonian Institution 2016), HHMI BioInteractive (Howard Hughes, 2016), and Short Attention Span Science Videos (Palumbi, 2012). The goal is to increase public engagement and make it easier for the public to understand. And make it easier for them to share and get involved. The ISRS has a unique position here as its members can do a lot

more! For example, ISRS members can bring the latest research findings in reef science to the classroom and help make science and conservation come alive. They can help spread the message that students, parents and even everyday citizens can do something – with their personal consumption pattern – if they truly believe in the cause.

Conclusion.

Coral reefs are worth conserving, and it's not too late to do so. The ISRS expanded its scope by going beyond research and added education and partnership for policymaking two decades ago (Wilkinson et al 2015). Now we can start by going beyond research, policy and management – by reaching out to schools around the world. We, students, have already learned the 3Rs – to reduce, reuse and recycle. We are ready and can do more!

And we must change the narrative. The point is: we are losing irreplaceable treasures like coral reefs. If we cherish these resources for ourselves and for future generations, if we feel emotionally invested in them, we will want to preserve and protect them. If they are worth protecting, then we must act. Through education and involving kids in conservation, policy and research, future generations will understand better, connect to them emotionally, and develop their own values and beliefs. And that will be a good thing.

As Sale (2014) put it, "We have spent far too much time thinking about how to manage reefs." Or, too much time discussing whether the climate is changing and how much change is caused by humans. Instead, we could spend more time to educate and "manage people." As Sale highlighted the need to bring the "real and enduring changes" in human behavior essential for improvement to happen, what better places than our schools, and what better people than students, through which and whom we start the next outreach? We can take key lessons from the past with policymakers and managers, and expand from there.

In summary, a good question I'd ask anyone who has seen corals in person or videos of coral reefs, "Would you prefer seeing muddy sea bottoms devoid of fish, or sea bottoms full of corals and teeming with fish?" We know the answer. We know reefs are severely threatened, but not doomed. We deserve a better future. Not just a declining baseline. We are ready to act.

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a brief overview

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Sixteen years have now passed since the three volume book Corals of the World was published. During this time there has been extensive new fieldwork, the Coral Triangle has been delineated, biogeographic affinities of all ecoregions have been elucidated and molecular studies have proliferated. The building of an open access website of the same name was started soon after the book was published and was publicly launched in draft form on 20th June, 2016. Fifteen weeks after that launch the website had 2357 users from 94 countries.

Background

Virtually all reef conservation decisions over the past decade have had as a primary consideration species diversity and the occurrences of particular groups of species, including threatened species. Scleractinian corals, the fundamental components of reefs, have been central in this, a role likely to be further extended over the forthcoming decades as the impacts of climate change become increasingly evident.

The central and most challenging task of this website has been to bring the taxonomy of all zooxanthellate Scleractinia into a coherent and consistent framework. If this was a matter of creating a catalogue of all names that have been used in the plethora of taxonomic studies that have been undertaken over the past two centuries such a task would have been significant but relatively simple because most of this information already exists. However, such an undertaking would not have supported the core operations of this website which require that all species be given a single identifying name wherever they occur. Only when this is done can we know how species can be distinguished from each other, their distributions mapped, and patterns of diversity and affinity determined. Furthermore, only when this information is made readily accessible to non-specialists do we have an effective foundation for conservation and management and for the many needs of other user groups.

Most people who take an interest in reef-building corals know that they can be difficult to identify especially as their appearance changes according to the environment in which they occur. It may also change with location or country. This has made our task very challenging for we have had to assess the work of others, integrate it, and then produce outcomes that are as inclusive as possible yet are accurate and meaningful. There is nowhere to hide in this process; it has taken ten years to reach initial release during a period of rapid and extensive taxonomic revision, yet the task has no end in sight because Nature is endlessly complex and there are always more details to discover and faults to correct.

This website should not be seen as an amalgam of facts. Certainly it is grounded in the best that science has to offer, but it should be seen as many hypotheses about the taxonomy and biogeography of zooxanthellate corals to be built on when new information becomes available and changed where found to be at fault.

History

This website is not the first attempt at the task just described. Three earlier products have played a key role in this process: (1) the three volume all-colour book, *Corals of the World* published in 2000, (2) a mapping project, *Coral Geographic*, commenced in the late 1970s and used to generate the global diversity map of species that revealed the existence of the Coral Triangle and (3) a CD-ROM *Coral ID* which allowed living reef-building corals to be identified and their characteristics documented.

These products and their precursors have serviced hundreds of research projects and conservation initiatives and have underpinned decision-making on the part of NGOs and governments involved in reef management for decades. However, since their publication, scientists have undertaken an unprecedented amount of fieldwork and molecular methods have come to the fore.

Work leading to this website was initiated in 2006 when it became clear that the abovementioned publications were going out of date and that only a website could (a) be freely available to all users, (b) be fully comprehensive, (c) be up-to-date, (d) have all components interlinked and (e) generate products according to user needs. During development the authors have been privileged to receive enormous support from hundreds of individuals and many organisations as acknowledged in the website. It certainly would not have been remotely possible without them.

Website content

In concept, our website has five central pillars embracing:

1. Coral taxonomy (a reassessment of all known reef-building species and used names applied to them since 1950, summarised in the *Taxon Finder* tool).
2. Coral distributions (*Coral Geographic*).
3. Coral identification (*Coral ID* – in preparation).
4. More complex coral investigations (*Coral Enquirer* – under development).
5. Each of these tools has as its principal end point the *Species Factsheets* which provides information about each individual species.

A range of ancillary factsheets and tools varying in complexity interlink these pillars to help users access the data that underpins the website.

Coral Taxonomy

Despite its problems, the taxonomy of corals is in a relatively advanced state compared to most other major marine invertebrate groups. Nevertheless, many problems arise when taxonomists seek to impose order on what are essentially the genetic continua occurring in Nature.

The taxonomic focus of our website is to maximise coral taxonomic accuracy and certainty whilst allowing for changes that stem from new studies and further information. The use of International Commission of Zoological Nomenclature (ICZN) regulations awaiting revision, artefacts of history as well as Latin declension, as reasons for changing established nomenclature are not supported. Results from molecular studies are accepted where they provide new information that is not overtly in conflict with morphology. The issue is not with the molecular study itself but with the sometimes questionable ability of molecular techniques, especially those that use cladistics, to reveal phylogeny. This website takes a conservative approach to such issues with the intention of making changes once the case for change has been fully established. The website makes note of differing opinions of others where specialist knowledge is involved.

ICZN regulations or the use of them by several recent taxonomists have departed, in some cases drastically, from the axiom that nomenclatural changes should only be made if they increase certainty. In total, the validity of

nineteen well established genera lack certainty for one obscure historical technicality or another. This website retains widely recognised generic names unless there is a compelling biological reason for changing them (see Veron, 2013, 2015) for further detail. Similarly, species names involving an unresolved issue over type specimens are retained if their usage is unambiguous, but not in cases where there is a clearly defined mistake.

Synonymies

Original taxonomic study of most corals requires a high degree of familiarity with species in both field and laboratory. Only after that familiarity has been achieved can the taxonomist work meaningfully with historical collections normally found in museums. Work on museum specimens without prior field knowledge has been the biggest single source of error in the history of coral taxonomy. For this reason, this website places reliance on field delineation of species into which museum-based studies and the nomenclature derived from these studies are integrated, rather than the other way around. A synonymy of names and the use of those names is provided in the Taxon Finder tool referred to above. Users should consult original publications including references provided in the *Species Factsheets* for details of the use of names by individual authors.

Taxon Finder

This tool not only underpins the species and entities classified as 'accepted' on this website, but it will also guide users from a name not used in the website to one that is, should that be possible. It includes synonyms of accepted species as well as names linked to lost or damaged specimens and images or descriptions that cannot be resolved with existing information. Further study or publication of additional detail may well give them future acceptance.

Users should note that *Taxon Finder* provides synonymies based only on original descriptions and type specimens. Except in unusual cases (such as inclusion of a misnamed real species which actually does not have a valid name) it does not attempt to include all the uses and misunderstandings of names by subsequent authors. The latter usage is often exceedingly complex and traditionally involves unending disagreement amongst taxonomists.

Coral Geographic

Our website does not contain static maps but rather uses website technology to construct maps according to user requirements, based on the occurrence of each species in 150 coral ecoregions globally. In summary, meaningful distribution data at species level is dependent on a globally coherent taxonomic framework combined with reliable identifications at site level. Each confirmed distribution point requires that a record, specimen or photograph is reliably identified. This is seldom straightforward. We cannot yet give reasons, other than in cited publications, for inclusion or not of species in ecoregions. This is an obvious priority, but is currently beyond our present resources.

Coral species, like most life, are not conveniently packaged into well-defined units which are readily recognisable everywhere and by everyone. Instead, they are notoriously variable within and between habitats and much more so across their full distribution range. This can make identification a challenge even locally, let alone on the global scale of *Coral Geographic*.

The long and complex history of coral taxonomy adds a further human dimension of complications arising from contrasting assessments of 'type' specimens of nominal species by different workers, leading to differing taxonomic interpretations and synonymies, all of which are bound to the present by rules of nomenclature.

These issues come into sharp focus for field workers. It takes a substantial investment of time, effort and resources to develop the skills necessary to discriminate between similar or cryptic species, to know these species well enough to recognise them wherever they occur and to produce consistent, reliable and meaningful accounts of them. All this is readily apparent to those who have spent years, in some cases lifetimes, working with corals. Even so, ensuring that the variant ascribed to a species by one researcher in a given part of the world falls within the boundaries of the taxonomic variability we attribute to that species within our taxonomic framework, has often required detailed and time-consuming confirmation and has frequently not been possible.

Importantly, this website is not simply a gathering and processing of published information. It is a compilation of our own work to which that of others has been linked. As detailed below, the research of our core team has been global in extent and has addressed all taxa at species level. It thus provides a consistent background against which we can assess records from elsewhere.

Ecoregions

Ecoregions (indicated in the map below) are intended to be internally cohesive and externally distinct from their neighbours. Many, especially those of Japan, the Coral Triangle and Australia have a long history and generally meet these criteria, others are defined by geography and some are somewhat arbitrary reflecting environmental partitioning. We have not always been able to meet these criteria, for example the Gulf of Aden, the widely separated Mascarene Islands and the very isolated islands and island groups of the South Pacific are not internally cohesive. However, in such cases there are currently insufficient coral records to allow existing ecoregion to be meaningfully subdivided. On the other hand, the Indonesian Archipelago is highly subdivided, the reason being historical, pre-dating the comprehensive coral data now available. In all cases, future developments will involve subdividing, not amalgamating existing ecoregions.

A measure of the internal consistency of ecoregions and external distinctions from neighbouring ecoregions is given, for each ecoregion, in *Ecoregion factsheets*.

Data management and quality control

Although species records have been examined at site level wherever available, the overall reliability of such data is very variable, particularly in relation to cryptic and lesser known species. Limiting distribution records to ecoregion level for which we have much higher confidence overcomes most such issues.

However, even at ecoregion level there are more than 120,000 data points (>830 species x 150 ecoregions) and for each of these we have between 0 and 50 records of each species. For some records, unless there are specimens or images or we have detailed knowledge of the research program in question, there is no easy way of confirming conclusively whether or not the species name associated with the record directly applies to our taxonomic framework. This is not a reflection on the fieldworker, it is the reality we are faced with in trying to draw into a common taxonomic framework the records of globally variable and difficult species from a variety of sources.

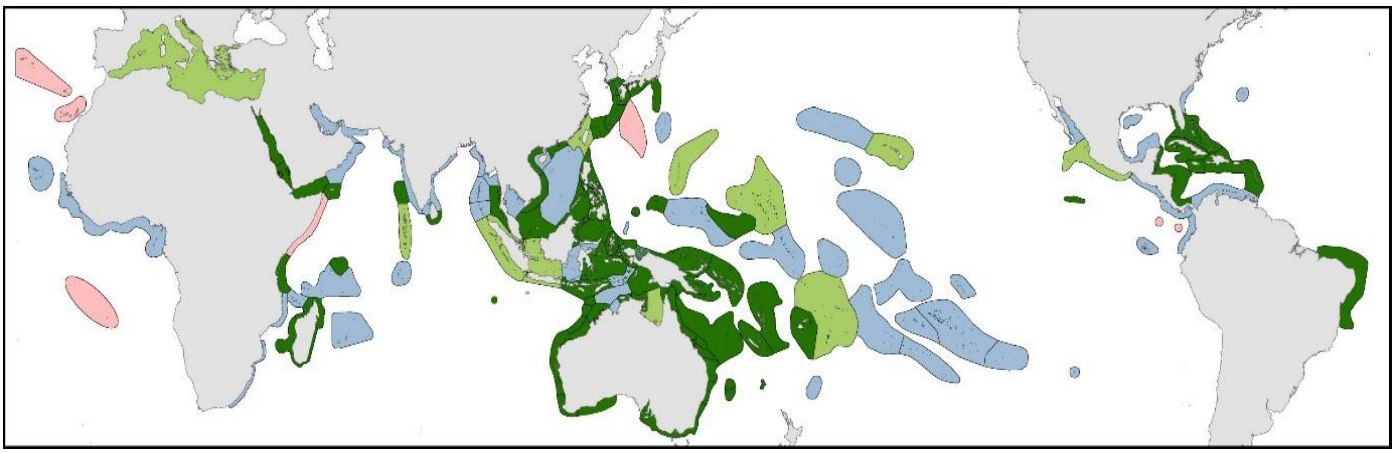
In our attempts to maintain the quality and integrity of the data presented, it has often been necessary to exclude or downgrade data (including our own) which we have been unable to verify adequately. Wherever possible we will rectify such omissions where further specimens, images or information can be provided for confirmation.

We are also aware that the result will be seen by some as representing the 'world according to Veron *et al*.'. To the extent that differences between taxonomists are resolved within the Veron *et al*. collective consensus, this is true, albeit following significant discussion and review of relevant literature and specimens by the team. Clearly, this is a necessary aspect of providing a single coherent taxonomic framework from which to make comparisons. We have integrated the taxonomy and views of colleagues wherever possible, and have cited alternative views where integration has not proved feasible.

Scope of original studies by the authors

The data presented in this website are underpinned by a multitude of detailed studies undertaken by the authors from the 1970s until the present day, collectively representing more than 20,000 hours of diving. The spatial breadth of these studies extends almost around the globe providing the ground-truthing necessary to assess data from other sources and to resolve conflicts that would otherwise be overwhelming. Currently this includes (a) comprehensive studies in more than 4500 sites in 50 ecoregions, (b) incomplete field studies targeting specific taxa in over 250 sites in 18 additional ecoregions and (c) transitory field observations in around 190 sites in 13 additional ecoregions.

This fieldwork was sometimes undertaken concurrently by one of us with our associates on the same expedition and sometimes on different expeditions as time and opportunity allowed. In total, our coverage involved over 5000 sites in 85 of the world's 150 ecoregions after separate studies in the same ecoregion are combined.



Locations of original studies by the authors. Dark green = detailed original field studies leading to species inventories, including extensive comparison with local collections; pale green = original but incomplete field studies, mostly of specific taxa, augmented by studies of collections across all available taxa; blue = studies of collections; pink = unstudied ecoregions except for some specimens available from other collections

Integrating distribution data from other sources

Distribution data from all available sources have been integrated into our databases. These sources include:

a) *Taxonomic literature.* Most monographs stemming from early expeditions of discovery provide little insight into coral distributions. However, many studies from the last century, particularly since the advent of scuba diving, provide good geographic records and in total over 1000 taxonomic publications have contributed to *Coral Geographic.*

b) *Biogeographic literature.* Reports of coral diversity in specific regions are small in terms of number of publications and are variable in quality, ranging from lists of species occurrences from previous studies and museum records ('armchair biogeography') to detailed original research.

c) *Ecological literature.* Studies involving individual species or groups of species in surveys of mass bleaching, *Acanthaster* outbreaks, disease, reproduction, physiology and other species-specific research have been taken into account where the authors are known to have appropriate identification skills.

d) *Collections.* Coral collections in 48 museums and research institutions were studied for both taxonomic and biogeographic purposes. However, since the mid-1990s, restrictions due to the Convention on International Trade in Endangered Species (CITES) have made specimen transfers increasingly problematic and many collections remain in their country of origin even though some have no facilities for their long-term curation.

e) *Photography. In situ* photographs of some genera, notably *Porites* and *Montipora*, are often unhelpful for species recognition, however photographs with accompanying field data and photographs of co-occurring species are often more reliable than museum specimens for identification. Photographic collections of about 120 photographers and research workers have been studied for this purpose with the number of identifiable photographs from each varying from one to hundreds.

f) *Personal communications.* This has been an extensive and much valued source of records and verification of records as acknowledged in our website.

Coral ID

Coral ID is not yet operational. When added to the website it will use the many functions of Lucid, the program on which the original (2002) CD-ROM version was based. *Coral ID* will enable people from all walks of life to identify corals far more reliably than previously possible. In ways analogous to birdwatchers accumulating information about

birds, the many thousands of knowledgeable divers that visit reefs every year, commonly with cameras, will be a significant source of detailed and anecdotal information about changes in coral species distributions and abundance.

Coral Geographic will track this information and use it in tandem with our own detailed abundance studies (not yet published) to indicate when and where further surveys are needed and to track reef deterioration.

Coral Enquirer

This is the target tool of this website and will be the last to be operational. As currently designed, it will be capable of amalgamating all relevant science in order to assess the vulnerability of all species to regional or total extinction. Key components will be (a) the distribution and abundance of species, (b) the characteristics of habitats, (c) environmental data including temperature regimes, (d) maps of mass bleaching, disease and other impacts, (d) the biological traits of species (e) the connectivity of ecoregions via ocean surface circulation and (f) future projections of oceanographic physico-chemical regimes.

Species factsheets

These provide the foundation for of all of the other tools of the website. They give straightforward accounts of all species we recognise as accepted. At the present time they include three principal pages: (a) a summary page with general description, taxonomic notes, brief accounts of habitat, abundance, similar species, Corals of the World history, and references; (b) global distribution; and (c) images. The image page includes both underwater photography of living corals as well as photographs depicting skeletal detail. Location-specific photography will be a primary focus of website development.

Concluding notes

There are many other aspects of our website, currently in operation or in planning, that are not mentioned here. All are described on the website. Two concluding points are:

1. The website will be versioned, allowing data that is regularly updated to be specifically referenced.
2. Users will be able to integrate their own information, images, data, map layers, biases and preferences into this website and use the tools and information we provide in personalised ways. Such additions will be private and only accessible to the user or their user-defined group. Some user elements are already available including the capacity to create and save species lists. These will be progressively enhanced to include ecoregion and GIS map layers, additional species pages and/or images for local variants or for species which we do not currently recognise or have a name for.
3. Feedback forms can be used to advise us of ideas and suggestions to benefit users. Where images, knowledge or other information would enhance or correct website data, users are encouraged to make it available to us. Such contributions will always be acknowledged.

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REEF ENCOUNTER
The News Journal of the International Society for Reef Studies
Reef Currents: Ecouter le récif corallien

Listening to Coral Reefs to Monitor their Condition

Ecouter le récif corallien pour connaître son état de santé

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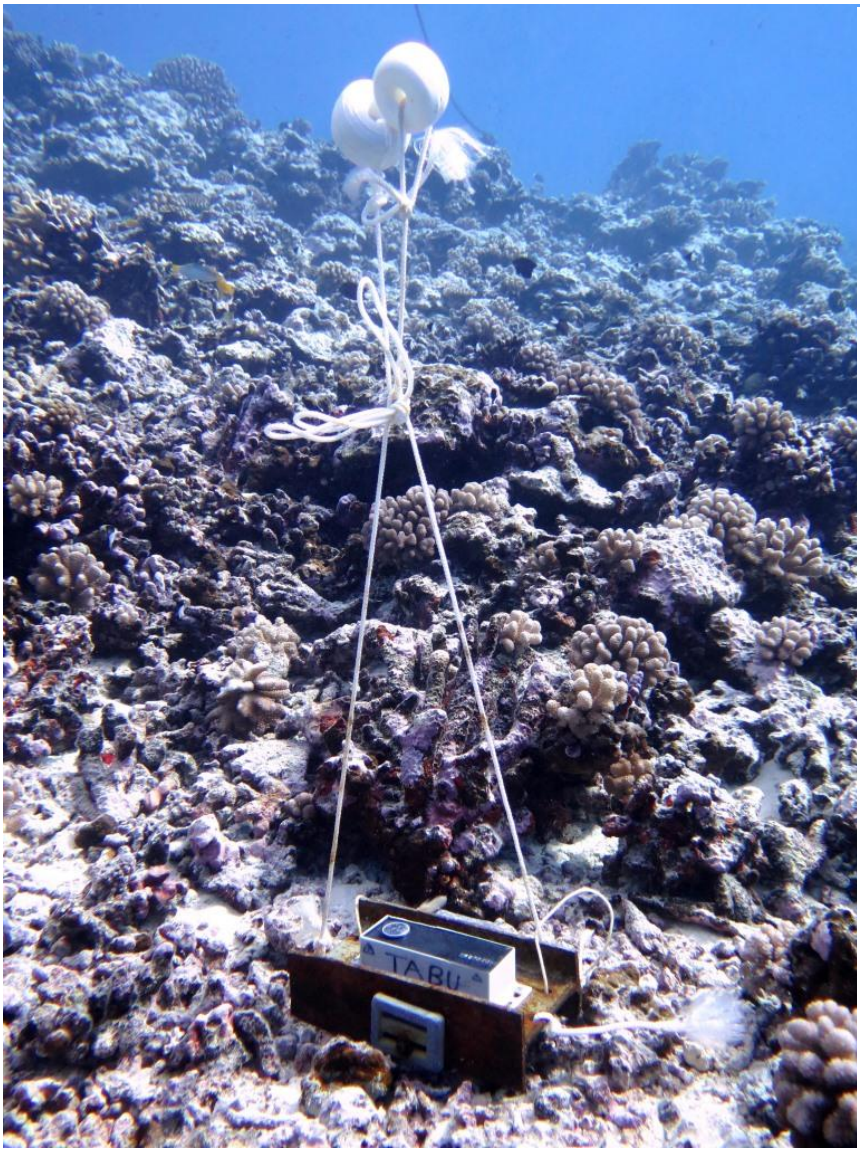
Les récifs coralliens sont parmi les écosystèmes (marin et terrestre confondus) les plus variés et complexes au monde. Face aux changements globaux rapides il est essentiel d'établir des AMP dans les récifs coralliens bénéficiant d'outils de gestion capables de mesurer rapidement et sur une grande échelle spatiale la vitesse de dégradation et/ou la capacité de résilience de l'environnement protégé. C'est dans ce contexte qu'est née une étude réalisée par des chercheurs du CRIOBE (Centre de Recherche Insulaire et Observatoire de l'Environnement, USR 3278 EPHE-CNRS-UPVD) et de l'université de Liège sur l'île de Moorea. Leur questionnement était le suivant : peut-on utiliser l'acoustique sous-marine pour déterminer la biodiversité d'un environnement ? Peut-on appliquer le concept de « paysage acoustique » au milieu marin ? Et si oui, peut-il nous apporter des renseignements sur la santé des récifs coralliens ? Pour écouter le récif corallien de Moorea, les chercheurs ont placé des hydrophones à différents endroits sur la pente externe de l'île, la moitié des instruments dans des AMP, l'autre moitié dans des zones non protégées. Le suivi, qui a duré 4 mois, a démontré qu'un récif avec un fort recouvrement corallien possède une activité sonore plus grande qu'un récif dégradé. De même, les sites ayant une plus grande biodiversité produisent un paysage acoustique plus varié. Cette recherche ouvre une nouvelle voie d'observation du milieu sous-marin, combinant deux éléments clés (niveau et complexité acoustique) et démontre deux choses : oui, l'acoustique sous-marine permet de déterminer l'état d'un environnement. Et oui, les Aires Marines Protégées de Moorea sont efficaces ! Les AMP de Moorea présentant une plus haute biodiversité grâce à leur paysage corallien en bonne santé étaient les zones les plus bruyantes. L'avenir du suivi acoustique dans le milieu corallien semble donc prometteur!

Coral reefs are among the most diverse and complex of ecosystems (terrestrial and marine). They are considered biodiversity hotspots and provide lots of economic (e.g. food, tourism, biotechnology) and physical services (e.g. shoreline protection) which are critical to human populations. Today, 2.1 % of the oceans are within Marine Protected Areas (MPAs). However, apparently natural (e.g., typhoons or predator outbreaks) and anthropogenic perturbations (like ocean acidification or sea temperature rising) that affect coral reefs have increased significantly during the past thirty years, causing a sharp decline in reef populations (Salvat, 1980; Chin et al. 2011; Kayal et al. 2012). In recent decades, many methods have been developed for biodiversity monitoring or the rapid inventory of taxa, with varying degrees of success. Management tools are needed to undertake rapid assessments, where practicable at a large spatial scale, and to monitor the degradation rate and/or the resilience of MPAs in order to check the relevancy and effectiveness of their protection. Thus, science has needed new, fast and reliable proxies for biodiversity, able to provide indirect integrated indicators of species diversity. Underwater acoustics has the promise to be one of them.

In this context, David Lecchini from CRIOBE (Centre de Recherches Insulaires et Observatoire de l'Environnement), and Frédéric Bertucci and Eric Parmentier from the University of Liège, have led a study on Moorea, the most studied island in French Polynesia. The question was: can we use underwater acoustics to assess the biodiversity of an environment? On land, many studies have shown that degraded forests present a less diverse "acoustic landscape" reflecting modified animal communities. Can we apply this concept of "acoustic landscapes or seascapes" to marine environments? If so, can it give information on the condition of coral reefs?

From "Silent World" to "Acoustic Seascape"

Cousteau's *"Silent World"* is long gone now, and we have known for more than 40 years that oceans are noisy, even loud. Of course there are waves, wind and even the sounds of tectonic movements, collectively referred to as the "geophony". But living organisms have to be taken into account, too! When we are listening to it, the "biophony" can also be loud. There are sounds produced by foraging animals, such as parrot fishes, shrimps and crabs, which snap together their teeth or claws. There are also singing fishes, which grunt, groan, moan or click, or rub their fins to show their hostility or interest towards each other. This acoustic environment is well-known to the scientific community, and studies have shown that crabs or juvenile fishes use such sounds to locate suitable habitats (Vermeij et al. 2010; Parmentier, et al. 2015).



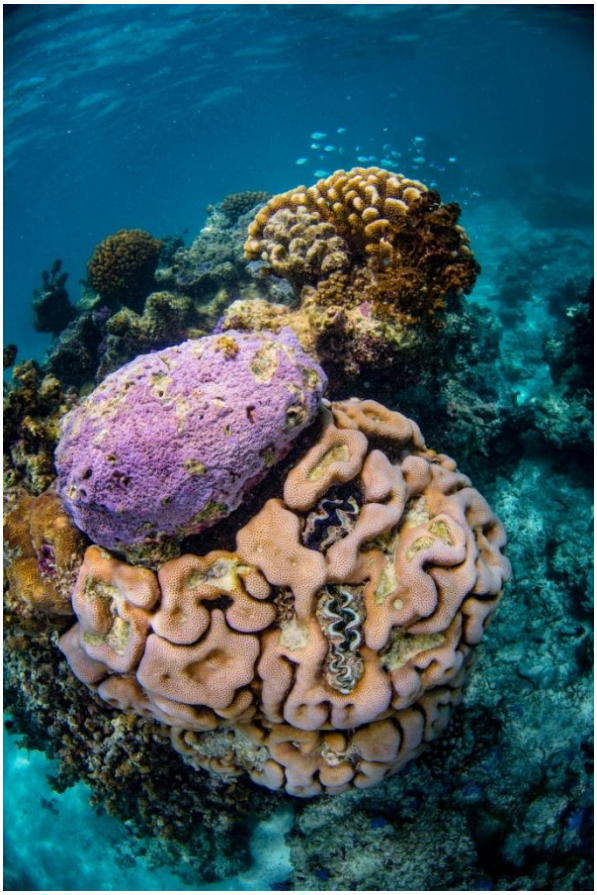
Monitoring hydrophone and recorder in situ on the reef

Advantages of acoustic monitoring

Acoustical recording offers numerous advantages in gathering data from the marine environment. First of all, this is a non-invasive method: once the hydrophone is in place, there is no need for human presence, and the device records normal behavior in the field. Second, the hydrophone can remain underwater for many days, recording day and night, in clear or turbid water. A hydrophone is able to record sounds over a larger area than a human observer can observe. Humans have the capacity to hear frequencies between 20 and 20 000 Hertz. On coral reefs, fishes make sounds between 20 Hz and 2,000 Hz and crustaceans between 2000 and 10,000 Hz. Thus we are able to hear

the general sounds of the reef, but acoustical software tools are more discriminating than human hearing and can be used to quickly distinguish tiny differences, such as those between two different species of damselfish.

Listening to the coral reef



To listen to the coral reef off Moorea Island, Lecchini and colleagues placed hydrophones at different sites on the outer slope, four within established MPAs, and four outside of any MPA (Bertucci et al. 2016). Since Moorea Island has been studied for 40 years, its underwater biodiversity is relatively well-known and its coral cover frequently monitored. Researchers focused on two acoustic indicators, derived from the terrestrial environment: the sound level and the complexity of recorded frequencies. The sound level gives information about the abundance of living organisms, while acoustical complexity gives information about the diversity of those organisms. After four months of recording, researchers listened to the audio files and compared them to what they already knew about the reef. The result: the greater the coral cover, the more sounds are made on the reef. When there are many coral colonies providing natural habitats, many living organisms will occupy them and create a noisy environment. Furthermore, the study showed a higher sound level during the night, supporting the advantage of using acoustic monitoring in marine environments, since those data could not have been collected by visual observation. That's not all: with important crustacean and fish populations, reefs show a high acoustical complexity, and the more species present, the greater the diversity of sound recorded!

Sound in the service of management

This new kind of monitoring, based on two key indicators (sound level and sound complexity), demonstrated two things: yes, underwater acoustics can provide information on the condition of an underwater environment. And yes, MPAs of Moorea are effective; the data from four MPAs and four non-protected areas, clearly showed a difference between the two treatments. Moorea's MPAs have a higher acoustical biodiversity thanks to their higher coral cover. The future of acoustic monitoring in coral reefs is looking bright, since it can reveal ecological status at both fine and broad scales, producing reliable data that can be integrated into decision-making and management actions directed at reducing the vulnerability of coral communities in the face of global changes.

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REEF EDGE

Scientific letters or notes describing observations or data

Foraging by a Caribbean spider crab on the threatened coral, *Acropora palmata*, during coral spawning

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A large Caribbean spider crab (*Mithrax-Mithraculus* species complex; ~90 mm carapace width) was observed feeding on the threatened coral, *Acropora palmata*, at Sand Island Reef, Key Largo, Florida during two annual *A. palmata* spawning events in August 2014 and 2015. In both years, a *Mithrax-Mithraculus* spp. crab was observed feeding on the coral during nights leading up to spawning and the night of spawning (observations made ~2200 hrs each night). The crab was observed feeding both on the base of a colony (Fig. 1a) and while perched at the tip of coral branches (Fig. 1b). At each observation the crab used its chelae to break off individual corallites, inserting each one into its mouth where manipulation with maxillipeds was observed. Mechanical damage to the coral was apparent, characterized by the removal of individual whole corallites (Fig. 1c, d). Surveys conducted during the week of spawning in 2015 revealed that 37% of all *A. palmata* colonies on a single reef spur (~450 m^2; total of 57 colonies surveyed) had recent predation marks characteristic of the ones created by *Mithrax-Mithraculus*. Two months following the spawning event only 4% of *A. palmata* colonies had recent *Mithrax-Mithraculus* predation marks.

Crabs in the *Mithrax-Mithraculus* species complex are largely regarded as herbivorous (Patton 1979; Coen 1988; Stachowicz and Hay 1996), but have been observed to consume animal matter (Winfree and Weinstein 1989). Smaller species in mutualistic associations with coelenterates are suggested to sometimes feed on lipid rich coral mucous (Stachowicz and Hay 1999). However, to our knowledge, this is the first record of a Caribbean spider crab feeding on coral tissue. It is possible that the crab was selectively feeding on gravid coral due to enhanced nutritional value which has been shown in other instances of corallivory (Rotjan and Lewis 2009). Although these crabs are found at low densities on Florida Keys reefs (<0.01 crabs m^{-2}), their functional role in coral reef systems is likely underestimated as they are primarily nocturnal, yet exceed grazing rates to that of herbivorous fishes (Butler and Mojica 2012). *Mithrax-Mithraculus* should be considered a potential consumer of *Acropora* tissue, especially during spawning periods. Damage to the coral inflicted by *Mithrax-Mithraculus* could be misidentified as parrotfish (on branch tips) or urchin predation (on base of branches) as localized removal of tissue and skeleton occurs.

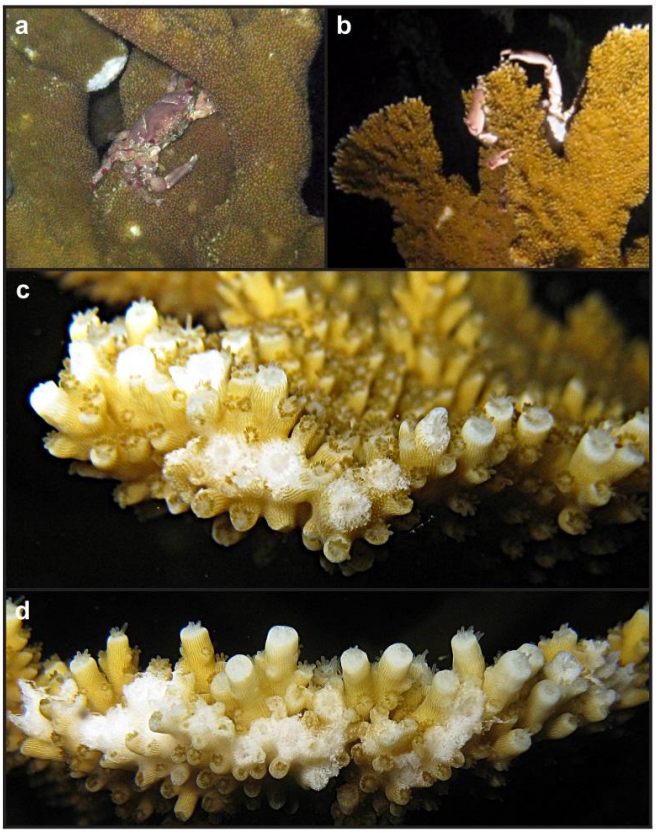

Figure 1. (a-b) *Mithrax-Mithraculus* spp. on *Acropora palmata* colony with gamete filled polyps. (c-d) Broken corallites on *A. palmata* branch tips resulting from *Mithrax-Mithraculus* feeding.

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Demonstrating effective Caribbean acroporid population enhancement: all three nursery-grown, out-planted taxa spawn August 2015 & 2016 in Belize

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Successful *in situ* coral cultivation has been demonstrated in multiple regions with multiple methods (Young et al. 2012), but information is sparse on the survivorship and effectiveness of outplanting nursery-reared corals to reefs. In Belize, *Acropora palmata* fragments were transferred to Laughing Bird Caye National Park in 2006 after bleaching, disease and hurricanes (1998 and 2001) had extirpated the local population. Based on their survival, the experiment was scaled up in 2009 by adding eight *in situ* nurseries. Host and symbiont genotypes were determined for 23 acroporids (Bowden-Kerby & Carne 2012; Baums et al. 2005, 2014). Host genotypes were established to ensure genet diversity of nursery-grown out-planted corals and allow for sexual reproduction to enhance the restored acroporid populations (Baums 2008). Large scale out-planting of *Acropora* began in 2010 and continues. Different genets of each taxon were out-planted close to each other with distances apart of 50cm-10m for *A. cervicornis* and 1m-10m for *A. palmata,* so that subsequently successful cross-fertilization could occur.

Figure 1. Spawning in nursery reared, outplanted *Acropora palmata* (above) and *A. prolifera* (below). Photos: Annelise Hagan.

In August 2015, all three nursery-grown acroporid taxa out-planted in December 2010 spawned: *A. palmata* (two genets), *A. prolifera* (one genet) (see Fig. 1) and *A. cervicornis* (two genets) (Fig. 2). Although nursery grown, out-planted *A. cervicornis* have previously been observed spawning in Florida (K Nedimyer, pers. comm.) and Belize, this is the first documentation of nursery-reared *A. palmata* and *A. prolifera* showing gamete release. Spawning of nursery-reared, outplanted acroporids was documented again in August 2016. These colonies had been outplanted from between 14 months and four years before

spawning was observed. Two additional *A. cervicornis* genets showed gamete formation 19 months aftert out-planting (Carne et al. 2016 in review). Spawning times for both years (2015-2016) were around 20:50-21:20 hrs (Belize time) and spawning dates and times coincided with the spawning of wild acroporids at Carrie Bow Caye, Belize (N. Fogerty pers. comm).

Figure 2. Spawning in nursery reared, outplanted *Acropora cervicornis.* Photo Annelise Hagan.

Documenting these spawning events is an essential monitoring tool to illustrate the success of the use of *in situ* cultivation and outplanting of genetically diverse acroporid populations. In future work, the proximity of outplanted corals should be manipulated to investigate optimal spacing for successful larval production. Cultivation followed by outplanting is an effective management strategy to enhance endangered acroporid populations.

Acknowledgements
Documentation of the 2015 -2016 spawning events was completed for the IDB's Coral Reef Restoration Program. The work was also possible thanks to collaboration with the Belize Fisheries Department and Southern Environmental Association and with the assistance of vessels donated by the Moorings, Belize. Genotyping was performed by Meghann Devlin Durante in the Baums laboratory at the Pennsylvania State University.

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A novel settlement tile design to facilitate the in situ detection of coral recruits

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Microhabitat of settlement surfaces is important for coral recruitment with surface structure and attachment technique shown to affect the suitability of surfaces for coral planulae settlement. Unglazed ceramic tiles have been widely used in coral recruitment studies (Doropoulos et al. 2014; Glassom et al. 2006; Harriott and Fisk, 1987). Surface irregularity influences the suitability of surfaces for settlement (Carleton & Sammarco 1987), with most recruitment occurring in micro-crevices on settlement tiles used in the field (Brandl & Bellwood 2016;

Nozawa et al. 2011; Roeroe et al. 2009) and laboratory (Doropoulos et al. 2016; Petersen et al. 2005; Tebben et al. 2014; Whalan et al. 2015). Planulae settlement at low latitudes occurs predominantly on the under surface of raised settlement tiles (Maida et al. 1994; Mundy 2000) or on the surfaces between stacked tiles (Mundy 2000; O'Leary and Potts, 2011). At high latitudes more settlement occurs on the upper, exposed surfaces of tiles, presumably because light is a limiting factor (Harriott and Banks 1995).

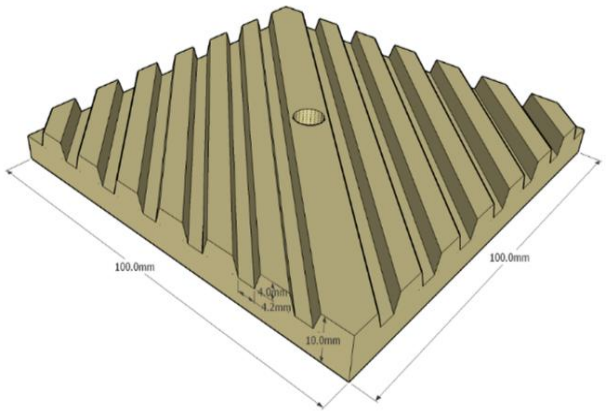

Figure 1. Oblique view of the grooved tile design.

Figure 2. Example of a coral recruit which has settled at the base of a tile groove.

Previously, coral settlement on a high-latitude reef in South Africa was found to occur predominantly on the vertical edges of horizontally attached ceramic tiles on which the horizontal top surface and vertical edges were exposed for coral settlement (Hart and Schleyer, submitted). This behaviour restricted the number of recruits which could be detected in situ with fluorescent photography. Here we describe a new customised tile design where the top surfaces have been structured to enhance the availability of microhabitats suitable for coral settlement.

A tile prototype was machined from HDPE plastic to create inclined grooves 4 mm deep and 4.2 mm wide at the base (Fig. 1). The prototype was sandblasted to create a textured surface and used to make replicate box moulds with Mold Max 10 (Smooth-On Inc.) silicone rubber. This enabled the production of multiple tiles which were cast from polyurethane resin (AXSON Fastcast F16) with a silica sand filler (25 g Part A, 25 g Part B, 65 g silica sand per tile). Tiles were numerically engraved, using a sharp implement, before they were fully set in order to facilitate identification. Multiple moulds were used as the production rate of tiles must be rapid due to the short pot life (~5 mins) of the resin. The tiles were cured in flow-through sea water before use. The use of this new tile design resulted in an increase in the proportion of settlement that occurred on the top surface of tiles compared to the edges. The majority of recruits settled in the grooves (Hart and Schleyer submitted) (Fig. 2), which potentially provide refuge and preferential light conditions for coral recruits. This in turn increased the number of recruits that could be detected and monitored in situ. The tile design may also be of benefit in settlement research on other benthic marine organisms.

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A Coral Bleaching Event at Secas Islands, Chiriqui Bay, Pacific Coast, Panama

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Increasing sea surface temperatures have been established as the primary cause of coral bleaching (Brown 2009), with bleaching reported as occurring either when mean seasonal temperature increases by as little as 1°C above the normal seasonal average for a period of weeks, or is at 2°C above average summer peak temperature for one week, or at 1°C above normal for 2 weeks (Jokiel and Coles 1990; Sapp 1999; Rowher and Youle 2010), depending in part on previous exposure to increased temperatures. Increasing solar radiation also often exacerbates coral bleaching (Brown 2009). At a national meeting of US reef scientists in 1991 global warming was concluded not to be the main culprit causing coral bleaching (Sapp 1999); instead, with bleaching being observed mostly in El Niño years, changes in ocean temperature due to this phenomenon were then considered the more important. Subsequently, even with the significance of climate change becoming clear (Hoegh-Guldberg 1999; Veron et al. 2009), it is nevertheless in El Niño years that many regions are most prone to experience coral bleaching, among them the Pacific coast of Panama, where in the past elevated sea surface temperatures have generally occurred semi-regularly every 3-7 years.

Figure 1. Map of Panama to show the locations of the Seca Islands, Playa Pargo and Coiba Island.

With global annual mean temperatures continuing to rise, the El Niño beginning in 2015 has been one of the most intense on record (Eakin et al. 2016). In Panama warmer than usual water may have been present as early as April (2015), since the Smithsonian Tropical Research Institute in Panama City reported that corals on Coiba Island, on the Pacific coast, had started to fade at that time (Smithsonian Tropical Research Institute website). By August, in the same area, there

was widespread mortality, with massive *Porites* being more affected than branching species. This present report documents comparable observations made on the adjacent Seca islands (Islas Secas), a small archipelago of about sixteen islands in the Gulf of Chiriqui (Fig. 1).

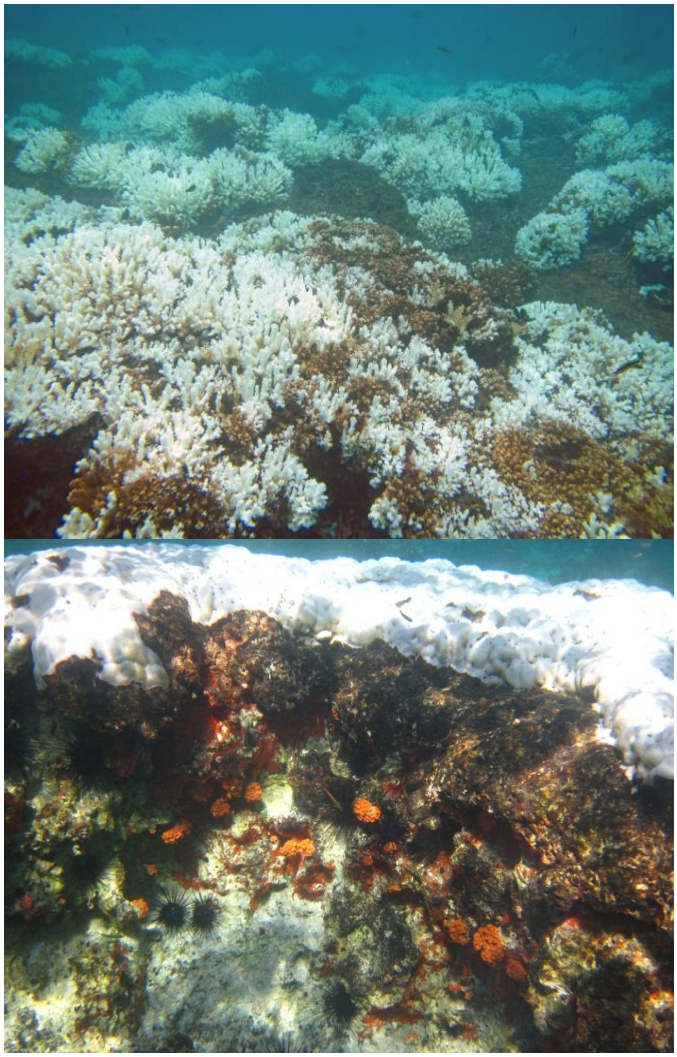

Figure 2. Pictures taken on 13th Sept 2015 showing extensive bleaching of both branching and massive corals.

During dives at the Playa Pargo on the Seca Islands, 27 km from the mainland of Panama (N 07.962260, W 82.049322), between 2012 and July 2015, corals normally appeared in good condition with no bleaching being observed. However, from 16 July 2015 onwards there was dramatic bleaching evident (Fig. 2), with individual corals affected to varying degrees, depending on species, depth, and color variety (Fig. 3). Some *Porites* appeared to change color from brilliant blue to tan to green without showing mortality (Fig. 4), possibly due to expulsion of symbionts (Rowher and Youle 2010), but others soon died as confirmed by the presence of algal turf growing on or over them. Unlike at the Coiba Islands, eventually both branching and massive corals were widely affected (Fig. 2).

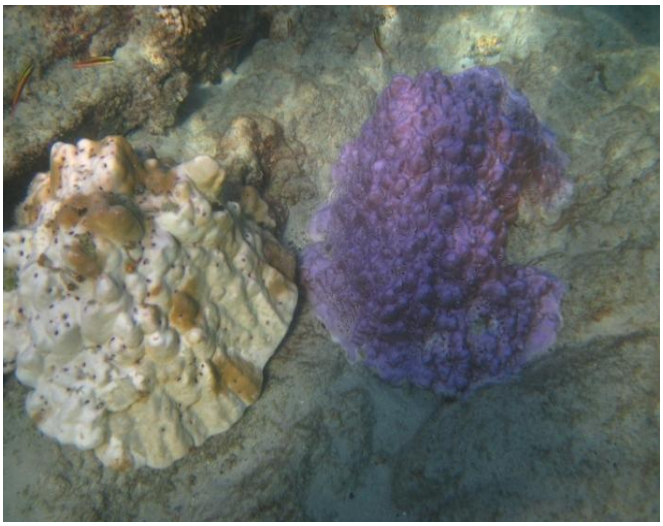

Figure 3. Picture showing how *Porites* colonies of different colors appeared differentially affected by bleaching. The brown colony on the left bleached, the purple colony on the right did not.

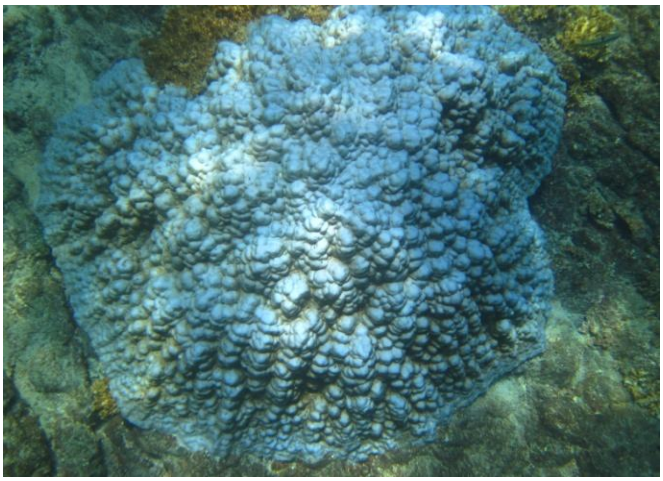

Figure 4. Pictures taken on 10th January 2016 showing brilliant blue color newly developed by some *Porites*

Sea surface temperature data from Punta de Burico (seatemperature.info), 93 km northwest from Secas Islands, showed an increase to >1°C above average during the period October 2015 to January 2016 (Table 1), while data provided by Guzman and Gomez (Smithsonian Tropical Research Institute, personal communication) from Coiba Island, 87 km southwest of the Seca Islands, shows that there sea temperatures at 3.1m below the surface likewise rose

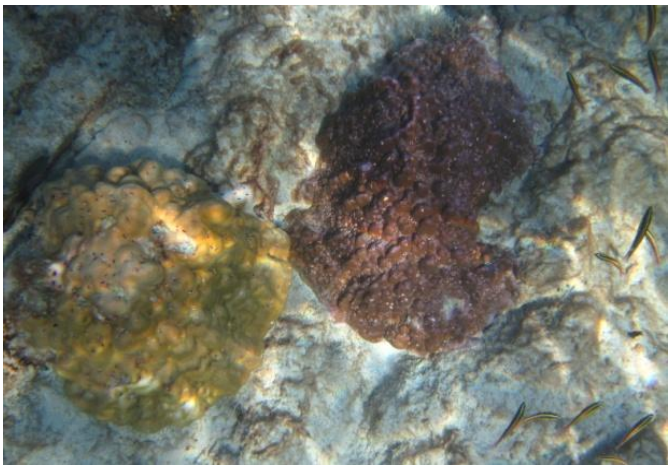

Figure 5. Apparent new color morphs of *Porites* first observed on 25th March 2016.

during August and September 2015 to 1.4°C over the 8-year monthly average, and by December 2015 had reached 1.9°C over the 8-year average (Table 2 upper). Data from the same area 18.1 m below the surface showed a similar trend, with temperatures averaging 1.6 °C over the 7-year monthly average during the month of August 2015, and reaching 2.1 °C over the 7-year average by December (Table 2 lower). Notably in August temperatures were higher at 18.1 m depth than at 3.1 m., and during September to December the difference in mean temperature compared to the monthly mean was also greater at 18.1 m.

Month	Av. °C	4 yr Av.	°C increase
Aug	28	28	0.0
Sept	28	28.0	0.0
Oct	29	27.3	1.8
Nov	28	27.5	0.5
Dec	29	27.8	1.3
Jan	30	28.5	1.5
Feb	29	29.0	0.0

Table 1. Sea Surface Temperatures at Punta Burica, Puerto Armuelles, Chiriqui Bay, Pacific Panama, during 2015-16 (seatemperature.info).

The temperature records for the northern Pacific coast of Panama show how seawater temperatures were well above the norm for many months so that probably all three of the thresholds mentioned above were exceeded. The pattern of temperatures with depth demonstrates how the presumed shut-off of upwelling currents in the eastern Pacific during El Niño may be more evident in deeper water, although visual observations showed that corals growing in shallow water were also widely impacted. The greater susceptibility to bleaching of some corals at greater depth suggests they were less adapted to significantly greater than normal temperatures. At the same time the variable pattern of bleaching and differences in color change between corals at similar depth suggest differential susceptibility to bleaching of different colonies, even of the same species. Post bleaching dives showed a degree of survival or recovery of the coral community, and notably several new color morphs such as the massive *Porites*, are now conspicuous (Fig. 5), possibly indicating some form of adaptation.

3.1m Month	2015-2016 mean °C	8-year mean °C	above mean °C
Aug	27.7	28.1	-0.4
Sept	29.2	27.8	1.4
Oct	29.1	27.4	1.7
Nov	29.1	27.4	1.7
Dec	29.8	27.9	1.9
Jan	29.9	28.1	1.8
18.1m Month	**2015-2016 mean °C**	**7-year mean °C**	**above mean °C**
Aug	29.3	27.7	1.6
Sept	29.0	27.3	1.7
Oct	28.9	26.9	2.0
Nov	29.0	27.0	2.0
Dec	29.6	27.5	2.1
Jan	28.9	27.2	1.7

Table 2. Sea temperatures at 3.1 meters depth (above) and 18.1 metres depth (below) at Coiba Island, Chiriqui Bay, Pacific Panama (pers.com. Guzman & Gomez, Smithsonian Tropical Research Institute).

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A novel approach to the restoration of *Diadema antillarum* on coral reefs in the Caribbean

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On many contemporary coral reefs, the abundance of benthic algae has increased, to the extent that they have become dominant at many locations in the Caribbean. Algal dominance can signify a loss in reef resiliency (Hughes et al. 2007), as fleshy macroalgae limit coral settlement, affect sediment deposition by trapping sediments, and alter chemical properties close to the benthos (Birrell et al. 2008). Herbivores, such as fishes (parrotfish and surgeonfish) and sea urchins (*Diadema antillarum*), may control algal abundance, however, the occurrence of these herbivores is now low on most Caribbean reefs (Bellwood et al. 2004, Mumby 2006, Adam et al. 2015). Regulating fisheries (limiting harvest) and restocking individuals are two ways to increase the abundance of herbivorous fishes and sea urchins.

In the Caribbean, the restocking of *D. antillarum* has been so far unsuccessful (Chiappone et al. 2003, The Nature Conservancy 2004, Miller and Szmant 2006, Leber et al. 2008), as most of the restocked individuals went missing or were eaten days to weeks after being

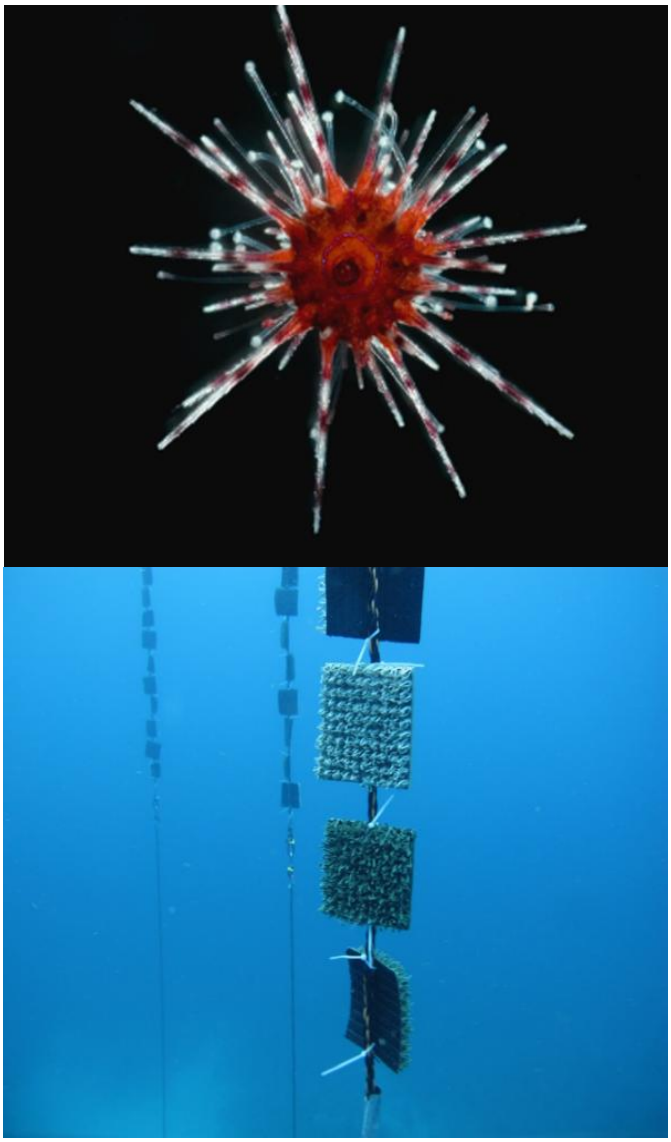

Figure 1. Photograph of a *Diadema antillarum* settler collected in La Parguera, Puerto Rico (left) and a picture of the settlement plates constructed out of Astroturf (right).

introduced to a coral reef. These restocking efforts have been limited to translocating adults or introducing juveniles, which were lab-reared from larvae. In this project, *D. antillarum* settlers (<1 mm test diameter) were collected at a shelf-edge reef in La Parguera, Puerto Rico, on Astroturf plates (Fig. 1) attached to moored lines (Williams et al. 2010, 2011). Twenty, 14cm x 14cm Astroturf plates were attached to each mooring line, ten lines in total. Plates were collected and replaced during the first week of each

month from May to October 2015. Plates were brought back to the wet laboratory at the University of Puerto Rico, Mayagüez. Settlers were picked off of each plate, placed in wet tables, and reared until they reached a young-adult size, 3-4 cm.

Figure 2. Photograph of the typical substrate at the back reef of Media Luna, Puerto Rico (left) and a picture of the laboratory-reared *Diadema antillarum* inside an enclosure one week after the restocking (right).

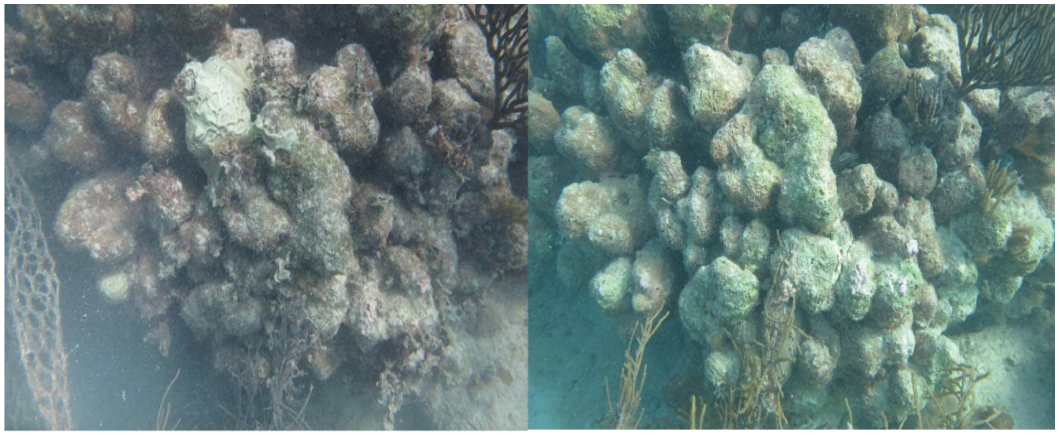

Figure 3. Photograph of the same enclosure before *Diadema antillarum* restoration (left) and two months after the restocking (right). The photograph on the right highlights the substrate free of benthic algae and an encrusting tunicate, *Trididemnum solidum*.

During June and August 2016 respectively, 152 and 191 laboratory-reared sea-urchins were transferred to the back reef of Media Luna, a mid-shelf emerged reef in La Parguera during the early evening. Only adult *D. antillarum* (> 7 cm) were present at this reef before the restocking, with a low abundance of < 0.05 ind m^{-2}. The dominant benthic substrate (ranging from 38% to 76%) on the backreef at Media Luna is a mixture of turf algae, growing intermixed with fleshy macroaglae, particularly *Dictyota* spp. and articulated calcareous algae, *Halimeda* spp. (García-Sais et al. 2015, Fig. 2). Given the depth of this reef, 5m, there were no large invertivore fishes, specifically triggerfishes. The numerically dominant fish species, were the bluehead wrasse (*Thalassoma bifasciatum*), princess parrotfish (*Scarus taeniopterus*) and french grunt (*Haemulon flavolineatum*).

Laboratory-reared *D. antillarum* were placed on six *Orbicella annularis* colonies which were enclosed by a piece of metal chicken wire mesh fencing, which allowed for the tracking of individuals. The height of the fencing was 0.6m, and the approximate radius of the enclosures was 1.2m in length. Restocking was successful as 79% of young adults were recorded four months after the first restocking in June, and 75% were recorded during July. Changes for example in benthic composition were evident in the enclosures one week after the restocking (Fig. 2). Ninety-five percent of the benthic substrate within each enclosure was effectively grazed of all algae, two months after each restocking (Fig. 3). *D. antillarum* even removed the encrusting tunicate, *Trididemnum solidum* (Fig. 3) and sustained removal of algae five months after restocking.

The benefits of this approach are that 1) the difficult stage of rearing larvae to settlers in the laboratory is bypassed, 2) "natural" predation of recruits (Williams et al. 2011) is avoided by restocking individuals of larger size, and 3) a new population of *D. antillarum* is introduced. This method of *D. antillarum* restoration has been successful in reducing algal abundance at a back reef in Puerto Rico and furthermore, this approach is easily transferable to other parts of the Caribbean and the Pacific.

Acknowledgments

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Correspondence

Tautology in Simulation Models: Comment on van Woesik and Lesser (2015)

Recently van Woesik and Lesser (2015) commented negatively on Maynard et al. (2015). There were several aspects of their criticism having to do with the data used for model development. I will not address these comments for two reasons. First, those criticisms are outside my area of expertise. Second, and more importantly, van Woesik and Lesser had submitted their criticisms to Nature Climate Change and their criticism was rejected. I only want to say a few words about the following quote from van Woesik and Lesser (2015): "…the approach is tautological, and the system simply behaved according to their explicit premises."

The most obvious response to this criticism was voiced by Peters (1976) and Ware (2015). In my recent article in RE, I said: "…despite the fact that nothing that comes out that was not put in, some results may not have been anticipated. New insights may be gained and/or results are produced that suggest further observation, experimentation, or modeling."

That is, every simulation is tautological. However, that does not mean "not useful". As Peters (1976) pointed out Euclid, after stating 5 axioms and 5 "common notions", developed the whole of what is now called "Euclidean geometry". Because all of Euclidean geometry is the direct result of the axioms and common notions, does this mean that Euclid's work should be dismissed as a mere tautology?

Peters (1976) also states that sometimes the axioms are so complex that their deductions are not readily apparent. As an example from my background, let me say something about submarines. Submarines are equipped with diving planes. When the diving planes are put in the 'dive' position, the boat goes down. However, back many years ago, my early simulations of submarines showed that there was a range of speeds for which, when the diving planes were put in the 'dive' position, the boat went up! This was a surprise back then, but the mathematical basis for the observation was quickly found and the phenomenon was demonstrated during sea trials.

That is, while nothing came out of the simulation that was not put in, nevertheless, interesting and unanticipated results sometimes occur. I am not claiming that the simulation developed by Maynard et al. (2015) falls into the category of Euclidean Geometry or even the complexity of submarine dynamics. I am simply emphasizing that stating that a simulation is a tautology, is not necessarily a valid criticism. To paraphrase Box and Draper (1987), All models are tautologies, but some are useful.

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CONFERENCES & WORKSHOPS

Informative overviews of recent conferences and meetings

Impressions of ICRS13

A Curmudgeon's Perspective

Through the history of the coral-reef symposia there has been a gradual shift from "pure" science to science for approaching practical problems. There were 37 presentations at the 1st ICRS (1969), most in English, but some in German or French. All were "pure" science. There were approximately 2,116 presentations (1482 oral, 634 poster) at the 13th ICRS, all in English. But for nearly every presentation, the research was clearly related to a practical problem. Whether explicit or implicit, the potential applicability of the research was usually very obvious. This shift from "pure" to applied science was gradual through the 47 years of coral-reef symposia, but the pivotal point may have been at a meeting of the editorial board of the journal Coral Reefs at the 7th ICRS (1992) in Guam. Here there was a debate between mostly elders and mostly youth over what was appropriate for the journal. One side, mostly elders, wanted Coral Reefs to be "pure" science (cell biology, geology, physiology), with manuscripts on MPAs, overfishing, sedimentation, and pollution routed to other, more appropriate journals (Conservation Biology, Fisheries). Obviously, the younger set won out, which I judge to be a good result.

I also have the impression that although there seem to be more oral presentations and posters with each international coral-reef symposium, there also seems to be an even greater emphasis on town halls, workshops, and similar meetings, i.e., on discussions rather than lectures. I have no explanation for the increased complexity in management of sessions. In the past, for example in the 7th ICRS, there was usually one person, sometimes two, acting as the chair of each session. There were sometimes more, but these were exceptions. At this symposium, there were often 10-

13 people, and sometimes up to 15, chairing a session. Session 66 had 11 chairs, but only 8 oral presentations and 2 posters. As with the increase in numbers of town halls, some sessions were more discussion than formal talks, which is perhaps appropriate since the term "Symposium" was originally used to refer to a gathering to discuss a specified topic. (*Perhaps even more appropriately, for a gathering of marine biologists, the term derives from the Ancient Greek word used to describe a drinking party with convivial conversation! eds.*)

Chuck Birkeland giving his plenary lecture

Not long ago, I was sitting near a middle-aged couple on public transportation. They asked what I taught, and I told them I taught a course on corals and coral reefs. They were surprised and said "But you could tell everything about corals and coral reefs in one lecture! How do you fill a whole semester?" Needless to say, I gave them my perspective for the rest of the ride. The reason I mention this anecdote was because the aspect of the 13th ICRS that was constantly on my mind was the breadth, diversity, and even disparity of important and timely topics. These traits have not changed over the past 47 years, but the volume has been increasing. The proceedings for the first 10 symposia take 16,517 pages, and judging by bookshelf length, my very incomplete (I gave up) collection of books on coral reefs or coral-reef organisms is about five times that number of pages. So there are at least a hundred thousand pages of books on the biology and geology of coral reefs and coral-reef organisms. Once we add journal articles, there is plenty of material remaining for some lectures after the first hour. I should remind myself that probably all topics that I may think are simple and brief are actually very complex and deep for those involved.

I heard many times about how well this dauntingly large symposium was functioning, that this was the best-organized ever. I do agree, but as a curmudgeon, I was outside the system. I perpetually saw young people checking the conference program on their tiny "smart" phones for the time and location of the next talk they selected to see. On those tiny palm-sized instruments, they were quickly determining which of the 88 sessions they were to go to next and in which room it was located. These days I cannot read on such a small screen and my fingers are too blunt to selectively touch such tiny letters and numbers. But I actually got along fine because I was kindly provided by the organizers with a printed Conference Program, and I could look at other materials on my large PC screen when I was home. I believe it was the best-organized symposium for me, too, but I did feel a little outside the cyberspace reality of most of the younger folk!

Charles (Chuck) Birkeland

The Developing Country Perspective

Coral reefs are found in more than 80 developing countries and are critical for the food and economic needs of some of the world's poorest and most vulnerable communities. Those of us that are scientists or conservationists from developing countries are acutely aware that our reefs are some of the most threatened on the planet and a large weight and responsibility lies on our shoulders to do something about it. But to do that we need to be connected to places beyond our own, and to find inspiring, highly collaborative people we can work with to help do good applied science that contributes to the protection and better management of our reefs.

As we gathered at the 13th International Coral Reef Symposium (ICRS), I wanted to reach out to other

scientists and conservation practitioners to hear their views and thoughts on attending the symposium and learn more about their work. Over the week I met with people from Fiji, India, Indonesia, Kenya, Malaysia, Maldives, Palau, Philippines, Sri Lanka, Thailand and Vietnam. I learned from many of my colleagues how incredibly intimidating it is to attend these conferences and present in English, when it is their second language.

So why were they attending ICRS? Many told me they wanted the opportunity to share their work and to have their voices heard by their international peers. They wanted to make new connections, learn about others' work and find new collaborations. Some said they hoped by attending ICRS they might find opportunities to do a Master's or a PhD overseas where they would have access to universities with laboratories with the latest technology, and have a competitive advantage when finding work in their own countries.

Delegates from Indonesia

So they prepare and practice and practice their talks multiple times to get it right. What particularly impressed me was the level of support they gave each other during the symposium. For example, my Indonesian colleagues set up a WhatsApp group which they used to keep each other informed of each other's sessions and presentation times. They used their WhatsApp group to send messages about good sessions they were in and what they learned, therefore creating their own peer learning network just for ICRS. And they attended each other's talks to provide support and friendly faces in the audience.

As I met different scientists and conservation practitioners during the week, I asked them what their favourite thing was about ICRS and their responses were:

"*Networking and meeting people whose papers I've read and listening in to some of their talks, and rethinking my own ideas and perceptions"* – Ron Vave, Fijian scientist studying at University of Hawaii

"The chance to interact with a wide range of people from different backgrounds, working in different areas, with different opinions. Feels like a breath of fresh air being able to 'get out' of my own little space." – Steven Lee, Fijian scientist at Leibniz Center for Tropical Marine Ecology (ZMT) and University of Bremen in Germany

"For me ICRS is the great event to share our conservation work in the ground. Meeting and discussion with other conservation practitioners and scientists from around the world is also the best moment. Some conservation work experiences from other regions applicable to do in Indonesia." – Purwanto, Indonesian fish scientist at The Nature Conservancy

"*Attending the conservation diva night and meeting women from all over the world, passionate and committed to the conservation of coral reefs*" – Naneng Setiasih, Indonesian scientist at ReefCheck Indonesia

Asked what they had learned at ICRS that they would be applying back in their home countries, their answers were:

"*Moving away from traditional fishing methods has affected the resilience of people and their resources. I would like to see how we can better incorporate traditional knowledge into locally managed marine areas.*" – Yashika Nand, Fijian coral scientist at the University of the South Pacific in Fiji

"Quality rather than quantity may be a better approach for conservation of resource management work e.g. rather than having a whole string of Marine Protected Areas which you are trying to manage, it may be more beneficial to choose just a couple and invest more into them. Let the neighbouring communities see firsthand the benefits and convince themselves of it rather than trying to

convince them." – Steven Lee, Fijian scientist at ZMT and University of Bremen

The Fiji Wildlife Conservation Society Team (Sangeeta Mangubhai on the right)

And lastly, I asked them what they would like to see more of at the next ICRS and they answered:

"I would like to see more managers and conservation practitioners at ICRS. We need to bridge the gap between scientists and decision makers" – Margaret Fox, Fijian social scientist at the Wildlife Conservation Society

"I recommend that talks be audio and/or video recorded, and made available online. We can't be in all places at once so it'd be good to listen or watch talks that we missed. And it would be great to have days in which, rather than talking to just ourselves we have sessions where we talk to the public." – Ron Vave, Fijian scientist studying at University of Hawaii

"It looks like we gave up on the speed presentations from the last ICRS, but I think new methods need to be included, and ways to make the conference more accessible to those who couldn't attend, particularly from developing countries. For example e-posters (PDF) could be an option that also provides a permanent outlet for physical posters by those that attend. But critically, we need to identify how to resolve the challenges of cost and of visa barriers for developing country participants, and to present a more diverse faces when the Society meets." – David Obura, Kenyan coral reef scientist and Director of CORDIO East Africa

From my side, my personal request would be to see a greater diversity of people involved in different panel discussions. If ICRS is truly an international symposium then there has to be more representation from developing countries on those panels so we can hear different perspectives. And our panels should not just be scientists – instead, we should mix it up and have conservation practitioners and government representatives present as well. And for a change, perhaps we could hear the voice of our youth, to listen to their ideas and thoughts about the future of coral reefs. Without this diversity, we are not going to get very far finding those innovative solutions we need to save the world's coral reefs.

The 13th ICRS was special to so many of us, so we send a heartfelt thanks to the organisers who put in the long hours to make it such a success. We look forward to ICRS 2020!

Sangeeta Mangubhai

ICRS13 Hawai'i Rawked!!

Well folks, we managed to survive another International Coral Reef Symposium! Although I have been excited about past ICRS events, I was particularly looking forward to this one. Why? Well, I am far enough along in my career that I am not petrified about getting raked over the coals by the audience (this happens to the best of us), I am not trying to find a post-doc or faculty position (right now anyway), and I had some exciting research to share. Oh, and it was a great excuse to visit Hawaii for the first time!

There were a lot of wonderful events at ICRS Hawaii, but for me the best part was receiving the Young Scientist Award from the International Society for Reef Studies. It was truly an honor to receive this recognition from the Society and also to be given a beautifully made, hand-crafted award by the President herself, Ruth Gates. I mean how cool was it that my mentors took the time to nominate me, and that I was actually awarded this honor by the first female President in the Society's history? Pretty darn cool, I tell ya! Other cool stuff at ICRS Hawaii included the opening ceremonies highlighting some of the local traditional chants (I still get that chant stuck in my head, so you know it must have been good!), being a

Erinn Muller receiving her ISRS Young Scientist Award from ISRS President Ruth Gates

part of the petition to show support of the Papahanaumokuakea Marine National Monument Expansion (and get free drinks to do so ☺), and the great group of scientists showing off their many talents by singing an incredibly creative version of "Resilience Rhapsody" (check it out here if you missed it: https://www.youtube.com/watch?v=wTLi6MzPPlc).

Of course you could not discuss ICRS without mentioning some of the great presentations. I really enjoyed all of the plenaries, but I have to say it was wonderful to hear Jack Randall share his life as one of the pioneering researchers on coral reefs. That man has had an amazing life. Ruth Gates' plenary also sticks out in my mind. I really think many reefs around the world are not going to survive without some bold steps by mankind. Terms like 'assisted evolution' may have sounded scary a decade ago, and probably still does sound treacherous to many, but when you work in a place like the Florida Keys, you realize quickly that this type of research is likely the only way some coral species may persist. My favorite short talk was one given within the coral disease session by Rebecca Certner from Steve Vollmer's lab. Rebecca turned white band disease activity on and off by controlling quorum sensing in bacteria. Simple, elegant experiments are always the epitome of good science to me, and this was a perfect example. Great job, Rebecca!

Performance of Scott Heron's Resilience Rhapsody

Although most of ICRS Hawaii was practically perfect, there were two aspects of this particular ICRS that I thought were missing compared with some of the others I have attended. First, there was very little, if any, free alcohol. Yes, I went there. This was a stark contrast to ICRS Australia, which had the booze flowing everywhere you looked and resulted in one of the most epic banquets to date. It was also likely why the registration for the Australia meeting cost an arm and a leg. However, I think (but don't quote me here) Bob Richmond did mention that they chose to use the funds for scholarships rather than alcohol. I mean, how can you complain about that?! I was perfectly happy traipsing across the road to 711 for a bottle of wine, which I did often, but I did hear some grumbling about this particular aspect of the meeting.

Second, I did not witness a single heated debate within the concurrent sessions. Maybe I missed them; I did miss like 97% of the talks even though I attended the entire time. Or, maybe people didn't have time to get into the meat of the research, or perhaps we were all on our best behavior. I thoroughly enjoy a heated debate, as long as I am watching from the sidelines, and I do wish I had witnessed a good one at ICRS Hawaii. All in all though, great job ICRS Hawaii!

I have to say, I am particularly excited about the announcement of ICRS 14 in Bremen, Germany, which highlights the globalization of coral-reef research. If the organizers can provide a venue like the one in Hawaii with the banquet provided by Australia then it will be sure to go down as one of the best ICRS events in history. One thing is for sure, this event will promise some good beer, a great venue for sharing information, and maybe, with enough beer and information sharing, it will even spark a good debate or two!

Erinn Muller

A Student Perspective

So amazingly, in June, just as scheduled, more than 2,500 marine leaders and researchers from almost every field of science and social science came together in a flurry of flower-printed fabrics for the 13th International Coral Reef Symposium, at the Convention Centre in Honolulu, Hawaii! The week-long conference mostly involved sessions discussing coral reef research and how we can move from scientific discovery to meaningful actions that will protect reefs.

As a relatively new graduate student (I just completed the first year of my Master's of Science program at the University of British Columbia), I initially found the sheer number of sessions overwhelming. It was difficult to decide which talks I should attend, but, with the help of my advisor and other colleagues, I was able to meet a variety of scientists undertaking crucial work in different parts of the world. I mostly went to talks given by names I recognized from scientific papers. I know that all I learned, and the connections I made, will help to make me a better scientist, and I am already looking forward to giving a presentation at ICRS14.

Inevitably we heard a lot of talk of gloom and doom – coral bleaching, overfishing, eutrophication, and ocean acidification dominated many of the sessions – leaving no doubt that the world's reefs are in serious trouble. But while the situation is dire, the sense of hope in Honolulu was palpable, and I hope we will have many success stories to share in 2020.

Climate change, warming sea surface temperatures, and ocean acidification were prevalent themes. Scott Heron from NOAA's Coral Reef Watch discussed the role that past temperature variability plays in coral susceptibility to bleaching, but reminded us that in the end, "If you're walking down the street and a piano falls on you, it doesn't matter if you've acclimated to survive a falling feather." It was reiterated that we must do something to curb global greenhouse gas emissions, sooner rather than later. In his presentation on the recent coral bleaching on the Great Barrier Reef, Terry Hughes of the ARC Centre of Excellence for Coral Reef Studies acknowledged that he is becoming more and more skeptical whether coral bleaching refuges exist, as more and more places bleach that have never bleached before.

Campaigning, in the lobby of the Honolulu Convention Center for the expansion of the Papahānaumokuākea Marine National Monument.

But, we also heard about studies of coral reefs that appear to be thriving, despite the odds. Hannah Barkley, a graduate student at MIT, shared her results on reefs in Palau that appear healthy even though the waters they call home are highly acidic. Joshua Cinner from James Cook University identified a number of "bright spots" - coral reefs (mostly in the Pacific) that are doing better than expected, and two-thirds of which are in densely- populated areas. Even Terry Hughes said he believes that, with enough effort, we can still save the Great Barrier Reef. And indeed one only has to visit hashtag *#oceanoptimism* on Twitter to find scores of reasons for hope.

Another prevalent topic was the importance of community-based management approaches and integrating cultural considerations into our work. Community leaders from Hawaii, Australia, Micronesia, and the Caribbean shared what the ocean means to them, how knowledge has been passed on to them by previous generations, and their hopes for passing knowledge on to future generations. Peter Houk from the University of Guam said that fisheries in Micronesia can't and won't be sustainable until we incorporate traditional management. Aulani Wilheim

from the Center for Oceans for Conservation International shared how the Papahānaumokuākea Marine National Monument in Hawaii became the first U.S. protected area to integrate cultural heritage and indigenous relationships into the management of its coral reefs, a process which has greatly contributed largely to its success.

We also heard from the President of Palau, Tommy Esang Remengesau, Jr., who opened the conference Monday morning and urged that action be taken urgently to protect the coral reefs of the Pacific, lest we doom coastal communities across the region. In 2015, Remengesau created the Palau National Marine Sanctuary which covers over 500,000 square kilometers (80% of Palau's waters), making it the sixth largest fully protected marine area in the world. Remengesau joined other heads of state from the Pacific in a Leadership Forum to discuss the challenges their reefs are facing and how these challenges can be combated.

Undoubtedly, there is still a lot of work to do. During a plenary session on marine biodiversity, Nancy Knowlton from the Smithsonian Institution noted that between 33 and 91% of all marine species have yet to be described by science. How can we possibly know how to protect marine ecosystems if we don't yet understand the inhabitants? Nevertheless, while it's universally agreed that the world's coral reefs are indeed in rough shape, by the end of the week my overwhelming impression was hope remains. It's hard not to be at least a little optimistic, when you see such a prolific group of people banding together to find innovative ways to protect reefs

Sara Cannon

A Mid-East Perspective

The seminal paper by Kinsman on "Reef coral tolerance of high temperatures and salinities", published 1964 in *Nature,* highlighted the unusual capacity of corals from the coast of Abu Dhabi to withstand environmental extremes. As reefs globally continue to degrade, research from the Mideast, particularly from the Persian/Arabian Gulf, the Sea of Oman, the Red Sea and adjacent water bodies, gains critical importance. These "natural laboratories" can

Haifa Ben Romdhane and Eric Hochberg in a discussion of remote sensing of reefs in Abu Dhabi.

help to answer the most pressing question that coral reef science is being asked today – "To what extent will corals and coral reefs be able to adjust to the changing environmental conditions that are being imposed on them by climate change?"

Accordingly, the scientific activity in the Middle East is booming and dedicated conferences on "Corals Reefs of Arabia" were held at the New York University Abu Dhabi in 2012 and 2015, accompanied by two special issues in "*Marine Pollution Bulletin*" and the founding of the "*Mideast Coral Reef Society*". With the inauguration of the Red Sea Research Centre at King Abdullah University of Science & Technology (KAUST) in 2011, research on reefs of the region was further boosted. In 2012, a dedicated session at the 12th ICRS, "Coral communities in extreme environments", focussed on research on Mideast reefs. At the 13th ICRS, the "extreme environments" were combined with the "compromised and marginal environments, and their roles as refugia", following the integrative strategy of the organisers to manage the increasing volume and diversification of coral reef research.

The recent newsletter of the "*Mideast Coral Reef Society"* counted well over 60 abstracts from the 13th ICRS that reported on work conducted in the region. These presentations covered a broad range of topics including research on the adaptation and acclimation potential of corals, anthropogenic impacts, benthic ecology, biodiversity and evolution, biogeochemistry, biogeography and functional ecology, conservation biology, mesophotic reefs, microbial biology, molecular biology, paleobiology, reef pathology and remote sensing. The diversity of topics was reflected by the range of sessions in which they were

communicated, a clear indicator of the high relevance of the Mideast region to coral reef science. On the downside, during the 13th ICRS, this success made it challenging to keep track of what else was going on, in particular during the first three days. The electronic program proved to be a life saver for many. One participant from Kuwait commented: "There was a lot of information to help get around. The app was very useful too."

The presentations were of high quality and several talks reported findings "hot from the press". Many speakers presented results that had been already heralded during the "Coral Reefs of Arabia" conference in 2015, which was also helpful in making a personal choice of talks to attend. Highlight presentations mentioned by Mideast participants included the work of Hume *et al.* on the role of a novel *Symbiodinium* species in the adaptation of corals from the Persian/Arabian to rapid climate change, of Howells *et al.* on the gain of heat tolerance that resulted from crossbreeding and of Alhazeem *et al.* on the long-term coral community stability in disturbed reefs in Kuwait.

Regional focus apart, various of the Plenary Talks also stuck in the memory. As one Mideast member of the audience commented "I particularly enjoyed the Darwin medal speech by Jack Randall, and found Ruth Gates' speech on the last day inspirational". Another especially enjoyed and was impressed by the presentation of Peter Mumby.
Otherwise the importance of the 13th ICRS as a platform for meeting other scientists at all stages of their careers was regularly emphasised:

"I found the 'lunch with mentors' very enjoyable and inspiring. Scientists, we used to refer to when writing, were there at our tables and that felt great!"

"It was a very positive experience, I met many colleagues from the Middle East and was able to network. However, it was also good to be exposed to different aspects of coral science."

"I had the chance to network with people from the field from all over the world."

In fact many younger delegates had wished they could have extended such discussions in a more informal setting and would have appreciated more evening social events.

As showcased by the 13th ICRS, our understanding of coral reefs is greater than ever and it was good to see that research conducted in Mideast reefs made significant contributions to this knowledge gain. However, as the closing speeches of the symposium rightfully concluded, there is now the urgent need to use these scientific results in order to inform effective management strategies that can be implemented by policy makers to protect coral reefs, not only in the Middle East, but in other parts of the world.

Jörg Wiedenmann

The ISRS Secretary's Perspective

My first experience of an international Coral Reef Symposium was of ICRS2, a hard to replicate event held on board the cruise ship Marco Polo in 1973, as she cruised the length of the Great Barrier Reef. It was there I first encountered in earlier life such stalwarts as Charlie Veron, Jim Porter and of course Jack Randall. We had presentations in the morning, dived in the afternoon, talked animatedly every evening and partied all night. Of course the scope of the meeting was negligible compared to the more recent Symposia, but it did benefit from one characteristic that I wish we could somehow rediscover. As I remember, at that meeting I was able to attend the majority of all talks. In Honolulu, as in Cairns and Fort Lauderdale, no one could attend more than a few percent of the fifteen hundred or so presentations. Surely there must be a way with today's digital technology of making sure all

Visitors to the ISRS Stall

delegates can benefit from as many as they wish of the presentations, if only by viewing the powerpoint presentations online, afterwards or even beforehand?

As it happened, in Honolulu there was another factor limited my ability to attend sessions - the need to man the ISRS stall in the conference exhibition hall. But in fact, as I have experienced before, this turns out to be an unbeatable way of networking with large numbers of delegates, of touching base with old friends and making new ones. I was most grateful to all those who took the time to stop by or relieved me when I was desperate - to get to at least one or two sessions!

The general tenure of the meeting as regards future prospects for the world's coral reefs was of course desperately depressing. Pristine reef areas are now far and few between. But reasons for hope were apparent. As we discussed at the Society's coral bleaching and climate change Town Hall, ISRS's efforts in support of the CoP21 Climate Change Meeting in Paris do seem to have had some effect. Thanks to members who were in Paris, notably Ove Hough-Guldberg and Sue Wells, recommendations from the Society's Policy Statement were well received. And now there is also a generation of mid-career scientists who are taking advantage of impacts to reefs to explore with cutting edge technologies both cellular and ecological mechanisms underlying the reef's vulnerabilities. But I left Hawaii feeling that an even greater cause for hope were the record numbers of young reef scientists who throughout the meeting repeatedly demonstrated their love of coral reefs and their commitment to reef science. Often their familiarity with advanced concepts and new methodologies was humbling.

Equally humbling and totally pleasing was the award of the Society's Darwin Medal to Jack Randall. Quite how anyone has been as productive over as many years as Jack has been, remains perhaps the greatest unsolved mystery of reef science! Nothing gave me more hope for the future of reefs than the sight of the oldest delegate being mobbed by so many of the youngest, after his Darwin lecture presentation. I am sure he will have inspired many to emulate what he has achieved!

Rupert Ormond

Younger delegates posing for "selfies" with Jack Randall

Japanese Coral Reef Society Supporting the Attendance of Young Researchers

To promote the development of young scientist in the field of coral reef science, the Japanese Coral Reef Society (JCRS) has, through its International Coordinating Committee (ICC), been obtaining financial support to assist relevant post-doctoral researchers and graduate students attend international meetings and symposia. Based on a fund donated to JCRS by the legendary Dr. Siro Kawaguti, the Society has provided financial support for attendance at successive ICRS, since the 11th ICRS in Fort Lauderdale, as well as at both 2nd and the 3rd APCRS (Asia Pacific Coral Reef Symposium).

Most recently JCRS was able to provide financial support for graduate students (participating in masters or doctoral programs at Japanese Universities) and post-doctoral researchers (under 40 years of age) to attend ICRS13. Applications were invited on the JCRS website home page in January 2016 and 100,000 yen provided to each of the 10 successful candidates.

Young researchers from Japan showing their JCRS Award Certificates, together with their professors and JCRS office holders, at the award ceremony in Hawaii

The selections committee was composed of five professors: Dr. Y. Suzuki (President of JCRS), Dr. M. Hidaka (Vice-president of JCRS), Dr. K. Nadaoka (Chairman of the Planning and Operational Committee), Dr. Kayanne (General Secretary) and Dr. B.E.Casareto (Chair of the International coordinating Committee). Selection of the successful candidates was based on the abstract submitted for presentation at ICRS13, the cv of the applicant, a statement on the relevance of the research topics, letters of support from supervisors and the candidate's case for wishing to participate in the symposium.

The winners of the awards were ITO Saori (Hokkaido University), KUNIHIRO Shiori (University of the Ryukyus), NAKAMURA Shohei (University of the Ryukyus), MIZUYAMA Masaru (University of the Ryukyus), YUASA Hideaki (University of Miyazaki), Laddawan SANGSAWANG (Shizuoka University), Md. Shafiul ALAM (Shizuoka University), Rian PRASETIA (University of the Ryukyus), Rumana SULTANA (Shizuoka University) and VU Manh Hung (Shizuoka University). Their names were announced on the JCRS home page on April 21st, an obligation of the award being that successful candidates should provide a report on their participation in the symposium.

An Award Ceremony for the recipients was held on June 23rd as a timetabled component within ICRS13 itself. It was attended by more than 40 delegates, including professors, colleagues of the winners, other members of the JCRS, and colleagues from a range of other countries, as well as the awardees themselves.

During the ceremony, the chair of the ICC, Dr. B.E. Casareto, offered advice to the winners, including a view of their future as researchers and their participation in future JCRS activities. Dr. Y. Suzuki also spoke before awarding certificates to each of the winners, who in turn each offered their impressions of the Symposium. Dr. Kayanne also congratulated the winners. The Committee then visited the awardee's posters and/or attended their oral presentations, and were proud to witness the achievements of these young researchers.

Beatriz Casareto

National Science Foundation US Investigators Coral Bleaching Workshop

Prior to the 13th International Coral Reef Symposium (17-18 June 2016), over 40 U.S. coral scientists, including graduate students, post-doctoral researchers and senior investigators, gathered for a two-day workshop on coral bleaching. The central goal was to discuss the state of the science, and to determine how coral bleaching research may move forward into the next decade and beyond.

In the face of global climate change, coral bleaching events are projected to increase in frequency and intensity. By mid-century, global-scale bleaching events may occur on an annual basis. Already, back-to-back bleaching events were observed throughout much of the tropical oceans in 2014 and 2015, and the northern Great Barrier Reef has recently experienced the worst bleaching event on record. Participants broke into three focal groups that centered on molecular, organismal, and ecological responses. Each group discussed the state of their field, sharing recent findings, knowledge gaps, and recommended avenues of study that we can use to best protect coral reefs going forward. The groups then reconvened to share

their prioritized list of pressing research ideas, which converged on three central topics that may serve as priorities to move the science of coral bleaching forward:

Mechanisms. Our understanding of how corals respond to bleaching stress at the cellular and organismal scale has grown considerably. The details of the interactions between the coral and its algal endosymbiont(s) as well as how the underlying genetic diversity of corals and *Symbiodinium* may affect the susceptibility to coral bleaching are starting to converge. However, key areas of research need to continue: a) study of the cellular and organismal pathways involved in bleaching, b) how the bacterial and viral microbiome interact within the holobiont to facilitate bleaching susceptibility, depressed immunity, and disease progression, and c) by what degree genetic variation, epigenetics or trans-generational responses can promote resilience to bleaching in the progeny of previously bleached parent colonies. Noted priorities included, better normalization of methods and experimental designs across research groups, testing generalist and specialist *Symbiodinium* and a range of coral taxa across multiple locations, and the development of a suite of physiological and transcriptomic proxies to better define bleaching vs. resistant phenotypes.

Recovery. While there has been intense focus on the initial aspects of bleaching susceptibility, we know much less about the processes governing (or hindering) recovery dynamics following bleaching. While studies to date have been informative, the temporal nature of the recovery process demands much longer experimental designs than those approached thus far. Long-term, multi-year, controlled experimental studies are needed to discern the useful metrics for defining baselines and recovery from molecular to ecological scales. Integrative studies wherein genomic, microbial and phenotypic responses are viewed as a whole, and coupled to the relevant environmental site conditions will be important to tackle this topic. Questions included, what biotic, abiotic and historical factors influence recovery rates and trajectories? What life-history traits, including plasticity, acclimatization and adaptation as well as ecosystem characteristics facilitate recovery? To what scales are bleaching events operating relative to the scale of connectivity? How will source recruitment (e.g. remnant populations or pockets of resistance versus connectivity to deeper reefs) affect the outcome in recovery of multiple bleaching events?

Refugia & Restoration. Locating bleaching refugia is of critical importance. Bleaching is not always uniform across a region, and we have yet to identify the spatial scales where locations may perform as refugia. What parameters (seawater temperature and beyond) will be the best indicators for predicting refugia at local, regional and global scales? Likewise, what community characteristics, both biological (e.g., species richness, functional redundancy, genetic diversity) and physical (nutrients, turbidity, and flow) could serve as refugia predictors? Identifying locations with one or more of these characteristics may provide a strategic rationale for selecting sites for coral conservation and restoration. Time series data, as well as attempts to link organismal responses and genetic connectivity to distribution models may also serve as promising approaches. In addition, designing programs in selective breeding, assisted migration, and restoration are also possible approaches to creating refugia.

An overarching conclusion of this workshop was that these pressing questions are far beyond the scope of any one laboratory. A broader consortium of research efforts designed to leverage expertise across multiple collaborators will be necessary if we are to successfully tackle these topics. The group is now preparing a white paper to be submitted to the U.S. National Science Foundation, summarizing these findings. This was an incredibly productive workshop and the unique convergence on these three topics in particular indicates their importance and the growing consensus among investigators on these research priorities. Many thanks to the National Science Foundation for support for the workshop!

Andrea G Grottoli & Mark E Warner

Workshop Participants prior to ICRS13

PROGRAMMES & PROJECTS

Overviews of Ongoing Programmes and Projects

New Insights on Coral Diversity from a Marine Biodiversity Observation Network (MBON) in the Florida Keys

Since the late 1970's, the cover of coral species on many reefs in the Caribbean Sea has declined (Gardner et al. 2003). There have been increasingly frequent extremes in water temperatures, both warm and cold, over the last 30 years which have been associated with this decline. The susceptibility of corals to temperature variation is species-specific, yet there is clear evidence that coral populations have been decimated during extremely cold or warm-water events, reducing coral cover and allowing other reef species (e.g. octocorals – soft corals) to occupy that space (van Woesik et al. 2011, Guest et al. 2012, Ruzicka et al. 2013).

Based on long-term benthic surveys and satellite-derived sea surface temperature data, Soto et al. (2010) concluded that shallow corals in the Florida Keys exposed to an intermediate range of sea surface temperatures (SST variance: 6.5–8.5 $°C^2$) nevertheless exhibited higher coral cover than those in deeper sites exposed to a narrower range of temperature changes. Recent studies confirm that patch reefs (2 to 11 m depth) in the Florida Keys show higher diversity of coral species and coral-cover than those in other reef habitats such as offshore shallow (shallow spur and groove; 4 to 8 m) and offshore deeper (deep spur and grove; 11 to 23 m) reefs (Ruzicka et al. 2013; Vega-Rodriguez et al. 2015). Most of the predominant boulder-type stony coral species in the Florida Keys (*Siderastrea siderea, Pseudodiploria strigosa, Orbicella annularis complex, Montastraea cavernosa, and Colpophyllia natans*) located in patch reefs are exposed to intermediate water temperature variability (SST variance: 7.0–10.9$°C^2$). Species that are a little more temperature-sensitive, such as *Acropora palmate,* are by contrast more typically located on offshore shallow reefs and exposed to narrower ranges in water temperature variability (SST variance: < 7.0 $°C^2$) (Vega-Rodriguez et al. 2015).

Presently, there seems to be a shift taking place in coral compositions and community structure (e.g. increased octocoral cover) in the Florida Keys (Sommerfield et al. 2008, Ruzicka et al. 2013). Data from the Coral Reef Evaluation and Monitoring Project (CREMP) of the State of Florida shows clear declines in coral diversity in years when both the warmest summers and coldest winters coincide, such as in 2009-2010 (Vega-Rodriguez et al. 2015). Indeed, the highest coral mortality ever reported in the Florida Keys occurred in 2010, during the severe cold water event when temperatures remained below 11°C for more than 48 hrs. (Lirman et al. 2010; Colella et al. 2012). Significant coral cover decrease was also observed during the warm summer of 2010 (SST > 30°C).

The length of time of exposure to extreme warm water can be quantified using satellite measurements of sea surface temperature (SST). Cumulative thermal stress products such as Degree Heating Weeks (DHW; °C-weeks) are a measure of the number of weeks that corals are exposed to temperatures above the average historical high SST temperature values since the 1980's (Fig. 1) (Liu et al. 2014). During the summer of 2010, patch reefs in the Middle Keys exposed to the high temperature extremes (DHWs > 6°C-weeks) seemed to be less impacted than those in the Upper Keys (Vega-Rodriguez et al. 2015). This suggests that predominant stony coral species located in some patch reefs of the Middle Keys have likely developed thermal acclimation and are thus more resilient to extreme thermally stress than corals in the Upper Keys (Vega-Rodriguez et al. 2015). However, further resilience is uncertain as stressful warm thermal anomalies (DHWs > 8°C-weeks) have occurred annually since 2010 (Fig. 1). Consequently, signs of thermal stress (paling), bleaching and the unprecedented spread of white-plague disease has been reported especially for corals

in the Upper Keys (Precht et al. 2016). Changes in coral populations have also been associated with human population growth in the Caribbean: urban and tourism development, increased nutrients, sediment inputs from riverine discharges and overfishing of reef species (Maina et al. 2011; Jackson et al., 2014). Certainly, combined temperature and human-related stressors may be the cause of an increased problem with coral diseases.

The conservation of high biological and habitat diversity is important for sustaining healthy coral reef ecosystems. However, it requires a deep understanding of the drivers that control reef population dynamics. To better understand factors that affect corals, and how their populations may be changing, Federal and State agencies are partnering with academic and private institutions to establish a Marine Biodiversity Observation Network (MBON). A pilot MBON has been funded by the National Aeronautics and Space Administration (NASA), the National Oceanographic and Atmospheric Administration (NOAA), and the US Integrated Ocean Observing System (IOOS). This pilot is sampling for habitat diversity in four National Marine Sanctuaries: Florida Keys, Flower Gardens Banks, Monterey Bay, and Channel Islands. The MBON is developing technologies and information tools for detecting changes in biodiversity over time. A major objective is to find the minimum set of observations necessary to implement a practical biodiversity observing system. Additionally, it is integrating biological and environmental data collected by past and ongoing programs. In the Florida Keys, MBON has established a partnership with the NOAA South Florida Program (SFP) which obtains bi-monthly water quality surveys led by NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML). 20 years of oceanographic data are compared with satellite images to make new seascape maps.

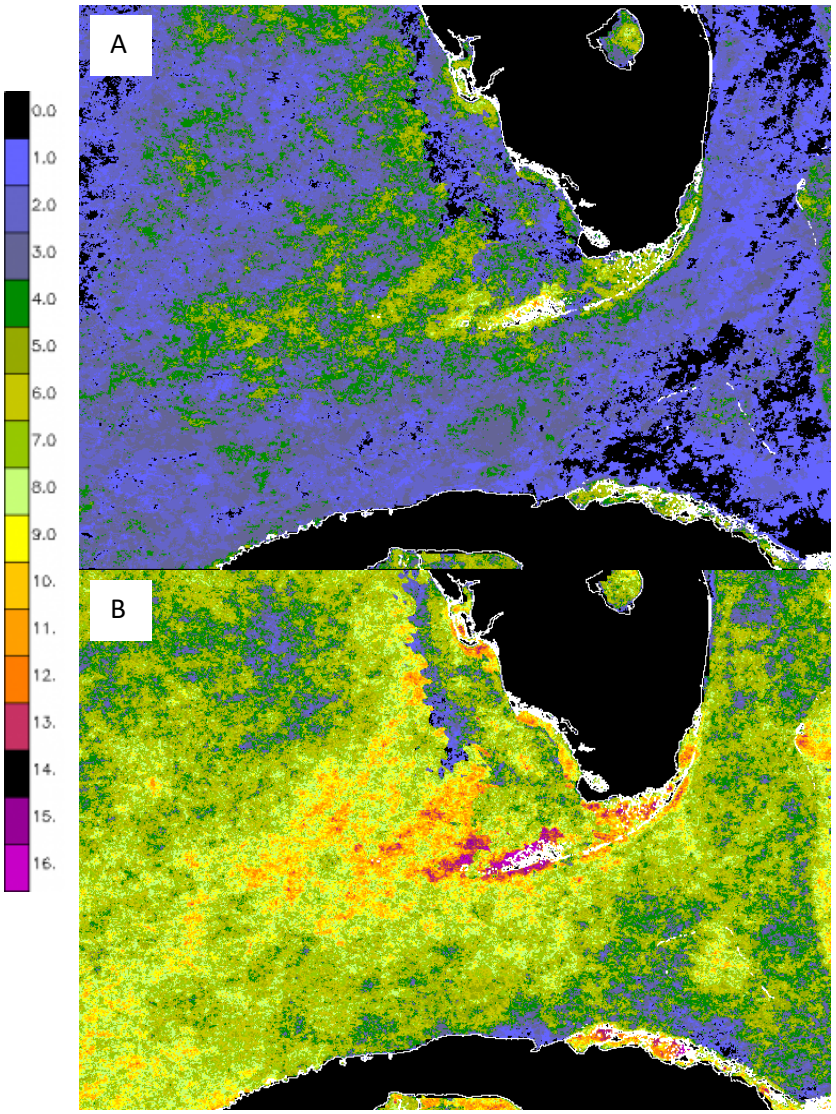

Figure 1. Degree Heating Weeks (DHWs; 1km^2 spatial resolution; °C-weeks) images for the Florida Keys on A) August 3, 2015 and B) September 14, 2015. These thermal anomaly products were developed in close collaboration with the NOAA Coral Reef Watch program (http://coralreefwatch.noaa.gov/satellite/index.php). When DHWs are ≥ 4°C-weeks but ≤ 8°C-weeks significant coral bleaching is expected; widespread coral mortality is likely when DHWs exceed 8°C-weeks (Liu et al. 2014).

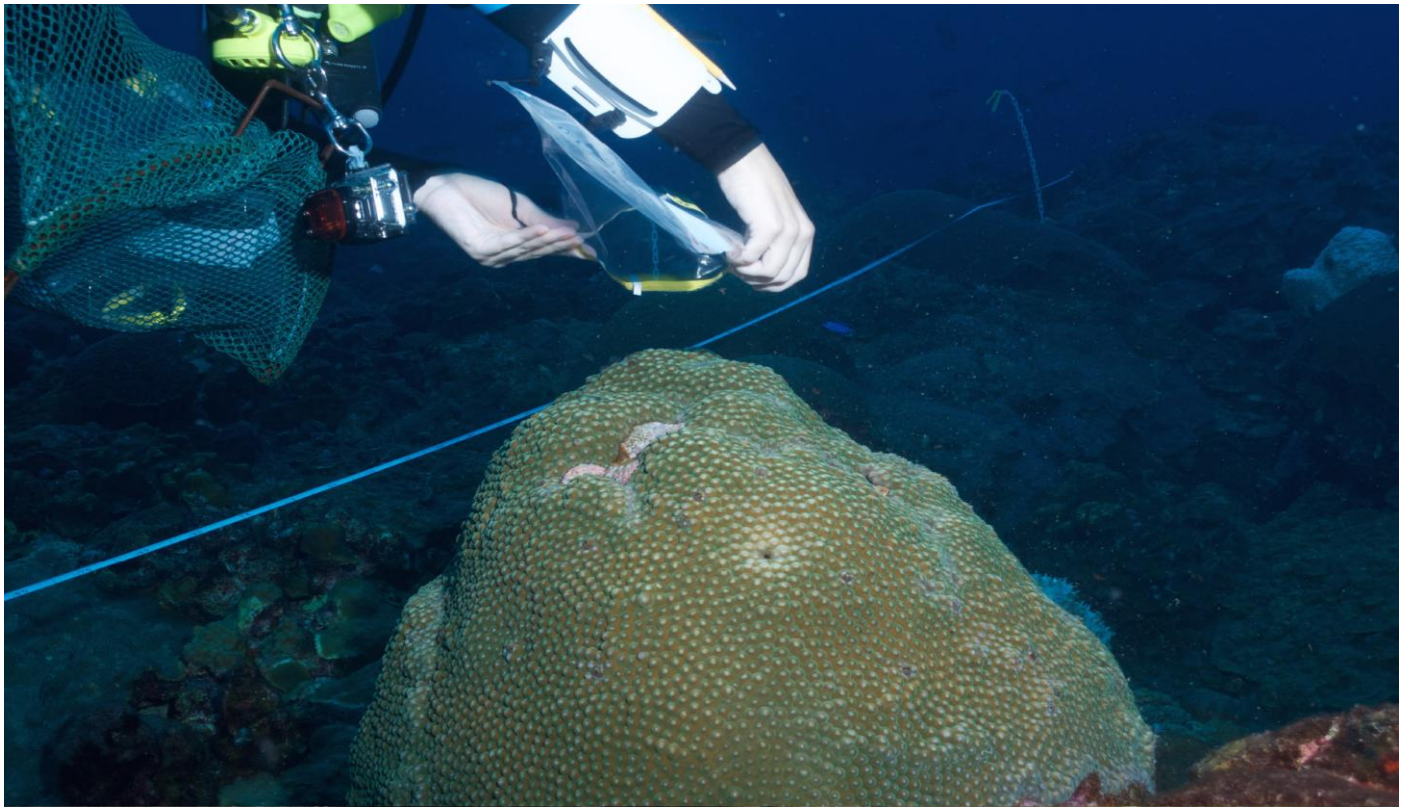

Figure 2. Diver collecting eDNA samples above a *Montastraea* spp. colony using 1-liter sterile bag. Pictures courtesy of Flower Gardens Bank National Marine Sanctuary Scientific Staff.

In the Flower Garden Banks National Marine Sanctuary (FGBNMS), the MBON seeks to monitor for any change due to gradual or abrupt (e.g. freshwater inputs) changes in environmental conditions. MBON provided satellite assessments and collected data in the FGBNMS to evaluate the aftermath of an unprecedented die-off of corals, sponges, brittle stars, sea urchins, and fish in July 2016. This die-off was likely related to a massive offshore flow of coastal, brackish water after heavy discharges due to rain in Texas. The MBON efforts is working with the FGBNMS and other Sanctuaries to test new genomic tools like environmental DNA (eDNA) (Figure 2). Satellite-derived data (e.g. sea surface temperature, chlorophyll a concentrations and other environmental parameters) will provide a synoptic view of the sanctuaries and help explain changes in the biodiversity indices. The main objectives of these regional efforts are to obtain ongoing biodiversity assessments and to understand the impacts of biodiversity and ecosystem health changes within the Sanctuaries (Figure 3).

Changes in marine biodiversity are occurring along both coasts of the Americas and from pole to pole. The international Group on Earth Observations Biodiversity Observation Network (GEO BON) and a consortium of American nations called AmeriGEOSS are leading a *Pole-to-Pole MBON in the Americas* to measure changes in marine biodiversity along the coasts of the Americas. This collaboration includes the Ocean Biogeographic Information System (OBIS), the Global Ocean Observing System (GOOS), the Smithsonian's Tennenbaum Marine Observatories Network (TMON), and the Global Coral Reef Monitoring Network (GCRMN). It is important for people to understand the impact of the changes occurring within their environments to make best use of resources while conserving them for future generations. In the face of rapid changes in regional and local marine ecosystems, these innovative and practical programs will help in this process. The scientific information generated by programs like MBON, OBIS, TMON, and GCRMN will help make informed decisions about solutions to environmental problems.

Maria Vega-Rodriguez, Enrique Montes & Frank E. Muller-Karger

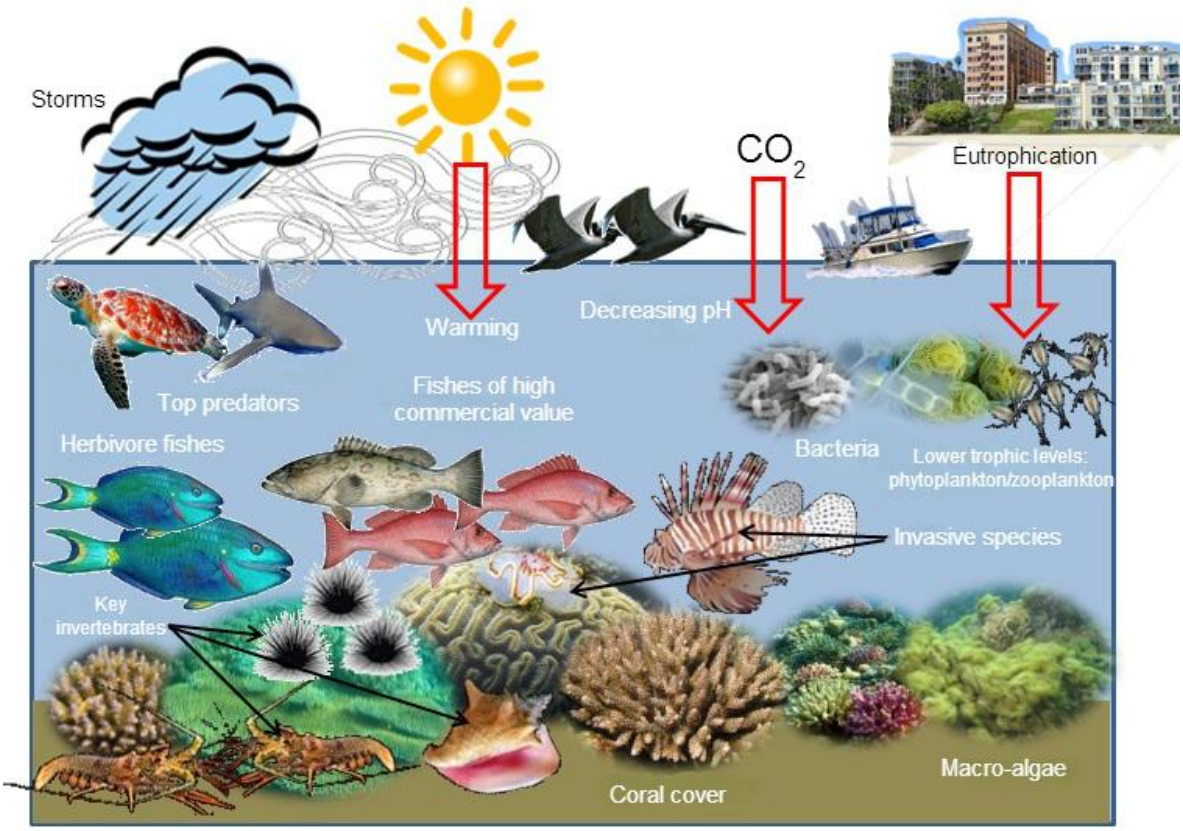

Figure 3. Representation of elements of the marine food web and aquatic environment that will be examined through the Florida Keys National Marine Sanctuary Marine Biodiversity Observation Network (MBON).

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REEF DEPARTURES

Memories of recently departed members and reef scientist

Donald William Kinsey (1935-2016)

Don Kinsey died peacefully in his sleep at his home on Magnetic Island, Queensland, Australia, October 28, 2016. He was 81. Don had been battling cancer for more than a year before his death. His wife of many years, Barbara, and his two daughters, Catherine and Anne, were with him.

Don was a man of many and disparate interests. Those who work on coral reefs know him primarily for two major directions of activity: as a coral reef biogeochemist with a particular interest in coral reef metabolism; and in the important roles he played in the management and conservation of the Great Barrier Reef (GBR).

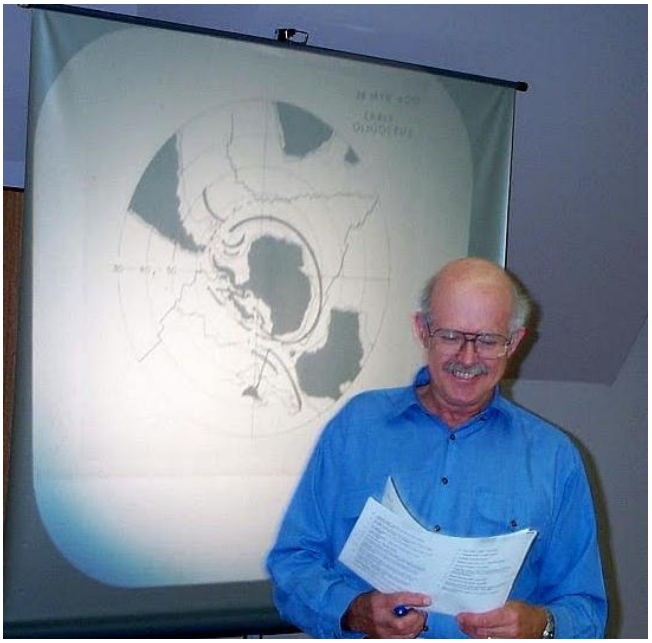
Before his career as a coral reef scientist, Don worked until 1976 as an industrial food scientist for Mauri Brothers & Thompson, Limited, in Sydney, Australia, having gained a BSc in microbiology and biochemistry from the University of Sydney in 1955.

Don's interest in reef metabolism began while vacationing with his family on Heron Island on the GBR, and from this he went on to pioneer the use of changes in the carbon dioxide (CO_2) chemistry of seawater (via the measurement of pH and total alkalinity), in order to characterize both the organic metabolism and calcium carbonate production rate of coral reef communities. "Metabolism" was particularly relevant because of some of his research for Mauri Brothers & Thompson[1], and so he chose to turn the family vacations into an intellectual pursuit. His initial studies, with Barbara, were done with oxygen measurements[2] using electrodes which he designed and constructed himself. His work on CO_2 chemistry[3] was first undertaken when he had the opportunity to join the 1967 and 1968 Australian Museum expeditions to One Tree Island, also on the GBR.

In 1970, shortly after I finished my PhD at the University of Hawaii, I was chatting with Bob Johannes,

Don with his medal as a Member of the Order of Australia, awarded among the Queen's Birthday Honours, in 1993. This represented the culmination of his career as a coral reef scientist and advocate for reef management.

then on the faculty of the Hawaii Institute of Marine Biology, about plans for a group study of coral reef metabolism to take place on Enewetak Atoll, in the Marshall Islands, in 1971. I asked Bob if an estimate of calcification (the most conspicuous metabolic process on coral reefs) was to be made. Bob had not thought about this and, on the spot, invited me to join the expedition. I had no idea how I would do it, but I accepted. Fortunately, another expedition member, Bill Wiebe, had recently met Don in Australia and was aware of his innovative work at One Tree Island. I contacted Don, who kindly shared with me a draft of his paper to be published in 1972 in the proceedings of the first ICRS symposium[3]. Don also provided me a great deal of more detailed advice about the method. I used this method successfully at Enewetak and eventually other locations, and Don and I subsequently published a methods paper using the technique[4].



Don giving a U3A lecture in oceanography, an example of his post-retirement continuing professional service.

In about 1975, Don decided he would like to do a PhD and turn his interest in coral reef metabolism from a hobby into a profession. He contacted me about the possibility of moving to the University of Hawaii and pursuing a PhD in oceanography. I was both surprised and delighted with the prospect of having my mentor in Hawaii as one of my first PhD students. Don and his family moved to Hawaii, took up residence in what had been the caretaker's residence on Coconut Island (the home of the Hawaii Institute of Marine Biology), and Don began his PhD research which included his two study sites in Australia and also work in Kaneohe Bay, Hawaii[5].

Shortly before finishing, Don learned that the University of Georgia was looking for a Director for its Marine Institute, and so he and his family moved from one island (Coconut Island) to another (Sapelo Island) to take up this post. He finished his thesis in 1979 and was Director and Associate Professor of the institute from 1978 to 1982.

Don and his family then returned to Australia, and he became Assistant Director, External Affairs and Principal Research Scientist of the Australian Institute of Marine Science in Townsville, a position until 1985. He then became the Executive Officer of the Great Barrier Reef Marine Park Authority, a position that he held until 1992, when he retired. In 1992-1993, he was the Establishment Director at the Cooperative Research Centre for the Ecologically Sustainable Development of the Great Barrier Reef.

Don was made a Member of the Order of Australia in the Queen's Birthday Honours in 1993, for his service to reef ecology and to the conservation and management of the marine environment. He became a Life Member of ISRS in 1994.

"Retirement," for Don, was just a beginning. Between 1992 and 2004, he operated a 35 acre macadamia and pecan orchard as a business, in partnership with his wife. He then made one more island move, to Magnetic Island, Queensland, where he tutored in courses in oceanography, coastal and marine ecology and global geomorphology and geochemistry. He was President of the NSW Council of the University of the Third Age (U3A) from1997 to 1999, Regional Adviser, Northern Region, NSW Council of U3A (2003-2004), and on Magnetic Island he established what became a branch of the Townsville U3A. He continued his teaching activities up until a few weeks before his death. Donald William Kinsey led a full and productive life up to the end.

Stephen V. Smith
Research Professor Emeritus
Department of Oceanography
University of Hawaii

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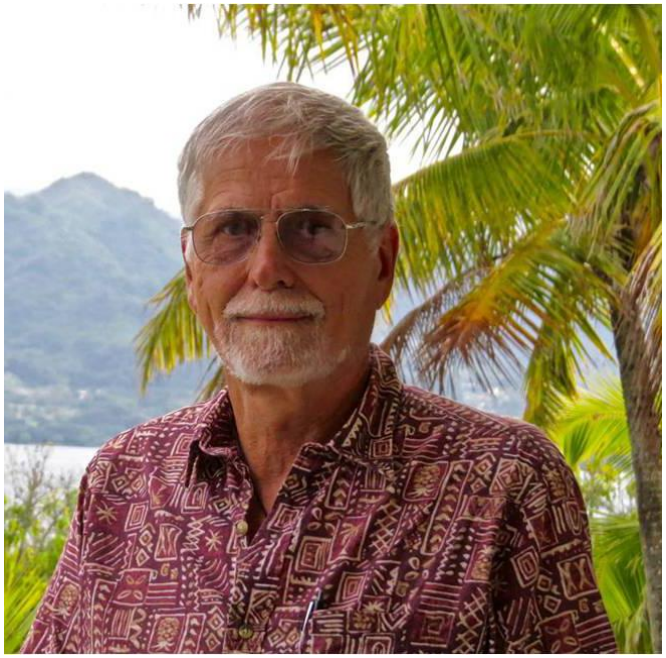
Paul L. Jokiel (1941-2016)



Paul Jokiel: coral ecologist and humanitarian

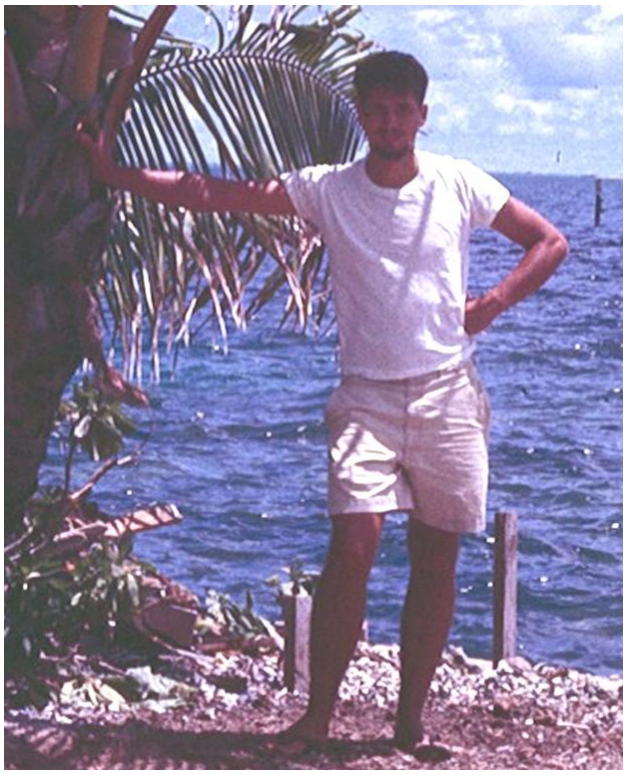
Paul Jokiel passed away in May 2016 in Washington D. C. while participating in a panel reviewing National Science Foundation (NSF) research proposals. Ironically, aged nearly 75, Paul had recently been informed of his own award of a three year grant from NSF to continue his work on the effects of acidification on reef corals and development of his Proton Flux Model.

Paul was born on May 20, 1941 in Chicago, Illinois, and received his undergraduate degree from Northwestern University in 1964. His research career began when, after teaching high school science for four years in the Chicago area, he was awarded a one-year NSF science teacher fellowship and went to Honolulu and the University of Hawai'i as a graduate student in oceanography in 1968. At the end of that academic year he was hired as a graduate assistant at the Hawai'i Institute of Marine Biology (HIMB) on a project to evaluate the effects of power plant thermal effluent on Hawaiian marine organisms in June 1969.

Paul designed an innovative seawater system for this project that produced high volumes of flowing seawater at controlled, fixed temperatures above and below ambient, enabling long-term experiments on the effects of temperature on corals and reef organisms. The results of these experiments and of field observations in Hawai'i and at Enewetak, Marshall Islands, verified that, at the warmest times of the year, corals live within 1-2°C of their long-term upper temperature thresholds, wherever they occur. This thermal threshold for coral bleaching and mortality has since been found to apply in the world-wide bleaching events that have repeatedly occurred since 1983.

Paul received his Ph.D in 1984 and, except for two years at the National Marine Fisheries Service from 1984 to 1986, he spent his entire career at HIMB where he received a staff research appointment in 1986. His research and interests were comprehensive and extended well beyond his initial work on coral temperature effects. He was author or coauthor of 125 peer reviewed papers in refereed journals, book chapters or conference proceedings (56 of which he was sole or first author), and 47 technical reports. His publications have been cited over 7000 times.

But, more important than the number of his publications, was the breadth and depth of the subjects that they covered. Paul was constantly curious and always looking over the horizon for other interesting things about corals that he could explore. He was a creative and innovative scientist who contributed greatly to marine science and coral ecology. He developed many methods that are used today worldwide, including coral buoyant weighing, measuring water motion using clod cards, and CO_2 dispersion techniques. He described the "Phoenix Effect" of coral regrowth after apparent mortality and did some of the earliest work on UV light impacts on corals and benthic invertebrates. His development of the "Rafting Theory" to explain how corals can travel long distances on floating objects provided the basis for the "Vortex Model" in the field of biogeography and ocean connectivity. His seminal work on climate change, that began in the early 1970s with the understanding of thermal tolerances and culminated with his work on coral acidification and with the



Paul in his youth

development of the "Proton Flux Model", provided a better understanding of coral metabolic responses to stresses related to increasing atmospheric carbon dioxide and temperatures.

Through his research, Paul also made a major contribution to coral reef management. He developed the first coral monitoring program to be used widely throughout the State of Hawai'i and that continues to be used to track coral and reef condition today. His studies of reef recovery in Kāne'ohe Bay following the reduction of sewage discharge, inundation by storm water, and coral bleaching, provided managers with the basis for understanding the connection of reefs to, and the impacts on them of, urbanization, watershed run-off and climate change. He was in the forefront of research involving coral restoration, response of corals to water motion, and coral reproduction and dispersal. His research and testimony provided scientific data for landmark court decisions on reef destruction and water rights. Numerous management regulations and education curricula in Hawai'i are based on his research. The Kahekili Herbivore Fisheries Management Area on Maui was set up using data collected during the long-term monitoring programme he initiated there. He was instrumental in the process that led to the first and largest settlement to the State of Hawai'i for damage to a reef in Pila'a, Kaua'I, by a landowner. He played a key role in the development of curricula and labs for public high school students on ocean acidification effects on coral reefs; and University of Hawai'i biometry classes now incorporate his extensive monitoring and assessment database as a component of their multivariate statistical analyses.

Along with his outstanding career in research, Paul was a major help to, and influence on, the professional development and well-being of many students and associates, from high school volunteers, marine options undergraduates and graduate students, to world recognized researchers and professors. For many years he organized and coordinated the HIMB Pauley Summer Program in which students had the great opportunity to work with Paul and other mentors doing coral-related research at the HIMB marine laboratory. For many of these students, who have since gone on to their own research, academic or

Paul working at the outdoor tanks

management careers, this was their first experience in working with corals in the lab or in the field. Through them, and through the students that they subsequently advised, Paul's inspiration has been far reaching.

In his capacity as a University of Hawai'i faculty member Paul was chairman and thesis advisor for 15 Masters and Ph.D. students, 12 of whom completed their degrees under his guidance and three who were still working with him. His students encompass a variety of backgrounds and life experiences, and many have said that they would never have considered pursuing an advanced degree had it not been for Paul's encouragement and guidance. The mentoring he provided to his graduate students is evident in the positions they now hold in higher education, federal and state government agencies, and as reef managers.

Paul had an offbeat sense of humor and could find something funny in just about any situation. A day working with him almost always provided a joke or an amusing observation. He was particularly fond of puns. For example, Paul was proud of his Polish descent and observed one day that whenever there was a political issue of concern, "someone takes a Pole". On one occasion when one of us (SC) came to the lab with an open sore on his leg Paul quickly took him aside and bandaged it, saying that "we don't want the staff to get staph".

In addition to his scientific career Paul was committed to helping people in other important ways. In the past 30 years, as a sponsor in various 12-step programs, he helped over 50 individuals and their families turn around their lives from substance addictions. He was involved with many other humanitarian efforts. He adopted two children of addicted parents, spread his message of environmental sustainability through the Vegetarian Society, and advocated for reducing carbon footprints through workshops, management agencies and public educational services. Paul considered these aspects of his life every bit, if not more as important as his scientific achievements. He never missed an opportunity to help others, and his positive outlook on life and his compassion will live on in the legacy he leaves behind. He dedicated his life to the service of mankind and he will be sorely missed.

Steve Coles, Ku'ulei Rodgers
and the HIMB Coral Ecology Lab

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)
- Access to the Society's on-line membership services, including the on-line Membership Directory
- Reduced registration fees for the International Coral Reef Symposium and other meetings sponsored by the Society.

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

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

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

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

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

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

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

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

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