MEMBERSHIP

The annual subscription for individual membership of **ISRS** is currently US$80, provided renewal payments are made by 1st March each year. Individual and Family Members receive the journal **Coral Reefs**, the magazine **Reef Encounter** and other periodic mailings. Family membership is US$90. Student membership costs US$25 and benefits include all of the above except the journal **Coral Reefs**.

The Category - Sustaining Member- is for those supporting the society with a subscription of $200. In addition to other benefits, sustaining members will see their names printed in each issue of **Reef Encounter**.

Renewals received between 1 March and 30 April will cost US$30 for a student member, US$90 for a full member and US$100 for a family membership. Those received after 1st May will cost US$32, US$100 and US$110 respectively. New members can join at the base rate of US$25, US$80 and US$90 at any time of the year. Financial assistance may be available to prospective members with legitimate needs. Please contact **ISRS** Corresponding Secretary Richard Aronson at raronson@jaguar1.usouthal.edu.

Institutional subscriptions to **Coral Reefs** must be placed directly with Springer-Verlag.

Subscriptions to the Society should be addressed to: International Society for Reef Studies, P.O. Box 1897, Lawrence, Kansas 66044-8897, USA.

NOTES FOR CONTRIBUTORS

Reef Encounter is the International Society for Reef Studies' magazine-style newsletter. In addition to our main feature articles, we include news on all aspects of reef science, including meetings, expeditions, book reviews, and information on student opportunities. We encourage discussion and debate on issues concerning reefs or the **ISRS**, and we welcome letters to the Editor for our correspondence column (Upwellings). We aim to complement the Society's journal, **Coral Reefs**, by publishing brief reviews of recent trends and developments that bear on reef studies. Please note that **Reef Encounter** does not publish original scientific data. We do, however, have a section reporting on recent publications (Reef Briefs). To have a paper to be included, please send a copy (reprint or corrected proofs only) to the Editor. Articles should range between 200 and 2000 words. Except in exceptional circumstances, text should be sent by email to suewells100@tiscall.co.uk

Reef Encounter has an informal and journalistic style, and while references are permitted, they should be kept to a minimum. Please number references in the text using superscript, and list them at the end of the article in the order in which they are cited, first through the text, and then through the table and figure legends. Each reference should have a unique number, and references should not be combined. Avoid the use of op.cit. or ibid, and use World List abbreviations. In all other aspects, references should follow the style prescribed for **Coral Reefs**.

We particularly welcome artwork and photographs to help us illustrate the magazine. Images can be sent as hard copy to the Editor. Electronic images should have a resolution of 350 dpi and must be a size appropriate for the magazine format. In particular, we cannot enlarge small electronic images and retain publishable quality. We prefer tiff format files. Where images are included in the article, please send legends and/or captions separately (not in the image file). Explain all symbols, abbreviations, shading patterns, etc. Maps should have a scale and indicate orientation. Please use either metric units or imperial with metric units. Please send with your article a short 'by-line' explaining who you are. Include your full address and email details which will be published with your article. We have no regular reprint system, but contributors who are not already members will receive a free copy of the relevant issue. Please consider joining the society if you are not already a member!

We acknowledge contributions by email. If you do not receive an acknowledgement within one week of submitting electronic material, please contact us to verify that it was received. We reserve the right to edit text to achieve a consistent style, and to minimize our changes you should use recent issues as style guides. We do not usually return articles for checking unless we consider our editorial changes may have altered your meaning. Articles are not refereed, and opinions expressed and errors of fact remain largely the author's responsibility. No published item should be taken as **ISRS** opinion unless indicated. Please note that **Reef Encounter** is an entirely voluntary effort. We do not have funds to pay contributors, and the editors are also unpaid.

We welcome contributions regardless of when they arrive. Issue 35 (expected out in November 2007) will have the updated yearly schedule of when you can expect **Reef Encounter** in the future. Submissions for issue 35 are due 15 September 2007. If you are planning a substantial contribution, it will help the Editor plan ahead by contacting her well in advance of the deadline. Thank you for your support.

DEADLINE FOR COPY FOR REEF ENCOUNTER 35 (DUE OUT NOVEMBER 2007) IS 15 SEPTEMBER 2007

Please send correspondence and submissions to one of these addresses:

editors@reefencounter.org

or

Editor, Sue Wells. Email:

suewells100@tiscall.co.uk

APPLICATION FORM FOR MEMBERSHIP

Name: .....
Address: .....
.....
.....
Title: .....
Fields of Interest: .....

I/We enclose a cheque (in US$ ONLY please) of:
..... US$80 for FULL membership
..... US$90 for FAMILY membership
..... US$25 for STUDENT membership
..... US$200 for SUSTAINING membership

Credit Card Payment: VISA/MasterCard

No. ..... Expir. Date .....

Signature .....

Bank drafts and cheques to be made payable to: International Society for Reef Studies. If a receipt is required, please request it at the time of payment. Send completed application forms and payment to ISRS, P.O. Box 1897, Lawrence, Kansas 66044-8897, USA.

Number 34 May 2007

REEF ENCOUNTER

Magazine of the International Society for Reef Studies

ISSN 0255-2787

EDITORIAL

Welcome to the 34th edition of Reef Encounter. This edition is full of interesting news and fun findings in the world of reef science! News of the election results and information on the make up of the ISRS community comes to you in **ISRS News**. The **News** section brings us information on management of reefs in the West Indian Ocean, and the results of an interesting study on citations in coral reef studies. In **Currents** we report on impacts to reefs from the tsunami of 2005, and unusual lesions associated with *Acropora* in the Atlantic. Our **Fellowship Reports** bring news of progress from all over the world including Australia, Fiji, the western Atlantic and more.

Reef Encounter will be under a new editing staff starting with the 35th issue. We wish Sue Wells and her staff luck with the journal we have worked so closely over the last several years. Thank you to all the contributors who make this journal worth reading. Keep the articles coming!

William F. Precht,
Martha Robbart, and
Beth Zimmer

ISRS NEWS

Outgoing ISRS President's message

My presidential term from 1 January 2003 to 31 December 2006 has been a busy time for me, but I am left with a sense that the ISRS did not engage fully with the fact that it is the world body of and for reef science. My tenure came at a time when the news about coral reefs has been dire, and at the same time public awareness has never been higher.

What did we achieve in the three years of my presidency? Singular achievements include: improved funding for editing the journal *Coral Reefs*; a very successful ICRS (10th, Okinawa); the 2nd highest *Coral Reefs* impact factor ever; the first membership survey; expansion of the ISRS fellowship program and 18 ISRS/TOC fellows funded; changes to the ISRS constitution voted on; excellent new editorial team engaged for *Coral Reefs*; two regional ISRS meetings (Kansas 2003, Bremen 2006); Ft Lauderdale engaged to host the 11th ICRS; three outreach ('briefing') papers disseminated; new web site established at FIT; and new regime agreed for production of *Reef Encounter*.

These and other achievements are important for the Society and for coral reefs, and would not have been possible without the work of many people. I would like to thank Rob van Woesik (web site, e-voting system and [latterly] fellow selection), Pete Edmunds (fellow selection 2003-04), all the members of the Local Organising Committee in Japan (10th ICRS), Dick Dodge and Barbara Brown and their editorial teams (*Coral Reefs*), Tim McClanahan (membership survey), an anonymous donor (ISRS/TOC fellowships), Rich Aronson (constitution, STAP, ICRS agreement, subsidized subscriptions), Michel Pichon (11th ICRS selection), Pete Mumby (e-voting, membership liaison), and John Ware (finances, financial reporting).

Given the Society is run by unpaid volunteers, who as accomplished coral reef scientists, are already committed heavily to their science and other professional activities (e.g. teaching, consultancy, management … families); maybe I should be fully content with our achievements. However, I believe the Society will only progress in its important role if it recognizes where it has not made the grade. Places where we have done poorly and need to improve include: failure to progress the briefing papers after 2004; low level of interaction between the ISRS membership and the ISRS Council; low voter turnout; decline in ISRS membership since 2004; few and irregular issues of *Reef Encounter*; lack of follow-up on member survey conducted via the annual membership renewals; inactivity of some ISRS Council members; poor reporting track-record of ISRS/TOC fellows on their work; ISRS largely unresponsive to key issues and events (e.g. tsunami); and the ISRS seemingly unable itself to engage in important issues such as worldwide reef degradation.

I believe there are ways we can improve our effectiveness as a Society for and about reef science. Some of the perceived deficiencies are being addressed (e.g. fellow reports herewith, new RE), but clearly there is work to do if the ISRS is to fulfil its key role in world coral reef science at this crucial juncture. The wider membership clearly has much to contribute in the new term just beginning, and the future President, other Officers and the rest of the Council will set the stage for this. Above all, it is important that the Society continue to play a leading role in upholding and disseminating good science. We must help the wider community understand that even if politicians are determined to ignore the pressing need for scientifically-based conservation of coral reefs, it is not because there is a lack of sound science and scientifically-based management advice.

Nicholas Polunin
ISRS President 2003-2006
15 November 2006

Incoming ISRS President's message

Are all coral reef ecosystems in imminent danger of collapse? What are the causes of reef degradation? Are reef fisheries recoverable? What is the role of nutrients? What can MPAs do for coral reefs? Which combinations of strategic actions will offer the best chance to save reefs? The only thing uncontroversial about these questions is that they are controversial. Whatever we believe to be the correct—or I should say the *more* correct—answers, we all share a profound sense of dismay at what is happening to the global environment in general and to coral reefs in particular. That is reason enough for us to come together as the society that is **ISRS**.

We are a large group of smart and opinionated students, policymakers, advocates, managers, amateur naturalists and scientists from over 65 countries worldwide, so disagreements are inevitable. Even heated controversies should be no surprise. Now is most decidedly *not* the time to lay aside our intellectual differences; we are, after all, a *scientific* society. Argument and debate in tandem with rigorous investigation, leading ultimately to reconciliation, is the only path forward to effective policy recommendations. For some questions, enough data are available for the overwhelming majority of the ISRS membership already to have reached consensus, and the ISRS is working to get those conclusions out to the public. As for the controversies, we can neither fiddle while the world burns, nor can we roll over and accept facile alarmism. We must redouble our efforts to reach scientific agreement without dissipating the strength of what we ultimately say to the public. This will be my toughest challenge as President.

Among outgoing President Nick Polunin's legacies, and directly connected to this challenge, is a strong impetus for the Society to continue producing Briefing Papers (BPs) on important topics in reef science. Incoming Vice President Tim McClanahan will direct this program. His task will be to identify topics and authors for the BPs, which will be published in *Reef Encounter* and on our website, with an **ISRS** byline. Tim will help the authors synthesize large amounts of information into short statements, which can be understood by general audiences and which can be further digested into press releases. The key to working with the media will be to offer up one new and discrete 'factoid' at a time. We welcome suggestions and participation in this program from all our members.

In another important outreach effort, the Society will begin developing curricular materials on coral reefs for primary and secondary school students. My institution, the Dauphin Island Sea Lab (DISL), has a prominent K–12 component, and we can use DISL and other institutions around the world as proving grounds. We will need plenty of help from the membership at large to get this program going and make it a success.

We will also ramp up our participation in such efforts as the International Coral Reef Initiative and the U.S. Coral Reef Task Force. Again, we will consider any and all offers of help from our members.

Nick worked hard to expand our student-fellowship program, which is funded largely by The Ocean Conservancy (TOC) through an anonymous donation. This issue of *Reef Encounter* showcases research supported by the ISRS/TOC Graduate Fellowships in Coral Reef Science. We are truly grateful to our benefactor and look forward to continued funding for deserving students who will do cutting-edge research on coral reefs.

Plans are in full swing for the 11th International Coral Reef Symposium, to be held in Fort Lauderdale July 7–11, 2008. **ISRS** co-sponsors the ICRS, and we are working with the Local Organizing Committee to ensure a successful, stimulating and enjoyable meeting. Travel funds will be available on a competitive basis for those with legitimate financial needs, and there will be an announcement about the Student Travel Award Program (STAP) closer to the time of the Symposium.

With this issue of *Reef Encounter*, Bill Precht steps down as Editor and Sue Wells takes over. We thank Bill and his team for their hard work and welcome Sue. This will also be the last printed issue of *RE*, because we will be going electronic under Sue's guidance.

We also thank outgoing Councillors Katharina Fabricius, Ove Hoegh-Guldberg, Tim McClanahan, Michel Pichon, Helmut Schuhmacher and Makoto Tsuchiya. The new and continuing Officers and Councillors are listed on the next page, and I look forward to working with all of them.

Finally, I offer Nick my sincere gratitude for his four years of hard work on behalf of **ISRS**. He has all but bled for this Society and he deserves heartfelt thanks from all of us. Past-Presidents and other former Officers remain a critical repository of corporate memory and are constantly dunned for advice, so to Nick and the other past-Presidents out there I say, "You know who you are, and so do we!"

Please feel free to contact me (raronson@disl.org) or Corresponding Secretary Isabelle Côté (imcote@sfu.ca) with any questions, suggestions or concerns. Good luck to us all in repairing the world's coral reefs.

Richard B. Aronson
ISRS Incoming President

2006 ISRS Election Results

Dear ISRS members,

I am pleased to report the following results from the 2006 ISRS election:

President
Dr Richard Aronson
Vice-President
Dr Tim McClanahan
Corresponding Secretary
Dr Isabelle M. Cote

Councillors
Dr Andrew H Baird
Dr Steve Coles
Dr Michio Hidaka
Dr Dennis K Hubbard
Dr Melanie McField
Dr Caroline Rogers

Changes to bylaws were accepted but since less than 40% of the membership voted the proposed changes to the Constitution could not be adopted. Note, however, that the turnout for electronic voting was more than double that of the last postal vote.

On behalf of the Society I'd like to thank everyone that stood for election (the results were pretty close). I'd also like to thank Rob van Woesik and his team for managing the website so effectively during the election.

Sincerely,

Professor Peter J Mumby
Corresponding Secretary, ISRS

International Society for Reef Studies: Financial Report 2005

Total cash assets as of December 31, 2005 were $150,751.24, all of which are in interest bearing checking accounts. At the beginning of the year cash assets were $148,368.42, representing a net increase of $2,382.82 (All in U.S. dollars.) This "profit" is misleading because it includes a deposit of $10,052.07designated for the next International Conference on Coelenterate Biology. Without this contribution, the Society actually shows a loss for 2005 in the amount of $7,669.25. This is attributed to a 14% decrease in memberships (representing a deficit of $10,232.28) plus a substantial increase in postage, publishing costs for **Coral Reefs,** and increased editorial subsidies some of which were disbursements for 2004 editorial expenses (Note: Springer Verlag also increased their editorial subsidy allowances to ISRS). Income and Expenses for 2005 were as follows:

Income:	
Memberships	62,075.00
Interest	744.38
Editorial Subsidies (from Springer-Verlag)	38,052.60
Contribution Reserved for Future ICCB	10,052.07
Total Income	**110,924.05**
Less Expenses:	
Editorial Subsidies Paid*	43,887.79
Travel/Meeting Subsidies	0
Postal Permit & Fees	13,984.16
Bank Charges	45.00
Credit Card Charges	1,258.82
Management Fees – Allen Marketing & Management	13,330.56
Marketing Fees – Allen Marketing & Management	1,579.34
Coral Reefs – Springer-Verlag	22,679.42
"Reef Encounter" – Allen Press	5,075.71
Briefing Paper	5,000.00
2004 Tax Prep.	650.00
Miscellaneous**	1,050.43
Total Expenses	**99,112.21**
Less ICCB Funds	10,052.07
NET INCOME(LOSS)	**($7,669.25)**

*Editorial expenses for 2005 included retroactive payments for 2004.

**Miscellaneous expenses include warehouse fees, honorariums, awards, software and publication of the annual membership directory.

Where do we fit in? An analysis of coral citations and ISRS membership

We might assume that the diligent coral reef scholar is a member of the ISRS, reads most of the abstracts to papers in Coral Reefs, follows a dozen or so other related journals, and stays in regular contact with a few dozen ISRS colleagues. This scholar, who we should assume feels pleased that he is following and staying in the forefront of his science, might be surprised to learn that between January 2000 and April 2004, when Coral Reefs published around 350 articles, the ISI Science Citation Index compiled 6466 papers in 1024 journals based on the keyword coral. These papers were produced by 20,147 authorships, which conservatively suggest that no less than 5000 people are publishing papers on coral or about five times the ISRS membership. Additionally, the keyword reef is expected to produce just over 2000 citations over this same period using GeoRef, the geological literature database (Gischler 2000), and the social and medical sciences are also likely to produce a considerable list of publications. Even the best intentioned of us will be daunted by the possibility

of reading a good portion of these papers, following these journals, and staying in touch with a significant portion of our colleagues. This also begs the question of where the Society and our journal fit into the larger view of coral and reef studies and how we can continue to play a central role in reef scholarship and avoid slipping into becoming a specialized society and journal.

In the past issue of Reef Encounters, I analyzed the membership data of the ISRS based on 463 respondents or a little over half of the membership (McClanahan and Nzuki 2005). This indicated that we are largely a society of academics that study the biodiversity and conservation of corals and fish in the Caribbean and Indo-Pacific. We are, however, quite interdisciplinary with a broad array of subdisciplines and some representation in most broad subject areas. The question I address here is how does the ISRS membership correspond to the larger academy of publishing coral scientists and are there ways that we can broaden our perspective to become more inclusive and representative of this wealth of knowledge and scholars?

In order to do this I examined the above natural science ISI database of journals, numbers of published papers, and citations per paper over the above 4.25 year period and classified the journals into major subject areas, which specifically included agronomy, biology, chemistry, conservation, ecology, engineering, geology, interdisciplinary, and oceanography. The papers in this database are included if the word coral is in the title, abstract, or keywords. I reduced the total number of journals from 1024 to 371 as 657 journals published less than 2 coral papers during the study period or, in a very few cases, coral was an acronym for something other than the organism we study. This reduced the total number of papers to 5606 and 18,862 citations.

I present the results of the top twelve journals in each subject area, based on total number of papers published, and for all journals combined in each subject area. I then compared the results of the total number of publications and citations with the stated subject areas of ISRS members to evaluate our correspondence with the broader literature. One problem with the ISRS membership survey, that became clear in doing this comparison, is that we did not give members the option of a few subject areas in the questionnaire, namely agronomy, chemistry, engineering, and interdisciplinary. We gave the option for chemical oceanography but not chemistry, as in natural products and other chemistry disciplines. This indicates a need to change future versions of the membership questionnaire.

When presenting my Impact Factor (IF4.25) for each journal, I also present both the mean and standard deviation. It is poorly appreciated that standard deviations on IFs are frequently larger than the means and that the mean and standard deviation of IFs are strongly correlated ($r2 = 0.75$ in this dataset). Much unnecessary importance and anxiety is created by small differences in IFs. If reporting variances around IFs were common, we would realize that there is probably little statistical difference between closely ranked journals. Citation of literature is patchy, cumulative, and path or history dependent (Kuhn 1996). Here you will see that there are often differences in the journals IF with the IF for coral papers, something that authors need to appreciate when deciding where to submit.

A few points to consider when examining these numbers and comparing with other IFs and reviews of citation; I did the classification of journals into subject areas and did not use the classification that the ISI reports, the length of time after publication to citation is 4.25 rather than 2 years, and the presented IFs are not for the journal as a whole but based only on coral papers. For example, the ISI would list Coral Reefs as a journal in aquatic sciences where as I listed it as interdisciplinary. The ranking of journals can be very dependent on the way they are pooled into a classification system and, again, ranks are probably a very poor statistic for comparing a variable where the standard deviations are larger than the mean, and mean and standard deviation are positively related. Nonetheless, the journals listed in Table 1, by number of publications, do represent the main contributors to coral natural science scholarship and will give the reader a good view of the state of leading journals publishing coral papers.

Marine Ecology Progress Series published the most coral papers while Coral Reefs published the second most followed by Marine Biology, Bulletin of Marine Science, Marine Pollution Bulletin, Journal of Experimental Marine Biology and Ecology, and Palaeogeography, Palaeoclimatology, Palaeoecology produced the most geology papers (Table 1). Of the 18,862 citations Marine Ecology Progress Series received the most, followed by Science, Coral Reefs, Marine Biology, Proceedings of the National Academy of Science, Nature, and the chemistry journal Natural Product Reports.

The average IF4.25 for this data set is 3.22+8.55 and Coral Reefs lies below that at 2.87+ 5.39, which makes it 160th on the list by this per paper measure (but note the SDs). The IF4.25 does hold some surprises, however, as two chemistry journals Nature Product Reports and Nature Biotechnology are the top journals, largely because fluorescent proteins derived from the coral Dicosoma are stimulating many advances in biotechnology. Even the leading producers of coral papers are not ranked high in this list with, for example, Marine Ecology Progress Series ranked 119th. Among the leading IF4.25 journals, the 7th ranked Science is probably the biggest contributor to coral science as practiced by most Society members and it published 69 papers with an average IF4.25 of 17+40. Clearly, a paper published in Science can get considerable attention but it can also be entirely ignored.

There are notable differences in the number of journals, citations, and

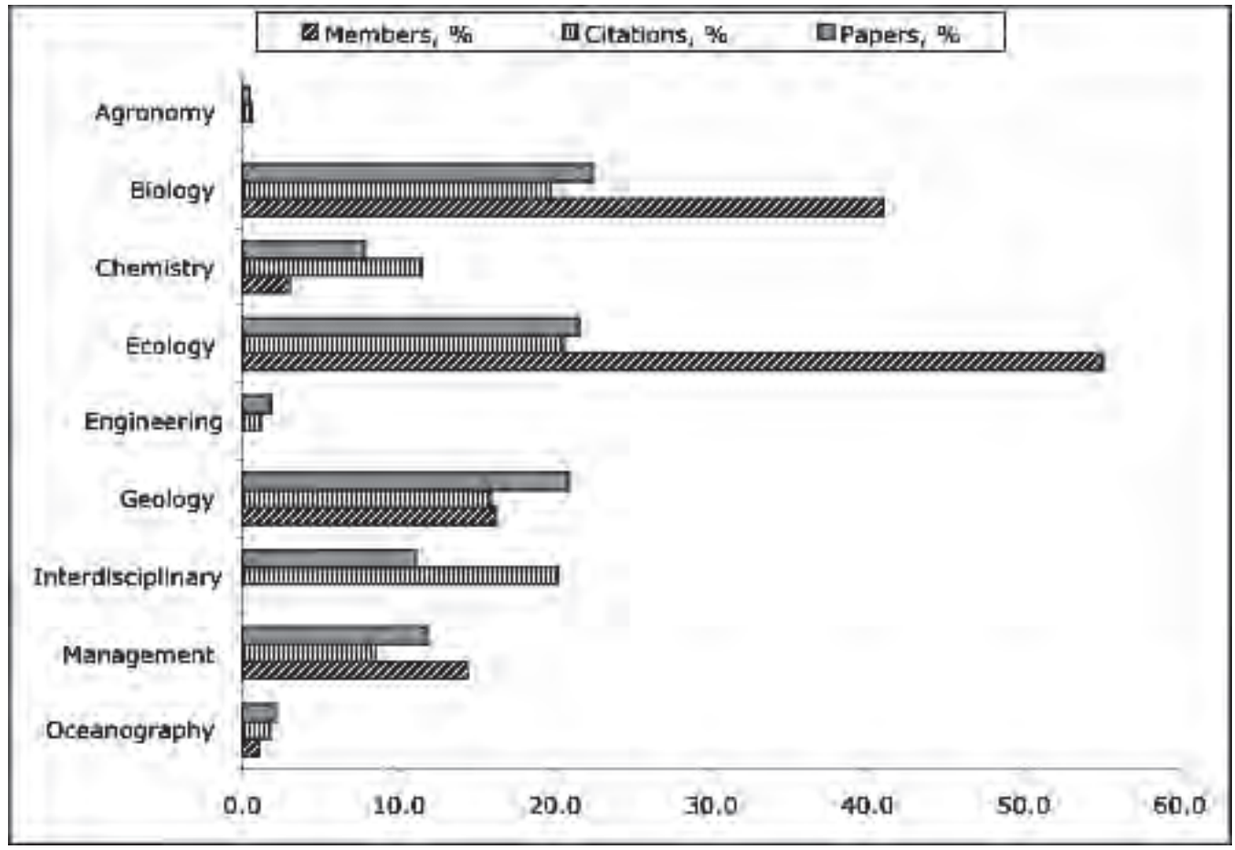


Figure 1. Percentage representation of the ISRS membership and total natural science citations and papers in the major subject areas for coral studies. Comparison based on a summary of ISRS membership survey of 463 respondents, the ISI database of 371 journals (>2 publications in 4.25 years), 5606 papers, and 18,862 citations.

citations per paper in the major subject areas (Table 1). The subject area of biology produce the most number of journals at 95, followed closely by geology at 92, chemistry at 56, ecology at 41, management at 39, interdisciplinary at 17, engineering at 15, oceanography at 12 and agronomy at 4. The total number of papers produced is highest in biology, followed by ecology, geology, management, interdisciplinary, chemistry, oceanography, engineering, and agronomy. Consequently, ecology is producing more and chemistry fewer coral papers per journal. Total citations are highest for ecology followed by interdisciplinary, biology, geology, chemistry, management, oceanography, engineering, and agronomy. Interdisciplinary journals have the highest IF4.25 followed by chemistry, ecology, biology, agronomy, management, geology, oceanography, and engineering.

Comparison of the percentage of total papers and citations with the subject area interests of Society members indicates that ISRS is both over represented in biology and ecology and underrepresented in chemistry relative to the number of papers and citations in these subject areas (Fig. 1). This fits with the observations that ecology published more and chemistry less coral papers relative to other subdisciplines in these subject areas. Geology and management membership subject area interests seem to match well with publications frequencies. Members were not given the options of agronomy, engineering, and interdisciplinary and we used chemical oceanography to represent chemistry, which may not always correspond closely with the members sub-disciplines and needs to be incorporated into future membership questionnaires. The interdisciplinary category is expected to spread evenly among the other subject areas and the agronomy and engineering subject areas are too small a proportion of the categories to greatly influence the results.

These findings suggest a number of possible scenarios for ISRS development. First, to be more representative of coral scholarship there is a need to increase the membership of chemistry focused members and their publications in Coral Reefs. The first step in this direction was recently undertaken with the addition of a Biology Subject Editor with a focus on genetics, molecular biology, and biochemistry to the journal. There is

a need to insure that other aspects of chemistry are represented on the editorial board, that these areas are also included in symposia as a regular part of our meetings, and that there are increased cross-society and discipline interactions with the other major chemical societies and journals. This will broaden the scope and relevance of the Society and is also expected to raise the IF of the journal.

Secondly, the Society should continue to promote interdisciplinary work as this is one of it's strengths, and is also a leading area of citation. Thirdly, as found in the membership survey, the Society's strength is in biology and ecology, particularly areas of biodiversity assessment and marine protected areas. In order to increase the relevance and application of this strength there will be a need to strengthen the social science aspects of coral reef studies, particularly socioeconomics. The above analyses focused on the natural sciences, as the medical, social, and natural science ISI databases are compiled and organized separately. Nonetheless, to increase the relevance and application of our natural science strength, a similar study of social and medical science literature is needed as well as larger representation of these subject areas in our Society. The Society should continue along its original mandate to study coral reefs in the most inclusive and interdisciplinary manner, avoid the pitfalls of scholastic isolation and tradeoffs, and expand into these underrepresented subject areas.

Tim R. McClanahan
ISRS Council Member

References

Gischler E (2000) Reefs - Challenges and opportunities for the new millennium. Palaios 15 (2): 85–86.

Kuhn TS (1996) The Structure of Scientific Revolutions, Third Edition. The University of Chicago Press, London.

McClanahan TR, Nzuki S (2005) Who are we? An analysis of the ISRS membership. Reef Encounter 33:6-8.

Table 1. Summary of the ISI Science Citation Index for the keyword coral published between January 2000 and April 2004. Journal listed by major subject areas where the top 12 journals by total numbers of papers is presented. The number of papers, number of citations, citations per paper and the standard deviation (SD) are presented. See paper for compilation details.

Subject area Number of Journals	Journal Titles	No. of papers	No. of Citations	Citations per paper	SD
Agronomy = 4	AQUACULTURE	13	103	7.9	18.6
	AQUACULTURE RESEARCH	5	12	2.4	4.3
	JOURNAL OF THE WORLD AQUACULTURE SOCIETY	4	1	0.3	0.5
	JOURNAL OF APPLIED ICHTHYOLOGY	4	2	0.5	0.6
	All journals	26	118	2.77	6.01
Biology = 95	MARINE BIOLOGY	213	877	4.1	6.0
	HYDROBIOLOGIA	89	260	2.9	4.4
	JOURNAL OF FISH BIOLOGY	62	217	3.5	5.3
	REVISTA DE BIOLOGIA TROPICAL	55	44	0.8	1.2
	JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM	42	61	1.5	2.0
	PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES B-BIOLOGICAL SCIENCES	36	194	5.4	5.5
	BIOLOGICAL BULLETIN	30	168	5.6	8.7
	JOURNAL OF NATURAL HISTORY	28	38	1.4	2.2
	JOURNAL OF PHYCOLOGY	26	156	6.0	8.9
	INTEGRATIVE AND COMPARATIVE BIOLOGY	26	4	0.2	0.8
	EVOLUTION	25	252	10.1	10.4
	JOURNAL OF EXPERIMENTAL BIOLOGY	24	32	1.3	1.8
	All journals	1257	3714	2.82	3.32
Chemistry = 56	JOURNAL OF NATURAL PRODUCTS	62	225	3.6	3.0
	MOLECULAR ECOLOGY	30	181	6.0	5.8
	TETRAHEDRON LETTERS	21	63	3.0	2.9
	MOLECULAR ECOLOGY NOTES	16	14	0.9	1.6
	CHEMICAL GEOLOGY	15	58	3.9	3.9
	TETRAHEDRON	14	82	5.9	8.9
	TOXICON	13	33	2.5	2.0
	JOURNAL OF BIOLOGICAL CHEMISTRY	12	125	10.4	9.5
	NATURAL PRODUCT REPORTS	11	491	44.6	70.4
	JOURNAL OF ORGANIC CHEMISTRY	11	67	6.1	5.7

Table 1. Continued

Subject area Number of Journals	Journal Titles	No. of papers	No. of Citations	Citations per paper	SD
	ORGANIC LETTERS	11	67	6.1	5.8
	JOURNL OF THE AMERICAN CHEMICAL SOCIETY	10	87	8.7	7.4
	All journals	438	2168	4.2	5.1
Ecology = 41	MARINE ECOLOGY-PROGRESS SERIES	347	1295	3.7	4.6
	BULLETIN OF MARINE SCIENCE	206	415	2.0	4.3
	JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY	123	375	3.0	4.4
	MARINE AND FRESHWATER RESEARCH	78	171	2.2	2.8
	ENVIRONMENTAL BIOLOGY OF FISHES	72	112	1.6	2.5
	ECOLOGY	50	364	7.3	8.0
	OECOLOGIA	41	217	5.3	7.6
	MARINE ECOLOGY-PUBBLICAZIONI DELLA STAZIONE ZOOLOGICA DI NAPOLI I	23	36	1.6	2.1
	JOURNAL OF BIOGEOGRAPHY	19	38	2.0	3.2
	NEW ZEALAND JOURNAL OF MARINE AND FRESHWATER RESEARCH	18	44	2.4	3.3
	SCIENTIA MARINA	17	24	1.4	2.2
	ECOLOGY LETTERS	16	163	10.2	13.6
	All journals	1208	3880	3.2	4.0
Geology = 92	PALAEOGEOGRAPHY PALAEOCLIMATOLOGY PALAEOECOLOGY	100	343	3.4	4.3
	SEDIMENTARY GEOLOGY	72	198	2.8	3.1
	GEOCHIMICA ET COSMOCHIMICA ACTA	70	199	2.8	5.4
	MARINE GEOLOGY	52	145	2.8	3.5
	GEOPHYSICAL RESEARCH LETTERS	42	111	2.6	3.9
	FACIES	39	64	1.6	2.0
	JOURNAL OF PALEONTOLOGY	35	43	1.2	1.8
	JOURNAL OF SEDIMENTARY RESEARCH	30	48	1.6	2.2
	GEOLOGY	30	109	3.6	4.3
	EARTH AND PLANETARY SCIENCE LETTERS	30	159	5.3	5.9
	GEOLOGY	30	109	3.6	4.3
	JOURNAL OF SEDIMENTARY RESEARCH	30	48	1.6	2.2
	All journals	1173	3002	2.0	2.4
Interdisciplinary = 17	CORAL REEFS	309	888	2.9	5.4
	SCIENCE	69	1179	17.1	39.6
	ESTUARINE COASTAL AND SHELF SCIENCE	48	104	2.2	2.8
	NATURE	42	608	14.5	32.3
	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	33	805	24.4	39.3
	CARIBBEAN JOURNAL OF SCIENCE	21	18	0.9	1.2
	CONTINENTAL SHELF RESEARCH	20	52	2.6	4.6
	ESTUARIES	15	73	4.9	5.9
	CIENCIAS MARINAS	13	3	0.2	0.4
	CHINESE SCIENCE BULLETIN	12	18	1.5	1.7
	CURRENT SCIENCE	10	4	0.4	0.7
	ISSUES IN SCIENCE AND TECHNOLOGY	8	0	0	0
	All journals	621	3806	4.9	8.7
Management = 39	MARINE POLLUTION BULLETIN	128	288	3.0	4.7
	ICES JOURNAL OF MARINE SCIENCE	70	90	1.3	2.3
	FISHERIES RESEARCH	37	49	1.3	1.5
	FISHERY BULLETIN	34	74	2.2	2.1
	JOURNAL OF SHELLFISH RESEARCH	31	28	0.9	1.8
	ECOLOGICAL APPLICATIONS	26	222	8.5	8.4
	CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES	25	128	5.1	8.6
	CONSERVATION BIOLOGY	24	67	2.8	3.7

Table 1. Continued

Subject area Number of Journals	Journal Titles	No. of papers	No. of Citations	Citations per paper	SD
	AQUATIC CONSERVATION-MARINE AND FRESHWATER ECOSYSTEMS	23	58	2.5	3.6
	BIOLOGICAL CONSERVATION	22	83	3.8	4.7
	AMBIO	20	68	3.4	6.7
	OCEAN & COASTAL MANAGEMENT	19	17	0.9	1.7
	All journals	101	226	1.9	2.2
Engineering = 15	INTERNATIONAL JOURNAL OF REMOTE SENSING	15	46	3.1	3.7
	REMOTE SENSING OF ENVIRONMENT	15	86	5.7	7.2
	PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON SERIES A-MATHEMATICAL PHYSICAL AND ENGINEERING SCIENCES	11	13	1.2	0.9
	WATER SCIENCE AND TECHNOLOGY	7	14	2.0	3.6
	MINERALS ENGINEERING	5	0	0.0	0.0
	MATERIALS SCIENCE & ENGINEERING C-BIOMIMETIC AND SUPRAMOLECULAR SYSTEMS	5	6	1.2	1.3
	MINERALS ENGINEERING	5	0	0	0
	IEEE JOURNAL OF OCEAN ENGINEERING	4	8	2.0	2.7
	ENVIRONMENTAL SCIENCE & TECHNOLOGY	4	7	1.8	3.5
	SEA TECHNOLOGY	4	0	0.0	0.0
	CHEMICAL & ENGINEERING NEWS	4	0	0.0	0.0
	CANADIAN JOURNAL OF REMOTE SENSING	3	14	4.7	4.7
	All journals	101	226	1.9	2.2
Oceanography = 12	LIMNOLOGY AND OCEANOGRAPHY	55	233	4.2	5.2
	OCEANOLOGICA ACTA	11	22	2.0	1.3
	JOURNAL OF PLANKTON RESEARCH	9	17	1.9	2.8
	JOURNAL OF MARINE SYSTEMS	6	0	0.0	0.0
	PROGRESS IN OCEANOGRAPHY	6	2	0.3	0.8
	OCEANOLOGY	5	0	0.0	0.0
	SARSIA	5	4	0.8	1.1
	DEEP-SEA RESEARCH PART I-OCEANOGRAPHIC RESEARCH PAPERS	5	16	3.2	1.9
	JOURNAL OF SEA RESEARCH	5	18	3.6	4.6
	FISHERIES OCEANOGRAPHY	4	6	1.5	1.7
	FISHERIES OCEANOGRAPHY	4	6	1.5	1.7
	JOURNAL OF ATMOSPHERIC AND OCEANIC TECHNOLOGY	3	11	3.7	2.1
	All journals	118	338	1.96	1.96
Grand total = 371	Grand Total (All journals)	5606	18862	2.9	4.1

BEST PAPER AWARD 2004 – Coral Reefs

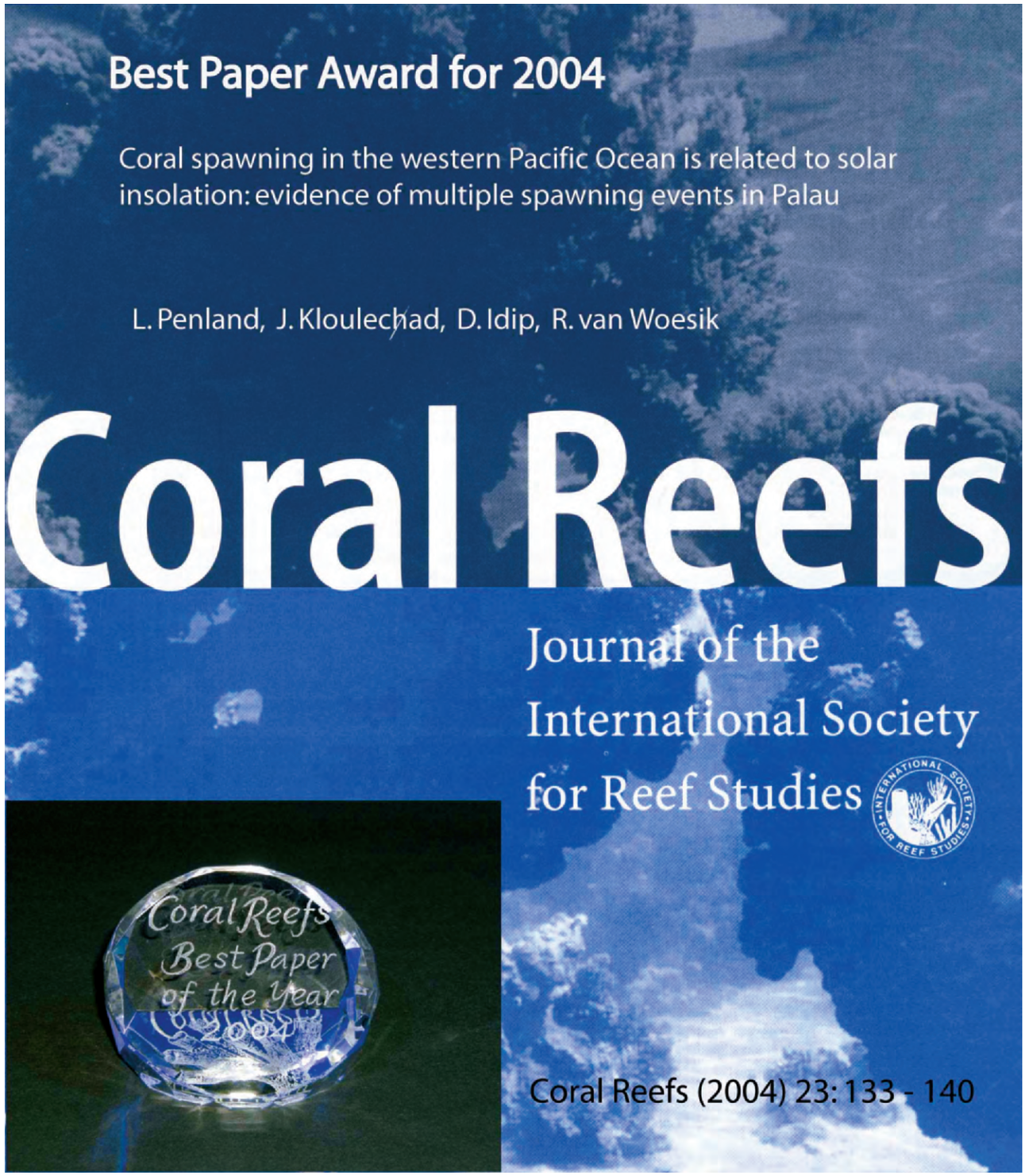
Each year the International Society for Reef Studies nominates one paper which has been published in its journal *Coral Reefs* for the "Best Paper of the Year" Award.

For the year 2004, the paper "Coral spawning in the western Pacific Ocean is related to solar insolation: evidence of multiple spawning events in Palau" (Vol 23:133-140), was nominated the Best Paper from a total of 63 published research articles. Nominations were received from the Editorial Board and the Topic Editors for the journal.

We are delighted that the award was made to a team of young researchers from the Palau International Coral Reef Center: Lolita Penland, Jim Kloulechad, and David Idip, supported by Dr. Rob van Woesik.

We congratulate the authors for their interesting and insightful research and wish them well in their continuing careers.

Barbara Brown
Emeritus Professor of
Tropical Marine Biology
Editor in Chief


Best Paper Award for 2004
Coral spawning in the western Pacific Ocean is related to solar insolation: evidence of multiple spawning events in Palau
L. Penland, J. Kloulechad, D. Idip, R. van Woesik
Coral Reefs
Journal of the International Society for Reef Studies
Coral Reefs Best Paper of the Year 2004
Coral Reefs (2004) 23: 133 - 140

An Open Letter to the Members of the International Society for Reef Studies (ISRS)

FLORIDA INSTITUTE OF OCEANOGRAPHY
830 First Street South
St. Petersburg, Florida 33701
Telephone (727) 553-1100
Fax (727) 553-1109

Many thanks to those of you who were nominated for office, who stood for election, and to the relatively few of you who voted. Congratulations and thanks to the outstanding group of members who were elected as officers and councilors and who have responsibility to lead us in our challenging times. Our collective concern and engagement in our influential International Society is critical to our future and, may I say, to the future of coral reefs.

Of course, I am concerned by the relatively few people who voted--less than 30% of our membership by generous calculation. Under our constitution this abysmal level of participation did not allow resolution of the proposed constitutional and by-laws amendments which were carefully considered and drafted by the officers and council. In two key positions the candidates ran unopposed. These are unhealthy signs of disengagement in the functioning of the Society.

Communication is the key and two new developments will help a great deal. First, the new leadership of our journal *Coral Reefs* has overcome many of the frustrating problems of publication delays and communication difficulties by the innovation of electronic manuscript submission and review. Second, our officers are moving to revitalize our newsletter *Reef Encounter*, a critical outlet for informal scientific and humorous articles, announcements, cartoons, and exchanges. It will be published more frequently and be available on line as well as by mail. These improvements will go a long way to restoring the inspiring international scientific communication and informal collegiality that initially drew many of us to join the ISRS.

I urge every member to resolve to become more active in the future. At the very least, every member should vote in the next election. Remember, we are led by volunteers whose success comes not only from their good ideas and hard work, but from the active support and engagement of the members.

Thanks again and best wishes to our officers, councilors, and editors,

John Ogden
ISRS President 1995-1998

NEWS

A New Report on Citations in Coral Reef Studies

Recently, *Essential Science Indicators (ESI) - Special Topics* reported citation data for the field of C*oral Reef Ecology* over the last 10 years (1994-2004). [1] The papers were written by 5060 authors affiliated with 1644 institutions in 103 countries. *ESI*, a Web product of *Thomson ISI* (Institute for Science Information) surveys papers from a broad range of scientific disciplines and ranks them according to the total number of times they have been cited in other papers. From an extensive citation database, begun in 1994 and updated every two months, *ESI* also ranks authors, institutions, countries and journals. Below are several of the citation results.

Top Nations and Institutions

In the *ESI* list of Top 20 nations with the most citations, the USA and Australia are ranked first and second, respectively. [2] The top ten countries account for 87% of the total number of citations (Figure 1).

The Top 20 institutions with the most citations include eight from the USA, six from Australia, three from England, and one each from France, Kenya, and Sweden. James Cook University, the Australian Institute of Marine Science, and the Smithsonian Institute are the top three in the world (Table 1).[3]

Top Authors and Papers of the Decade

The ten most highly cited authors from 1994-2004 include four from Australia, three from the USA, and one each from Kenya, England and France (Table 2).[4]

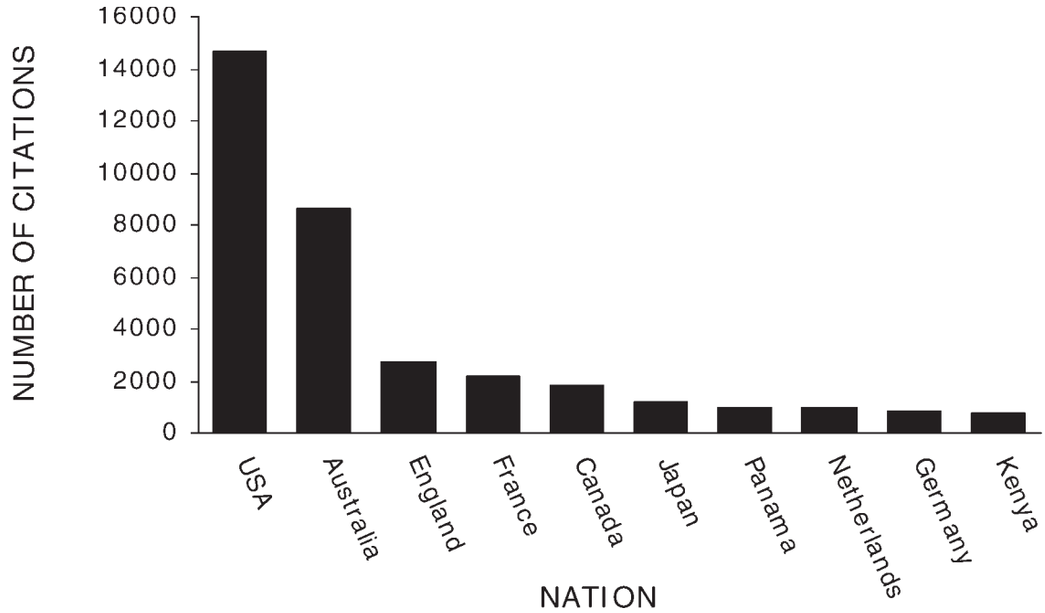


Figure 1. The top ten nations with the most citations in *Coral Reef Ecology*. (Modified from the *ESI* website).

Table 1. The top 20 institutions with the most citations in *Coral Reef Ecology* from 1994-2004. (Modified from the *ESI* website).

Rank	Institution	Number of Citations	Rank	Institution	Number of Citations
1	James Cook University	4031	11	University of California at San Diego	684
2	Australian Institute of Marine Science	1917	12	Wildlife Conservation Society	649
3	Smithsonian Institution	1720	13	University of Newcastle Upon Tyne	637
4	University of California at Santa Barbara	1536	14	Australian National University	618
5	University of North Carolina	1270	15	University of Queensland	575
6	University of Miami	1080	16	Stockholm University	479
7	University of Hawaii	927	17	State University of New York at Stony Brook	442
8	Oregon State University	804	18	University of York	434
9	University of Sydney	761	19	University of Cambridge	423
10	University of Perpignan	699	20	Australian Museum	414

Table 2. The top ten most highly cited authors in *Coral Reef Ecology* from 1994-2004. (Modified from the *ESI* website).

Rank	Author	Nation	Institution	Total Cites	Number of Papers
1	Hughes TP	Australia	James Cook University	1125	25
2	McClanahan TR	Kenya	Wildlife Conservation Society	633	34
3	Hixon MA	USA	Oregon State University	617	12
4	Jones GP	Australia	James Cook University	597	29
5	Carr MH	USA	University California Santa Cruz	540	10
6	Warner RR	USA	University California Santa Barbara	518	29
7	Bellwood DR	Australia	James Cook University	460	39
8	Roberts CM	England	University of York	423	20
9	Gattuso JP	France	Université Pierre et Marie Curie	420	20
10	Caley MJ	Australia	James Cook University/AIMS	416	13

The Top 20 most highly cited papers in *Coral Reef Ecology* characteristically address environmental issues that affect coral reefs, such as overfishing, global warming and human impact. Other topics in this highly cited group include recruitment of reef organisms, population modeling, chemical ecology, and reef geology. Table 3 lists the five most frequently cited papers of the past decade.[5]

References:

[1]http://www.esi-topics.com/coralreef/index.html

[2]http://www.esi-topics.com/coralreef/nations/d1a.html (Top 20 Nations - most citations)

[3]http://www.esi-topics.com/coralreef/inst/c1a.html (Top 20 Institutions - most citations)

[4]http://www.esi-topics.com/coralreef/authors/b1a.html (Top 20 Authors - most citations)

[5]http://www.esi-topics.com/coralreef/papers/a1.html (Top 20 Papers 1994-2004)

Table 3. The five most highly cited papers in *Coral Reef Ecology* from 1994-2004. (Modified from the *ESI* website).

Rank	Paper	Number of Cites
1	Hughes, T.P. (1994) Catastrophes, phase-shifts, and large-scale degradation of a Caribbean coral reef. *Science* 265, 1547-1551.	441
2	Caley, M.J. *et al.* (1996) Recruitment and the local dynamics of open marine populations. *Annu. Rev. Ecol. Syst.* 27, 477-500.	244
3	Carpenter, S.R. *et al.* (1998) Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecol. Appl.* 8, 559-568.	230
4	Doherty, P. and T. Fowler (1994) An empirical test of recruitment limitation in a coral reef fish. *Science* 263, 935-939.	203
5	Hoegh-Guldberg, O. (1999) Climate change, coral bleaching and the future of the world's coral reefs. *Marine Freshwater Res.* 50, 839-866.	195

The Bleeker Award for Distinguished Contributions to Indo-Pacific Ichthyology

The Scientific Advisory Committee for the 6th Indo-Pacific Fish Conference (IPFC) initiated an award for distinguished contributions to Indo-Pacific Ichthyology. This award was named in honor of the "father" of Indo-Pacific ichthyology, Pieter Bleeker, and will be awarded every four years in conjunction with the IPFC.

The **Pieter Bleeker Memorial Award for Excellence in Indo-Pacific Ichthyology** is awarded to a living ichthyologist for "an outstanding body of published work in Indo-Pacific ichthyology, mainly in systematics and ecology." Nominations were solicited worldwide for "The Bleeker," and it was decided that for the inaugural award two Bleekers would be available; one for excellence in systematic ichthyology and one for excellence in ecological ichthyology. The awards are based on the nominee's specific contributions and their impacts on ichthyology.

A committee consisting of members of both the Scientific Advisory Committee and the Organizing Committee for the 7th IPFC was assembled to select the award winners. The inaugural awards, consisting of a plaque and prizes, were presented during the opening ceremonies of the 7th IPFC (20 May, 2005) to Dr. John E. Randall (systematic ichthyology) and Dr. J. Howard Choat (ecological ichthyology). Each winner presented a plenary talk to open the IPFC.

Introductions for each of these outstanding ichthyologists were prepared by former students, and the Bleeker Awardees provided a full listing of their publications. These are posted on the website of the Ichthyological Society of Japan (http://www.fish-isj.jp/english/meeting.html) and serve as a valuable resource.

Thanks to the Bleeker Awardees for their outstanding career contributions and for their excellent talks, and congratulations to them on the honor bestowed by their fellow ichthyologists. The awards could not have been made without the nominations that were received, and the nominators deserve our thanks. Thanks are also due to the members of the Bleeker Award Committee for their hard work in the difficult task of selecting the winners from a stellar list of nominees. The Organizing Committee of the 7th IPFC, under the able chairmanship of Dr. Kwang-Tsao Shao, provided the award plaques and prizes, in addition to putting on an excellent conference. Thanks, too, to Drs. Kent Carpenter, Richard Pyle and Kendall Clements – former students of the award winners – for their excellent introductions of the winners, and to Dr. Keiichi Matsuura for arranging for the Bleeker Award information to be posted on the ISJ website.

Jeffrey M Leis, Chair,
Bleeker Award Committee

Livening up PowerPoint presentations with movie clips – a new resource

Getting the right balance between information and animation in a PowerPoint presentation is never easy. I once saw a conference talk in which the speaker 'livened up' his slides by having cartoon birds flying across the screen. Everyone was very impressed but many, like me, spent the remainder of the talk wondering how to do that in PowerPoint. I don't think anybody remembered what he was talking about. In contrast, conveying the importance of bioerosion to the Women's Institute requires something more intriguing than blocks of text. I believe that video clips can transform a presentation and help an audience visualise the topic more clearly.

Over the last few years I've taken a fair amount of underwater video whilst on research trips. Today's computers have so much memory that it's perfectly feasible to incorporate large video in PowerPoint. With the help of John Hedley, who designed a database and website, I have now placed the archive of over 500 clips online. Clips can be searched by topic, species or location and span a range of geographic areas (Caribbean Sea, Indian and Pacific Oceans) and topics (coral bleaching, fishing, mangroves, tourism impacts, ecosystem processes, reef habitats, etc). Files are FREELY available for scientific and educational purposes and can be downloaded at: http://www.reefvid.org

I hope you find them useful.

Peter
Dr. Peter J Mumby
Marine Spatial Ecology Lab
University of Exeter
p.j.mumby@ex.ac.uk
6 October 2006

New MPA Newsletter for the Western Indian Ocean (WIO) Region

By Nyawira Muthiga and Julius Francis

During the third Regional Training Course in Marine Protected Areas (MPA) Management in the Western Indian Ocean region held in August 2004, in Malindi, Kenya, the participants and the trainers involved in the course agreed to establish a Regional MPA Newsletter. The Newsletter intends to inform MPA practitioners, experts and other MPA stakeholders on various issues or activities taking place in the regional MPAs. Also, through the Newsletter, MPAs in the region will be able to inform wider audiences of their activities and raise their profile and visibility. Furthermore, the Newsletter will act as a bulletin board for different announcements of relevance to MPAs in the region. The Newsletter is produced quarterly and its production is coordinated by

Keith Spencer
De Hoop Nature Reserve
Private Bag X18
Bredasdorp
7280 South Africa
Email: keith@goweb.co.za
Nyawira Muthiga (nmuthiga@wcs.org) and Julius Francis (julius@wiomsa.org).

Monitoring bleaching in the Western Indian Ocean – going beyond some white corals

By Tim McClanahan

The ability to monitor bleaching on a global basis has increased greatly with the regular reporting of temperature anomalies, hot spots, and degree heating weeks data that are now regularly posted on the NOAA website (http://www.osdpd.noaa.gov/PSB/EPS/SST/SST.html). Biologists working in the field have not responded to the possibility of monitoring these events with equal sophistication or coordination. A first attempt to start this process was recently undertaken in the Western Indian Ocean associated with a hot spot that developed in the southern Indian Ocean in early 2005 and spread from southern Africa to the Mascarene Islands. A group of 12 collaborators working in different countries agreed to use a single system for monitoring bleaching (McClanahan 2004) and to nearly simultaneously undertake the same set of measurements in areas with and without reported hotspots.

The methods classify haphazardly selected coral colonies into seven categories from normal color to recently dead. The method is simple and a single investigator can sample about 300 colonies in less than one hour. Data entry and partial analysis take less than 15 minutes, and this makes it possible to monitor a half dozen sites in just a few days of field work. The results give a "bleaching index" for every coral taxon sampled and for every site. The coral bleaching results can be compared over sites and time quantifiably in a specific and repeatable way. This opens the possibility of comparing sites, taxa, and times in a way that will allow quantification and improved tracking and comparing of bleaching reports. This study has produced one of the first broad-scale surveys of bleaching and a baseline for future monitoring.

One of the spin off effects of this project is that coral communities and

biodiversity are quickly assessed at a rate that is much more cost effective than the current reliance on transect methods. The project will, therefore, produce a single snapshot of biodiversity and community structure in a large region, which would be very time consuming without a simple method. Plans and proposals are being developed to maintain this program over time and to expand it to other regions. For more information and interest in participating in this project contact Tim McClanahan tmmclanahan@wcs.org

McClanahan, T. R. 2004 (Mar. Biol. 144(6): 1239-1245)

Toolkit and Management Effectiveness Workbook for Managers in the WIO Region

By Julie Church

Toolkit

Recognizing the difficulties and complexities involved in managing Marine Protected Areas (MPAs) in the Western Indian Ocean (WIO), partners involved in the WIO Marine Biodiversity Conservation Project decided to publish a Toolkit for managing MPAs in the WIO. This consists of a ring-binder of theme sheets, each of which would address a key issue faced by a MPA manager, with a focus on the situation in the WIO. The Toolkit also has a complementary website (www.wiomsa.org\mpatoolkit.htm). It is designed to be a dynamic product that will be revised as new information becomes available, or as new sheets are developed. WIOMSA and GEMPA-EA have been instrumental in the development of this Toolkit and will act as the focal point for this ongoing review and updating. Comments and reviews should be addressed to: secretary@wiomsa.org.

Workbook

A workbook for assessing the effectiveness of marine protected areas was produced in order to test and adapt the World Commission on Protected Areas (WCPA) methodologies for use at MPAs in the WIO. It is based mainly on the approach used in the World Heritage project and the WCPA Management Effectiveness Task Force (METF) Framework. It has been tested in eight MPAs in three countries in the WIO – Kenya, Tanzania and the Seychelles. It is designed to allow for a dynamic process of MPA management, based on the lessons learned through piloting the first draft of the workbook in the eight MPAs. It takes into account the management issues faced in the WIO, is cost effective, and encourages self-assessment by the managers. The Workbook will have a complementary website (www.wiomsa.org\mpaworkbook.htm and CD ROM. There are also plans to translate this into French and Portuguese.

Launch and Training

There are plans to launch, distribute and provide basic training on the Toolkit and Workbook along with a Fisheries Database from September to December 2005 in all ten countries in the WIO along with the Toolkit and Workbook. Four workshops will be organized by lead country fisheries and wildlife management authorities. A coordinator will be hired to oversee the workshops and to train the participants on the various products. The audience will include key decision-makers, and marine and fisheries practitioners and researchers. (Contact Julie Church at cjulie@africaonline.co.ke)

Fisheries Database for the WIO Region

By Julie Church

The WIOFISH database has just been developed, led by the Oceanographic Research Institute (ORI), South Africa, with three contractual phases that involved partners from Kenya, Seychelles, Mozambique, Tanzania and South Africa. Madagascar, Comoros and other IO Island States are to join at a later stage.

The main objective is to identify all the types of small-scale fisheries that exist in the WIO region and to gain better understanding of their biological and socio-economic characteristics. This in turn will provide a regional overview of inshore, especially small-scale fisheries (and associated offshore fisheries that impact them), including their problems and specific management needs. This will then enable comparisons of policy and management strategies among these fisheries. The database will provide semi-quantifiable indicators of the status, and progress, in the management of these fisheries which will increase the understanding of the threats to biodiversity of the WIO fisheries.

The basic information was compiled during the initial phase of the Project in 2002 and 2003. The second phase was the development of the database in 2004. In order to make the information widely accessible and to facilitate the generation of reports, the system will be made accessible via the Internet by August 2005 (www.wiofish.org). WIOFISH is designed to be dynamic and evolving, accessible to a wide audience through the world-wide web, and will be managed and updated by a regional node (ORI), in close collaboration with the national nodes.

The Fisheries Database will be launched and distributed from September to December 2005 in all ten

countries in the WIO along with the Toolkit and Workbook. Four workshops will be organized by lead country fisheries and wildlife management authorities. A coordinator will be hired to oversee the workshops and to train participants on the various products. The audience will include key decision-makers, and marine and fisheries practitioners and researchers. Contact Julie Church at cjulie@africaonline.co.ke

OBITUARIES

Obituary: Hans Mergner, 1917–2005

Particularly the older generation of reef workers remember Hans Mergner well, as he regularly attended many of our reef conferences (from the first one on Mandapam Camp, India, in 1969 to the eighth in Panama, 1996). Moreover, he was one of the first members of ISRS. In the following I will attempt to point out how he got acquainted with and "infected" by the phenomenon of coral reefs.

Hans Mergner was born as the second of three children in Lemgo, a small town in central Germany on 8 May 1917. His father was a schoolteacher and provided his children a broad background of bourgeois culture. His financial status, however, allowed only the oldest son to attend a university; Hans, although very much interested in life and geosciences, had to enter a professional career in the army. In 1936, Hitler's (semi-) secret rearmament of land, sea, and airforces absorbed young men who would have been unemployed otherwise. Hans became an officer in the artillery and qualified as a spotter. During the war he served in France but spent most of his time in Russia, where he was taken prisoner in 1944. He was kept in Siberia until 1949 working as a wood-cutter. Hans was a talented artist: his gift

Figure 1. Hans Mergner (right) during a reef course at the site of the future Marine Science Station, Aqaba (Jordan) in February 1972.

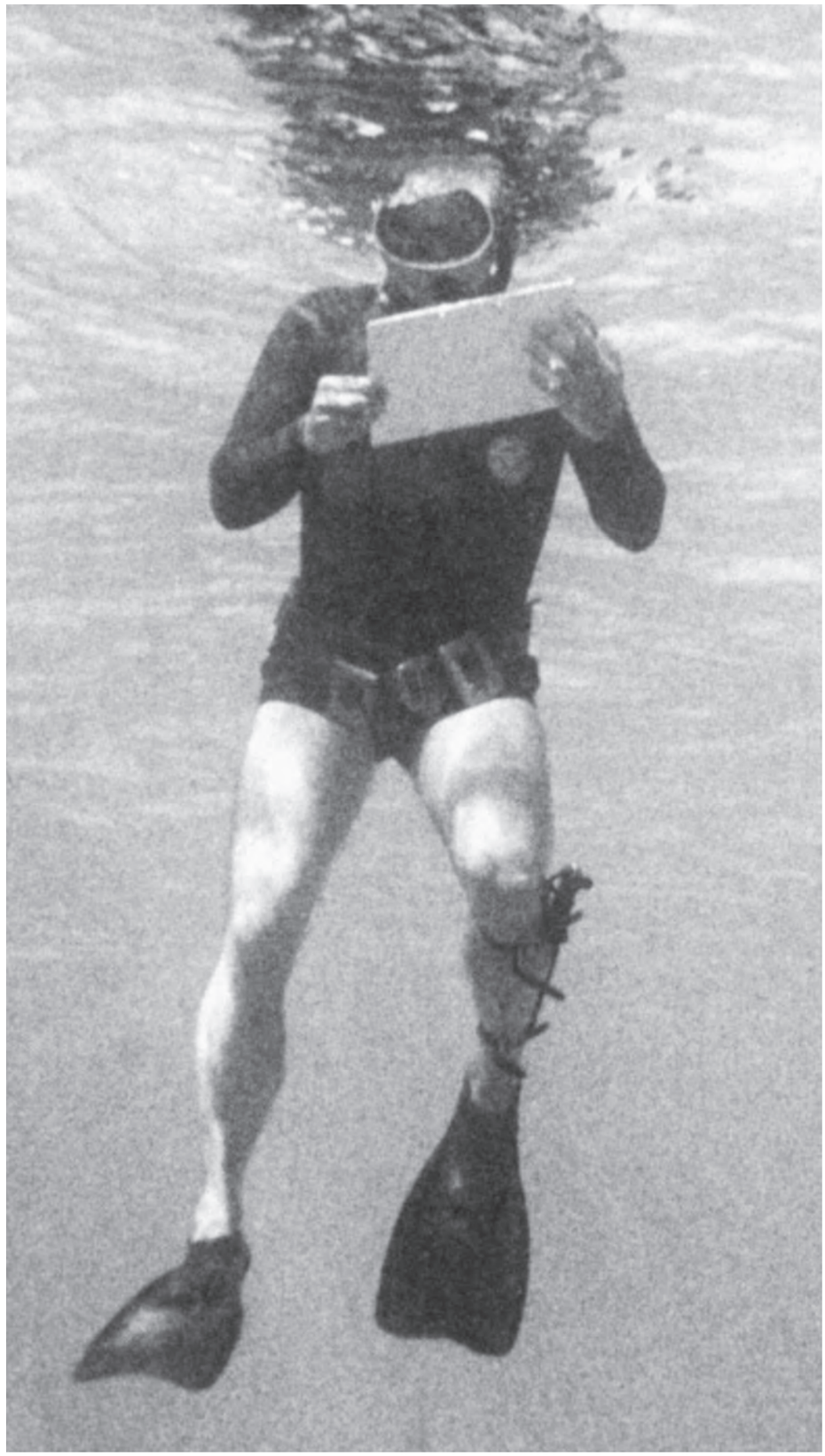


Figure 2. (page 19) Part of an underwater panorama, drawn by Hans Mergner at Aqaba and used as cover of a special volume of the journal Deep-Sea Research. This page: Hans Mergner making this drawing.

to draw and paint true to nature probably relieved him during his captivity, since he painted portraits and other ornamental services for his guards.

At the age of 32 he became a student of biology and geology at the University of Tübingen. He earned his PhD in 1956 with a thesis on the ontogeny of the hydroid *Eudendrium racemosum* under the supervision of Prof. A. Kuehn. After an intermezzo in brain research he took over a position as Assistant Professor at the University of Giessen, where he joined a team studying developmental physiology of freshwater sponges. The artificial induction of oscular openings was the scientific basis for his habilitation in 1963. In 1964, a "Meteor"-cruise through the Red Sea brought him, as a hydroid specialist, for the first time in physical contact with coral reefs. A 16 weeks travel grant to the Caribbean to collect and observe hydroids in the field was another experience which sparked his passion for coral reefs and their different patterns of appearance and zonation.

Hence, his appointment as a full professor of zoology at the newly founded Ruhr-University, Bochum, in 1970 happened in due time: he had the possibility to form a team of marine zoologists with emphasis on reefs - in addition to his commitments to research in functional morphology and developmental biology.

Hans Mergner learned SCUBA diving and from then on

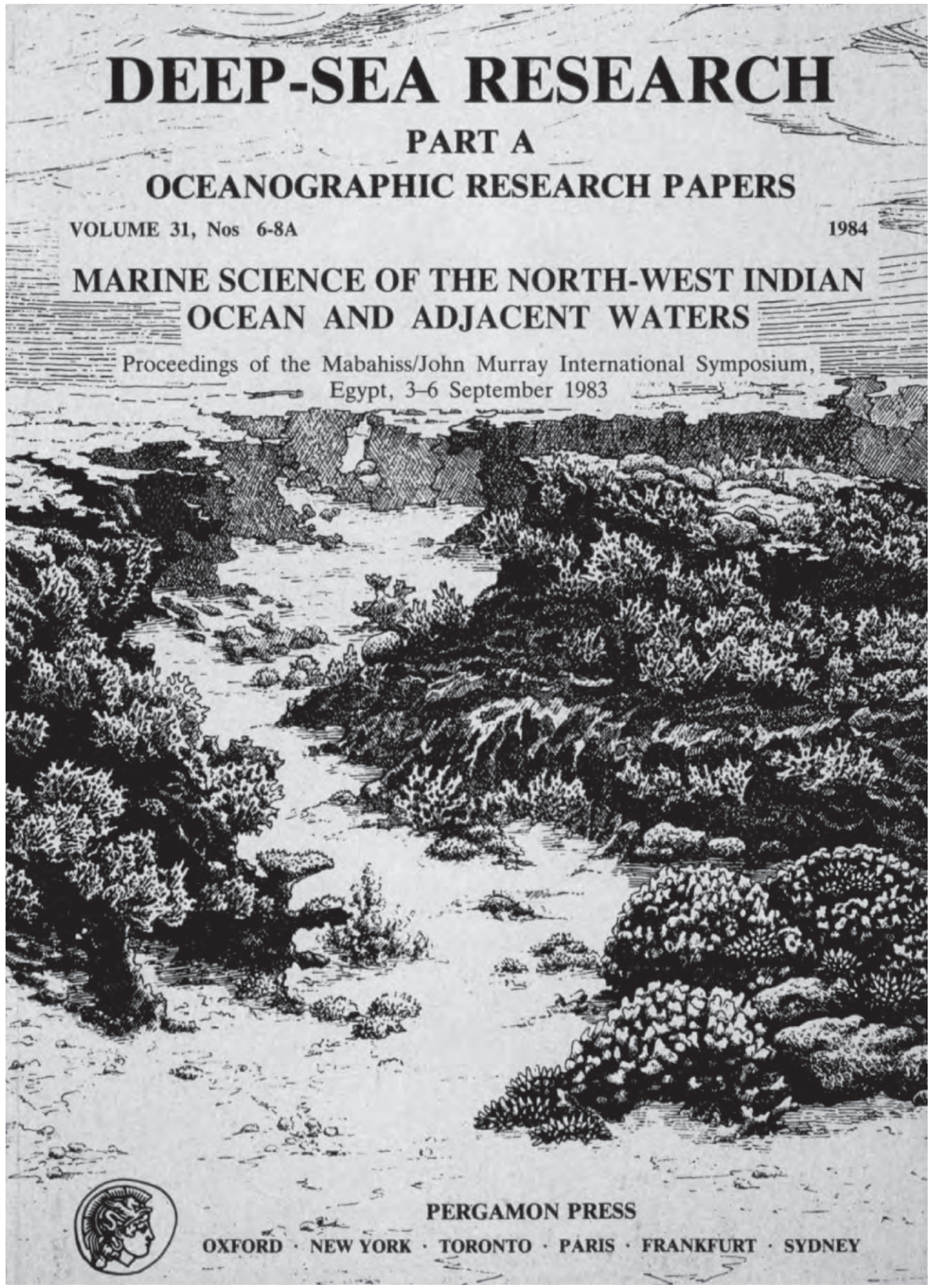

DEEP-SEA RESEARCH
PART A
OCEANOGRAPHIC RESEARCH PAPERS
VOLUME 31, Nos 6-8A
1984
MARINE SCIENCE OF THE NORTH-WEST INDIAN OCEAN AND ADJACENT WATERS
Proceedings of the Mabahiss/John Murray International Symposium, Egypt, 3–6 September 1983
PERGAMON PRESS
OXFORD · NEW YORK · TORONTO · PARIS · FRANKFURT · SYDNEY

Figure 3. One example of Hans' superb paintings of orchids

supervised courses, master and PhD theses with ecological focus on the Mediterranean and the Red Sea (Fig. 1). The site of the future Marine Science Station of Aqaba (Jordan) was selected during such an expedition in 1972 (in cooperation with the Jordan University, Amman). Reef studies in the Northern and Central Red Sea as well as in the Indian Ocean and Western Pacific resulted from his never ending passion for underwater landscapes.

I was lucky to join Hans Mergner's team in 1971 and collaborate with him until 1982. During field work I learned to appreciate his talents to recognize the principal physiographic features, to estimate dimensions and proportions minutely and to represent them graphically. Although he became a skilled underwater photographer he preferred to make drawings to show the essentials (Fig. 2).

Hans Mergner retired from university in 1984; six years later the weighty book "Orchideen-kunde" – a profusely illustrated manual to grow orchids (Fig. 3) – bore witness to how seriously he pursued his hobby as an artist. Hans Mergner is survived by his wife Maya and three sons.

Helmut Schuhmacher

Vicki Harriott – Tribute to a Renowned Coral Reef Ecologist

It is with great sadness that we write this tribute for a very special colleague. Dr Vicki Harriott, Associate Professor in the School of Environmental Science at Southern Cross University, New South Wales, Australia passed away in March 2005, to the loss of the marine science community. Her career spanned just 25 years, yet was impressive for the diversity of contributions she made in a range of roles. In particular, she will be remembered as a strong advocate whose work in coral reef research, education and management was internationally recognized and widely respected.

Vicki's career was rich and varied. She gained a BSc (1976) and then an MSc (1980) from the University of Queensland, Australia for her research on holothurian reproduction and population ecology at Heron Island Research Station in the southern Great Barrier Reef (GBR). She was awarded a PhD from James Cook University in 1984 for her research on coral reproduction and community structure at Lizard Island Research Station in the northern GBR. Even at this early stage in her career, Vicki's clear-sighted and focused approach to research was an inspiration to her peers. She completed some of the inaugural work on coral reproduction at Lizard Island - before coral mass spawning was recognized, and published one of the first papers on bleaching of GBR corals - before bleaching was widely acknowledged as the harbinger of environmental stress it is known to be today. Her subsequent postdoctoral work at James Cook University, similarly established foundations for a number of new directions including coral reef restoration techniques, spatial and temporal patterns in coral recruitment and the impacts of crown-of-thorns starfish on the GBR.

Briefly leaving Academia in 1987, Vicki became the inaugural Assistant Curator at the Great Barrier Reef Aquarium (Reef HQ) in Townsville, Australia, and put her knowledge of coral community structure to practical use when she set up the main exhibit – then the largest coral reef tank in the world. Always expanding her horizons, she applied for and received a Churchill Fellowship to travel to the U.S. and S.E. Asia to research ways of improving conditions in the Aquarium.

In 1990, Vicki accepted a lecturing position at Southern Cross University, Lismore, where she taught and developed undergraduate teaching units in Biology, Marine Ecosystems, Ecology, and Aquaculture. In addition, she coordinated the development and accreditation of the Fisheries and Aquaculture stream in undergraduate teaching. Shifting her focus to subtropical coral communities, Vicki initiated collaborative research programs on latitudinal patterns of coral recruitment, coral growth and environmental records from coral cores, coral-algal interactions, fouling communities, impacts of divers on coral communities, coral community rehabilitation, and impacts of sewage and other disturbances on reef communities. With her colleagues and students, Vicki developed a body of information about temperate reefs that was very timely in relation to global change and its impact on coral reefs, which represents one of her most important contributions to coral reef science. Her longstanding focus on latitudinal patterns in processes controlling coral community structure culminated in the publication of a biophysical model in a recent (2002) paper with Simon Banks in the journal Coral Reefs. In addition to successfully supervising postgraduate and Honors students at Southern Cross University, Vicki played a key role in the formation of the Southern Cross University Branch of the National Tertiary Education Union (NTEU), subsequently being

elected as President of the Branch. In recognition of her outstanding contributions to Southern Cross University, Vicki was rapidly promoted to Senior Lecturer and then Associate Professor.

Next, Vicki turned her considerable skills to managing and promoting education at the CRC Reef Research Centre, returning to Townsville in 2000 for three years as the Program Leader for the Education and Communication section. In recent years, her efforts have supported a wide range of postgraduate students working on coral reef research. Her dedication to students was such that she commented on thesis drafts from her hospital bed. She expanded the role at CRC Reef, tackling extension activities, website development and publications, in addition to issues relating to postgraduate scholarships and training. Focusing her research more on issues pertinent to reef management, Vicki wrote a seminal report on the Coral Harvesting Industry on the GBR, which led to the Prime Minister overturning a decision by the Environment Minister to ban the industry. As a result of this work, Vicki was invited to be a plenary speaker at a workshop in Indonesia in 2001 to develop internationally acceptable guidelines for the live coral trade. Vicki's work is also used as the basis for managing the industry by the Great Barrier Reef Marine Park Authority.

Vicki returned to Southern Cross University in 2003 to continue her roles in teaching and research despite her deteriorating health as a consequence of a particularly pernicious cancer. Focused research and prescient insights have been a hallmark of her career, and will undoubtedly contribute to the legacy provided by her more than 45 papers in international refereed journals and conference proceedings, and at least 34 other papers, technical reports, book chapters and consultancy reports and their influence on the next generation of reef researchers and managers.

In recognition of Vicki's lifetime work on coral reefs and reef management, the Australian Coral Reef Society (ACRS) arranged a plenary address and a memorial student prize for the best paper in her name at their annual ACRS conference. Details of how colleagues and friends can donate to the fund to support the student prize appear below. The NTEU NSW Division has also announced a substantial contribution to a memorial fund for coral research in recognition of Vicki's leadership and mentoring of women at University and in the NTEU.

Vicki was supremely successful at balancing her professional and personal life, and enjoyed close friendships with many colleagues from around the world. Vicki's life, achievements and friendships were celebrated at gatherings of friends and colleagues in Townsville and at Southern Cross University recently.

The coral reef community will sadly miss her insights, her vitality, her good will and her friendship.

Bette Willis
Marine Biology and Aquaculture
James Cook University, Australia

Peter Harrison
Environmental Science and Management
Southern Cross University, Australia

Helene Marsh
Tropical Environmental Science and Geography
James Cook University, Australia

Carden Wallace
Museum of Tropical Queensland
Australia

Donations sought for the Vicki Harriott Memorial Stuudent Prize Fund

In recognition of the special contribution to coral reef research by Dr. Vicki Harriott, marine biologist and educator, the ACRS has established the Vicki Harriott Memorial Student Prize. The prize is presented each year at the ACRS Annual Scientific conference for the best student presentation. A formal tribute was paid to Vicki Harriott at the ACRS Annual Scientific Conference held in August 2005 at Heron Island. There was a very high standard of presentations by eligible students from a range of universities, with the inaugural prize being awarded to Meir Sussman of James Cook University and the Australian Institute of Marine Science.

The ACRS Council has established a dedicated fund to support this prize and invites colleagues and friends of Vicki's to donate to the memorial fund so that Vicki's great contribution towards marine science and education can be acknowledged and remembered. The ACRS Council has set a fund-raising target of AU$10,000 (ten thousand Australian dollars) for the fund to enable this prize to be awarded "in perpetuity". Some generous donations have been received but we are still short of our target and further donations would be greatly appreciated.

A specific bank account has been established by the ACRS Council so that donors may contribute directly to the fund. Details are provided below. The easiest way to make your payment is via internet banking and in doing so you can opt to record your name as a donor. Other options suitable for donors in Australia are to send a check or money order to the ACRS made payable to the "ACRS Vicki Harriott Award Fund," or make a deposit at any branch of the Westpac Bank and ask for a reference number for the payment.

Bank: Westpac Banking Corporation
Account Name: ACRS Vicki Harriott Award Fund
BSB Number: 034061
Account Number: 221697
SWIFT identification: WPACAU2S (for contributions from outside Australia)

Thank you for your support.

Dr Selina Ward
President
Australian Coral Reef Society

c/- Centre for Marine Studies
The University of Queensland
St Lucia QLD 4072 Australia

Website:
www.australiancoralreefsociety.org

CURRENTS

Target Phenomena on South Pacific Reefs: Strip Harvesting by Prudent Pathogens?

Mysterious circular patterns resembling targets, ranging from a few centimeters up to several meters in diameter, commonly occur on vertically-orientated coralline algal crusts (Fig. 1) throughout South Pacific coral reefs. At first, we thought the target-like concentric circular configurations might be related to gastropod grazing or egg laying arrays, but closer microscopic examination eliminated these hypotheses. The conspicuous bright-white concentric bands (Fig. 2) appear to be CLOD-like pathogens[1,2], but unlike CLOD, which kills on a broad scale along a moving front, "target phenomena" attack the corallines in relatively stationary parallel/concentric strips (Fig 3). The infected coralline algae quickly begin to regrow back over the dead zones (arrows), while the pathogen presumably "leapfrogs" outward over narrow living zones to infect increasingly longer parallel strips of host material (hence the "prudent strip-harvesting" analogy).

To date, we have no evidence identifying the mechanisms responsible for the target-like patterns, but we suspect that they must be related to some unusual dispersal/settlement behavior of the putative pathogens. Since "target phenomena" are so conspicuous throughout the South Pacific, we would welcome any further insights/hypotheses from the readership—the suggestion of "alien crop circles in the sea" has already been proposed.

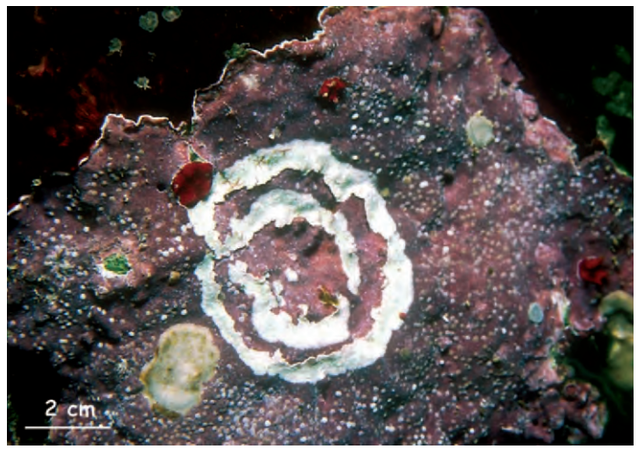


Figure 1.

References

[1]Littler MM, Littler DS (1995) Impact of CLOD pathogen on Pacific coral reefs. Science 267:1356-1360

[2]Littler MM, Littler DS (2003) South Pacific Reef Plants. OffShore Graphics, Inc., Washington DC 331 pp

Figure 2.

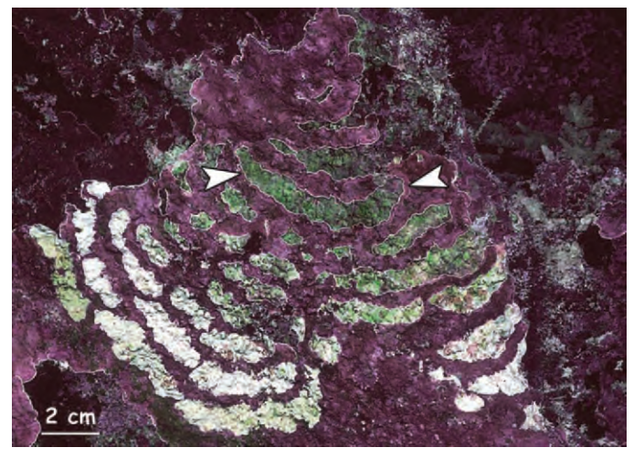


Figure 3.

Acknowledgments: We are sincerely grateful to Joan Koven, Robin South and the people of Dravuni for their hospitality and assistance. Funding came from the Marpat Foundation and the Smithsonian Marine Station at Fort Pierce. SMSFP Contr. No. 678.

M. M. Littler (littlerm@si.edu) • D. S. Littler • B.L. Brooks Smithsonian Institution, PO Box 37012, Department of Botany, MRC 166, National Museum of Natural History, Washington, DC 20013, USA

Ecosystem structure in degraded Caribbean coral reef ecosystems and the role of marine reserves

The geological record indicates that two living species, *Acropora cervicornis* and *A. palmata* were the major contributors to reef construction in the past (Pleistocene and Holocene). These two species were well adapted over the millennia to deal with natural disturbances such as hurricanes and predators. However, by the end of the 1970s, populations of these species started to diminish in abundance and today they are rare on most Caribbean reefs. Declines are not limited to *Acropora* species, and overall, cover of Caribbean corals has declined from approximately 50% to 10% or less over the last three decades. While climate has been relatively stable over the last 10,000 years, the last several centuries have witnessed increased disturbance on reefs as a result of human activities, such as pollution, fishing, and habitat destruction. The influence of specific anthropogenic disturbances on coral reefs and the immediate local consequences have been studied extensively over the last two decades. Yet, it has become increasingly difficult to demonstrate causality among the multiple disturbances and the dramatic change in ecosystem structure that has occurred across the Caribbean during this time period. We currently lack critical information on the impact of multiple disturbances at the regional scale (Caribbean wide), largely due to the difficulties of collecting and analyzing ecosystem-wide data. One solution to this problem is to track the effects of a gradient of human activities across a large spatial scale. In this space-as-time approach, the gradient of human disturbance due to geographical differences in human activities serve as a proxy for the changes observed over time. In this manner we can more appropriately investigate how ecosystems respond to large-scale disturbance regimes.

We collected information from all major ecosystem components (including fish and benthic communities) using standard visual census techniques across the Caribbean. Sites were selected based on published data on the history of exploitation. We traveled to several reef sites in Florida Keys, Dry Tortugas, Belize, Cozumel, Jamaica and Cuba and surveyed reefs in both protected and unprotected areas. Our results show a remarkable range of fish biomass across all sites, from 14 to 593 gm^{-2}. There was a large overlap of species biomass abundance across sites from different areas, which indicated similar community structure overall. These results, combined with specific changes observed in the fish community structure, strongly suggest that differences in our sites can be attributed to anthropogenic disturbance, most notably fishing, and not just geography. Both size of fish and the average trophic level decreased along our gradient. Particular fish groups (families) had lower species richness or were almost absent in the most degraded reefs (i.e. groupers, Serranidae).

In addition, coral abundance was very low in all sites surveyed, with two isolated exceptions. In these sites, higher cover and biomass was a result of large, relic heads of century-old corals and not from recent recovered populations. Otherwise, the benthic community in all sites was dominated by macroalgae. While corals showed no relationship with the abundance of fish, macroalgal biomass was negatively correlated with herbivorous fish biomass. Other invertebrate groups were rather inconspicuous and showed no pattern of response to fish biomass (our proxy for anthropogenic pressure).

Despite the lack of response in the benthic community, our results do reveal the first signs of recovery in the fish community. It is critical to note, however, that high fish biomass and large proportions of apex predators were only found inside reserves that were large, no-take, and had been enforced for at least a decade. Our study demonstrates that fish communities in the Caribbean can resemble that of healthy reef fish communities, such as those found in the Pacific, within this relatively short time period.

Regardless of which factors have had the largest effect upon reefs, our results indicate that chronic human disturbance has resulted in a homogeneous reef landscape across the region that no longer resembles earlier descriptions of Caribbean coral reefs. Yet, we also show that recovery can occur within the fish community when at least fishing is prohibited. This limited recovery however occurs only within one segment of the coral reef ecosystem, and full recovery remains absent.

Over the past few thousand years, environmental conditions have been fairly stable and coral reefs have thrived, constructing the reef structures we see today, despite natural environmental disturbances. Against this background of constancy and growth, we must recognize that the combined effect of anthropogenic change over the past few hundred years has driven the entire region to an extremely deteriorated state. The future of Caribbean coral reefs and the services they pro-

vide are compromised. Management via marine reserves must be applied in conjunction with other conservation actions such as the improvement of the water quality and run-off control. We must ensure that the sporadic events of recovery revealed in some reef sites over the past few years actually persist and extend to other Caribbean reefs. We believe that only a multinational Caribbean-wide conservation strategy will ensure the survival of these ecosystems.

Gustavo A. Paredes
Center for Marine Conservation and Biodiversity
Scripps Institution of Oceanography
University of California San Diego
9500 Gilman Dr.
La Jolla, CA 92093-0208

Impact of the December 24, 2004 Tsunami on coral reefs of Andaman and Nicobar Islands, India

The Andaman & Nicobar Islands are a low mountainous chain of islands, which rise from a submerged north-south trending ridge separating the Andaman Sea from the Bay of Bengal between 6°45′13″ .41 N and 92°12′93″ .57 E. This island group includes 306 islands and 226 rocks, with a coastline of about 1962 kilometers. The islands located north of 10° N Latitude are known as Andamans (Figure 1) while those located south of 10° N Latitude are called Nicobars with a total area of 8249 square kilometers. These islands are supposed to have arisen from the ocean bed in the Mesozoic period about 110 million years ago and have since then undergone several periods of partial submergence and elevation. Fringing, Patch and Barrier reefs are present here, covering about 948.8 square kilometers. The total mangrove area is approximately 762 km^2. There are 106 Protected Areas, 96 designated as wildlife sanctuaries, 9 National Parks and one Biosphere reserve. Among the 9 National Parks, 2 are Marine National Parks (Mahatma Gandhi Marine National Park and Rani Jhansi Marine National Park).

6000 species were recorded from Andaman & Nicobar Islands, amounting to 7.5% of the total Indian fauna (3% of the Terrestrial Fauna and 4.6% of Marine Fauna). So far 235 species of scleractinian corals, 111 species of soft corals, 112 species of sponges, 411 species of crustaceans, 1422 species of mollusks, 425 species of echinoderms, 750 species of fishes, 14 species of reptiles, 50 species of marine birds and 64 species of algae have been reported from Andaman and Nicobar islands. As per the year 2001 census, 25 islands in Andaman group and 13 islands in Nicobar group are inhabited with a total population of 356,265 people. Recently there was an undersea earthquake in the Indian Ocean. A rupture occurred off Banda Aceh in northern Sumatra (3°09' N, 94^0 26' E) at 00:58:49 GMT (06:28:51hrs IST) on Sunday December 26, 2004, with a magnitude of Mw = 9.3. The rupture spread northward at roughly 2.8 km s^{-1} for approximately 8 minutes over a 1300 km-long aftershock zone. Comparisons with the aftershock areas of other great earthquakes indicate that the Sumatra-Andaman earthquake did indeed have a moment magnitude of ~9.3. Its rupture, in both duration and extent, is the longest ever recorded.[1] The earthquake generated a tsunami surge that was among the deadliest disasters in modern history. According to official data, the tsunami took a toll of 3513 lives, including 1177 children. About 350 children were orphaned and 85 of the 322 government schools on the islands were washed away, another 34 were left completely dilapidated. As many as 46,000 tsunami-victims have been in 207 relief camps.

The Indian Ocean tsunami caused extensive damage to coral reefs of the Andaman and Nicobar islands. Most of the islands' coastline was eroded by the tsunami surge and sediments were dumped on adjacent reefs. These island reefs were not affected by the bleaching event in 1998. It has been found that the area has moved southwestward about 4-5 meters at North Andaman (Diglipur), about 4.5 meters at Middle Andaman and about 3 - 4.5 meters at South Andaman. In addition to this the North Andaman landmass was lifted up by 0.60-0.90 cm resulting in a fall in the water level. Due to this, almost all reef flats on

Figure 1. Map of Andaman & Nicobar Islands.

Figures 2&3. Mass mortality of corals on reef flat at Anderson Island.

Figure 4. Incredible coral damage around North Reef.

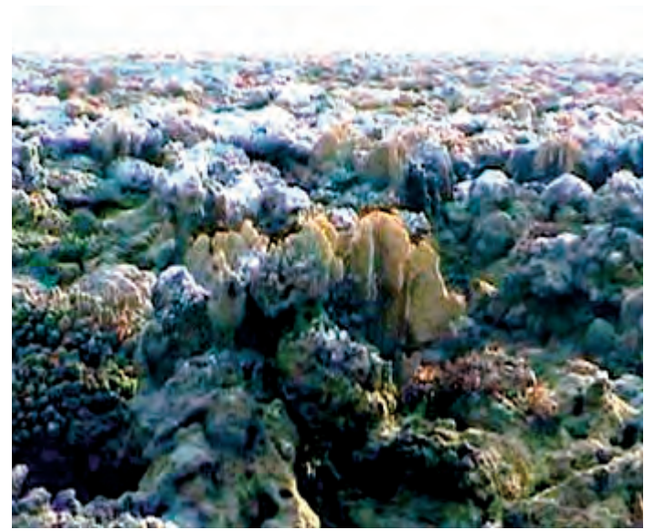


Figure 5. Mass mortality of corals at reef flats of Interview Island.

the western side of northern group of islands (i.e west coast of Interview Island, North Reef Island, Latouche Island, South Reef Island, West Island, Landfall Island, East Island and Anderson Island) were exposed and dried up (Fig 2-5). Almost all corals in the reef flats and other associated fauna seemed dead beyond regeneration, appearing like a graveyards of corals. The corals in reef slope were not as affected by the tsunami and the live coral percentage is 55-60%. In contrast, South Andaman subsided by 1-2 m, and seawater inundated the agriculture fields and coastal mangroves. The western coast of the North Sentinel Island, which is further south in South Andaman, was uplifted by half a meter.

Extensive coral reef surveys were made at Mahatma Gandhi Marine National Park at South Andaman during the month of January 2005 using SCUBA diving and snorkeling. It consists of 15 islands of different sizes, scattered over a total area of 281.50 km^2. In Jolly Buoy, Redskin and North Bay reefs, overturning of large corals especially *Porites lutea* colonies was observed. There was more damage on the northeastern side of Jolly Buoy Island where nearly 10m^2 of reef area was covered by sand. The Jolly Buoy Island lies in a northeast/southwest direction. On the northeastern side, the beaches and near shore land areas were around 6-10 m wide and were devastated by the tsunami. At one site, nearly 20m^2 area of coral reef was buried under the sediment and no corals were visible. Most of the branching

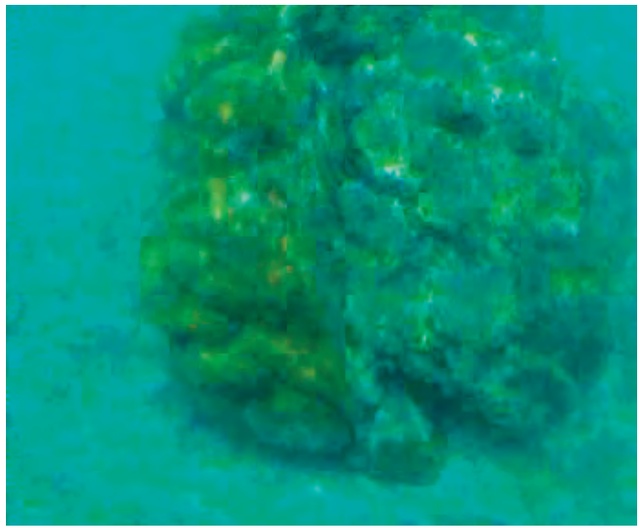


Figure 6. Overturned massive coral *Porites lutea.*

Figure 9. Sand deposited over on coral beds in MG National Park.

Figure 7&8. Uprooted massive coral *Porites lutea.*

Figure 10. Sand deposition on *Porites* colonies in MG National Park.

corals belonging to the genera *Acropora*, *Hydnophora* and *Montipora* were broken into small pieces and some washed away. Large size boulder corals, *Porites* spp., (more than 1m wide), were overturned and most of the colonies were uprooted (Fig 6-8). Some colonies were completely buried under sediment excepting the top portion (Fig 9&10). The island reef was remarkable for its richness of mushroom coral species belonging to the family Fungiidae. Most of these

Figure11. Massive *Porites* coral washed to the Land of Car Nicobar Island.

specimens were washed away by the tsunami and existing live mushroom corals were suffocated by sedimentation and likely result in death. The survey showed 50% mortality in north-eastern reef of Jolly Buoy Island. The reef at the southwestern side was not much affected by the tsunami, and the reef slope corals were in pristine condition.

The corals around the Nicobar group of islands were extensively damaged due to heavy sand and silt deposits brought by tsunami waves. The Nicobar Islands include serpentine gabbros, marine deposits of the late Tertiary including sandstones, slates, clay marls and plastic clays and coral reefs of recent origin. About 6000 ha of coconut gardens were affected by tsunami and 20,000 coconut trees were uprooted. The corals were washed away onto the land at Car Nicobar island(Fig 11&12). The tsunami caused the worst damage to this island and the wave reached almost more than 7 meters in height. The area between 7°45′–8°15′N and 93°25′–93°40′E consists of Camorta, Trinkat, Nancowry, and the Katchall

Figure 12. Uprooted coconut trees along with coral fossils in Car Nicobar Island.

islands. Extensive coral reef flats of about 2.5 km^2 occur at the northeastern and northwestern side of the Camorta Island. These reefs were severely damaged by the earthquake and tsunami. On the northeastern side about 2.0 km^2 of landmass was eroded and all sediments were dumped onto the reef. The reef flats around the Trinkat Island extend up to 2.5-3.0 km^2 from shore. Due to the earthquake and tsunami the island was divided into two parts. A heavy load of sediments were deposited over the reef and led to mass mortality of corals. The windward reef on the northeastern side of Nancowry Island was the worst affected by the tsunami, resulting in a mass mortality of corals. The tsunami in the Nancowry group of islands caused extensive damage to mangroves and 94% of mangroves were submerged. On Katchall Island alone 1550 ha, or 38% of mangroves were submerged. The coral reefs of these islands somehow played an important role in attenuating the tsunami wave height, thus lessening its destructive effects. Similar phenomena were observed in the Philippines during 1992.[2]

Detailed coral reef survey in Great Nicobar Island showed the live coral coverage of the island was 55%.[3] The coral reefs here were not affected by the bleaching event in 1998. Unlike the Andaman Island reefs, the dominant reef building corals in Nicobar Island was *Acropora* sp. Of the 55% live coral coverage, *Acropora* was 26% and the boulder coral *Porites* was restricted to 6%. The subsidence of 2-3 meters affected the Great Nicobar Island and a maximum down throw at Indira Point (Southern most land part of India). The lighthouse on Indira point and the adjacent land are still under the sea. Large amount of mud and trees settled down over the reef flats smothering the corals. The corals in the reef flats of Great Nicobar Islands, particularly on the western side, were in pristine condition before the tsunami. These reefs are now covered by sediment.

Coral reefs of Andaman and Nicobar islands are the biodiversity hotspots of India. The post tsunami survey results showed the reduction of moray eels, sharks, triggerfishes, boxfishes, puffer fishes and angelfishes. The coral associated fauna i.e. polychaetes, nudibranchs, flat worms,

alpheid shrimps, Mantis shrimps, hermit crabs and brachyuran crabs belonging to the genera *Trapezia*, *Phymodius, Cymo* and *Chlorodiella* were not found during the survey. Eight species of birds in the Andaman group and five species of birds in the Nicobar group of islands were reported as endemic. A small Megapode island on the western side of Great Nicobar Island was completely sunk under sea. This island was the habitat of the endemic bird *Megapodius nicobariensis.* It builds mounds in coastal areas and, therefore, suffered from habitat destruction and degradation before the tsunami. A mud volcano erupted on Narcondam, on June 7 2005, which had been lying dormant for nearly a century. The Barren Island, which is the only active volcano in the country, erupted once again on May 28 2005, after remaining silent for a decade. Hence, these bird species may have been severely affected by the tsunami and other subsequent changes.

Research has indicated a real danger of another earthquake in the region.[4] The prediction was based on the increase of co-seismic stress on the contiguous Sunda trench subduction zone and neighboring vertical strike-slip, Sumatra fault.[5] The prediction came true on 28 March 2005, the Sunda megathrust in Indonesia ruptured again, producing another great earthquake three months after the previous one. An earthquake in the Sumatra fault might be expected in the near future. The Andaman & Nicobar Islands are in earthquake prone zone 5, part of the Sumatra fault. The proposed coral reef survey in the Nicobar group of Islands by the Zoological Survey of India after the monsoon will reveal more details.

Acknowledgements

The Authors are thankful to Dr. J.R.B. Alfred, Director of the Zoological Survey of India, Kolkata for constant encouragement and excellent facilities. Thanks are also due to Chief Wildlife Warden and other staff of the Department of Environment & Forests for several courtesies.

References

[1]Ishii, M., Shearer, P. M., Houston, H. and Vidale, J. E. 2005. Extent, duration and speed of the 2004 Sumatra-Andaman earthquake imaged by the Hi-Net array. *Nature* advance online publication; published online 22 May 2005 A| doi: 0.1038/ nature 03675

[2] Besana, M.G. and Masataka, A. 2004. The May 17, 1992 event: Tsunami and coastal effects in Eastern Mindanao, Philippines. *Science of Tsunami Hazards*, **22**(2): 61-68

[3]Jeyabaskaran, R. 1999. *Report on Rapid assessment of coral reefs of Andaman & Nicobar Islands*. GOI/UNDP/GEF Project on Management of Coral Reef Ecosystem of Andaman & Nicobar Islands. Project executed by Zoological Survey of India, Port Blair.110pp.

[4]Mc Closkey, J., Suleyman, S. and Nalbat, S. S. 2005. Earthquake risk from co-seismic stress: Last year Indonesian's earthquake has increased seismic hazard in the region. *Nature*, **434**: 291-230. published online 17 March 2005.

[5]Nalbant, S.S., Steacy, S., Sieh, K., Natawidjaja, D., and McCloskey, J. 2005. Seismology: earthquake risk on the Sunda trench. *Nature*, **435**: 756-757 published on line Jun 9, 2005.

*R. Jeyabaskaran**
D.V. Rao
Zoological Survey of India
National Coral Reef
Research Institute
Andaman & Nicobar Regional Station
Haddo P.O, Port Blair – 744 102
INDIA
**Email: jeybas1@rediffmail.com*

Unusual lesions and growth anomalies encountered in *Acropora palmata* from two sites in the tropical western Atlantic

Phenotypic plasticity in scleractinian corals is common and is generally a consequence of environmental variability. These variations in skeletal morphology are normally not detrimental to the organism's normal functioning, and in some cases are the mechanism by which the animal is able to better exploit the resources of its environment (e.g., light exposure, wave energy). Additionally, altered patterns of skeletal deposition may be caused by physical injury or boring organisms, but overall are not harmful to the coral colony.

The development of tumors or neoplasia, however, can lead to the manifestation of disease and ultimately cause the death of an organism. These physical anomalies are caused by unnatural cellular proliferation, which can be the result of the disruption of normal genetic control, either due to environmental degradation or genetic predisposition. Tumors in corals were identified as early as the 1960s[1] and have been described in at least 10 different families[2]. Little is known about whether these tumors result in a disease where the functioning of the coral is depressed. However, neoplastic lesions have been described on corals belonging to the genus *Acropora.* These lesions are the only identified true neoplasm of corals and were described as calicoblastic epitheliomas[2] because the authors observed the proliferation of immature, metabolically active calicoblasts, the cells that produce the exoskeleton. A neoplasm is "an abnormal tissue that grows by cellular proliferation more rapidly than normal, and continues to grow after the stimuli that initiated the new growth cease" (*Stedman's Medical Dictionary*, 26th Edition, 2000). Similar lesions have been reported in other coral species.[3] Coral growth anomalies that appear to result from proliferation of the gastrodermal cells to form porous protuberant masses

with abnormal polyps as gastrovascular canals increase have been found.[4] The calicoblastic epitheliomas have thus been reported from the Netherlands Antilles, Florida Keys, the Pacific Ocean, and the Indian Ocean.[2,5,6]

In August 2003, 13 sites on the reefs of Punta Cana, located on the southeast coast of the Dominican Republic, were surveyed in an attempt to collect basic information on the state of the reef. Living colonies of the branching coral *Acropora palmata* were noted at all sites and represented approximately 10% of colonies surveyed. At three shallow (backreef, 0.5 to 4.0 m depth) and three deep sites (forereef, 5 to 10 m depth), colonies of *A. palmata* were identified exhibiting skeletal (growth) anomalies consistent with those described as calicoblastic epitheliomas (Fig. 1). No other species of coral were observed with these lesions. Signs of the condition were consistent for all colonies observed. Raised, white, irregular areas of skeleton, covered by translucent tissue that displayed no corallite structure and varied in size from approximately 1 to 10 cm in diameter, were present either on the surface or underside of colony branches. Live tissue next to these raised areas exhibited normal corallite and polyp structure and tissue color. In general, only 10 to 20% of the coral colony displayed these lesions, although in the most dramatic case, every branch of the colony exhibited lesions.

The Dominican Republic lesions recorded here would constitute the third report of calicoblastic epitheliomas in the tropical western Atlantic Ocean; however, histopathological examinations are required to confirm the nature of these lesions.

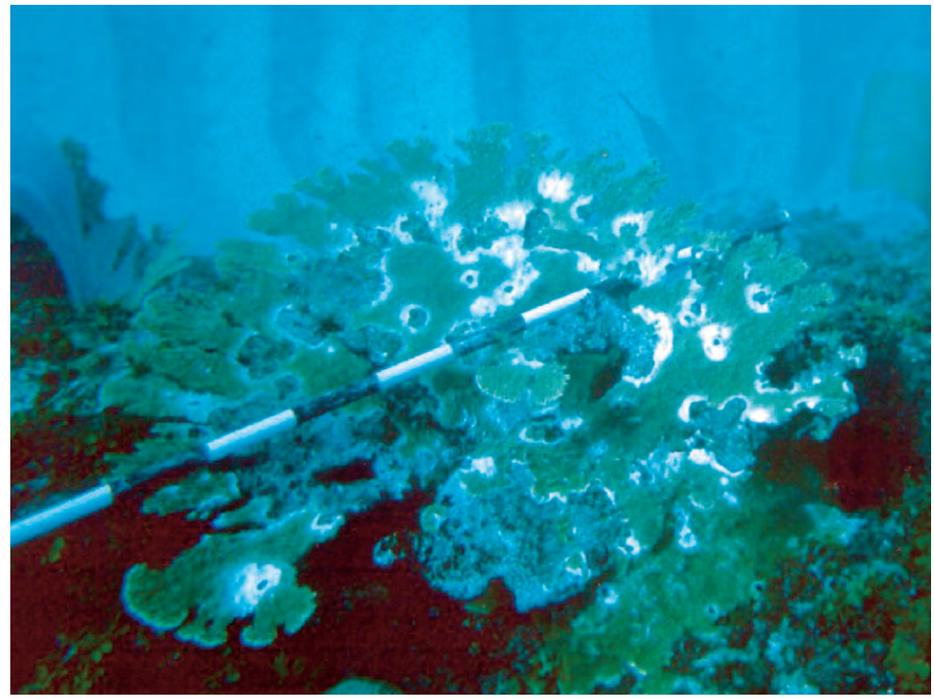


Figure 1. Possible neoplasia, Dominican Republic (stick is 1m).

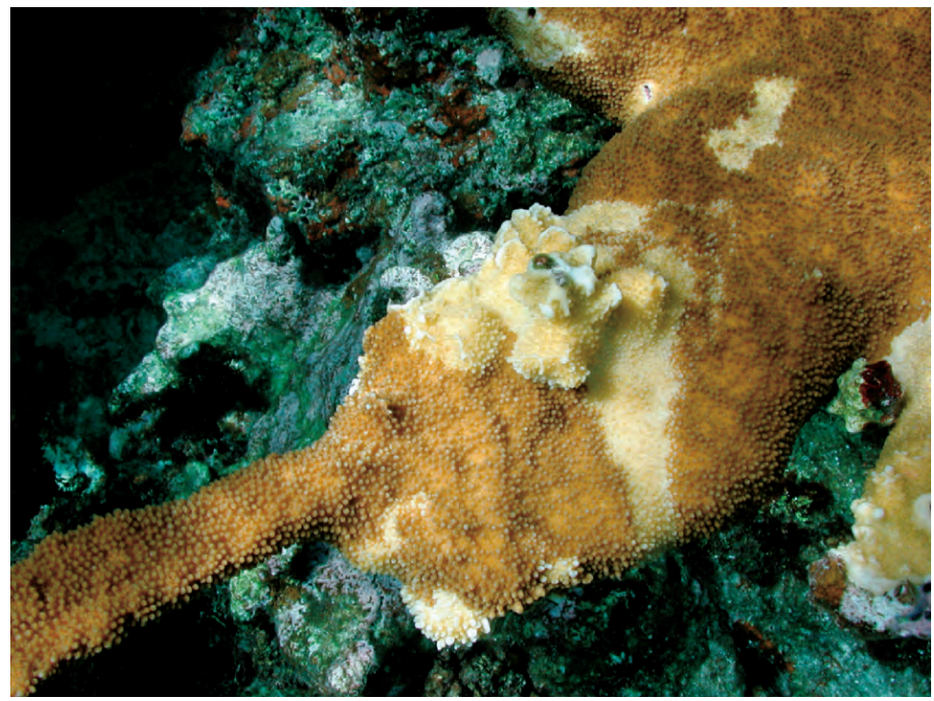


Figure 2. Unknown growth anomaly, Bahamas.

In July 2004, an unusual growth pattern was observed on an isolated *A. palmata* colony on a shallow coral reef near Noname Cay in the Abaco islands of the Bahamas (Fig. 2). This colony is located at a depth of less than 2 meters and was the only colony observed with an abnormal growth pattern within a 10-mile stretch of shallow coral reef that was photographically surveyed in the summer of 2004.

Efforts made to investigate these unusual growth patterns and lesions, using biochemical and molecular genetic techniques, and to culture abnormal tissues, have been hampered by loss of specimens. For example, the Grecian Rocks (Florida) and Gulf of Oman affected acroporid populations are known to have died before sampling was possible. The Registry of Tumors in Lower Animals is conducting a collaborative study to examine coral growth anomalies and evaluate their pathology and etiology, and is interested in receiving other reports of such lesions. Please contact Dr. Esther Peters for more information (administrator@pathology-registry.org).

Marilyn E. Brandt
National Center for Caribbean Coral Reef Research, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Cswy, Miami Fl, 33145, mbrandt@rsmas.miami.edu

Esther C. Peters
Tetra Tech, Inc., 10306 Eaton Place, Suite 340, Fairfax, VA 22003
Registry of Tumors in Lower Animals, 22900 Shaw Road, Suite 107, Sterling, VA 20166-4311

Craig Quirolo
Reef Relief, P.O. Box 430, Key West, Florida 33041

References

[1]Squires, D.F. (1965) Neoplasia in a coral? Science 148: 503-505.

[2]Peters, EC, Halas, JC, and HB McCarty (1986) Calicoblastic neoplasms in *Acropora palmata*, with a review of reports on anomalies of growth and form in corals. J Natl Cancer Inst 76 (5): 895-912.

[3]Yamashiro, H, Yamamoto, M and R van Woesik (2000) Tumor formation on the coral *Montipora informis*. Dis. Aquat. Org. 41:211-217.

[4]Work, TM, SL Coles, and RA Rameyer (2001) *Johnston Atoll Reef Health Survey*. Report to U.S. Fish and Wildlife Service, Interagency Agreement No. 122000N004.

[5]Bak, RPM (1983) Neoplasia, regeneration and growth in the reef-building coral *Acropora palmata*. Mar. Biol. 77:221-227.

[6]Coles, SL and DG Seapy (1998) Ultraviolet absorbing compounds and tumorous growths on acroporid corals from Bandar Khavran, Gulf of Oman, Indian Ocean. Coral Reefs 17(2):195-198.

Highlights of the Coral Reef Restoration Conference

Oct, 18-19, Coral Reef Restoration Conference
Miami, Florida
Keven Reed (ISRS member since 1996)

Several excellent presentations were given at the Coral Reef Restoration conference, which was held in the Hyatt Hotel's adjoining James L. Knight International Center of the University of Miami. There were about 100 attendees according to Mr. William F. Precht, Ecological Sciences Program Manager for PBS&J and Chair of the conference. Precht's impressive style and moderation skills elicited many lively discussions. During his first presentation he noted the many mistakes made with wetland restoration projects over the last 30 years, since the American Clean Water Act was passed, but added that ecologists and preserve managers are now fairly skilled at freshwater habitat restoration. He asked the audience whether marine restoration projects could have a shorter learning curve. He also challenged attendees to think about whether one is doing 'restoration' or 'rehabilitation', the former being a subset of the latter, and whether society should be spending taxpayer dollars on restoration before removal of the root causes; which include boaters without captains licenses, sewage outfalls along the coasts, broken septic systems, overpopulation, ecologically unfriendly farming practices, and global climate change. During Mr. Precht's second presentation, he vetted a new tool, Functional Reef Assessment Method (FRAM), a structural metric for permitting projects with agency representatives. He said FRAM & AGRRA (Atlantic & Gulf Rapid Reef Assessment) methods had high positive correlations on multiple Caribbean reef sites, without being coral centric.

Dr. Richard Dodge, Dean of NOVA Southeastern University's Oceanographic Center, overviewed Habitat Equivalency Analysis (HEA), a tool increasingly used by local governments in the United States during environmental impact claims and litigation. Dr. Walt Jaap gave his last formal presentation before retiring from Florida Fish & Wildlife Conversation Commission (FFWCC). On a final note, he mentioned that an additive called Force 10,000, could be combined with Portland Type 2 Cement , that seemed to buffer pH and decrease 'burning' at the edge of coral transplants. Other topics discussed were the use of funds for restoration projects v. traditional research projects. The Allee Effect, or underpopulation effect also came up in discussion with regards to the Florida Keys. The Allee Effect, originally described by W.C. Allee in 1931 in a sociological context occurs when successful reproduction and survival does not outpace the death rate in a population, and the population as a whole declines. Currently, the Florida Keys coral cover is at best 10%,and

because of the lack of successful reproduction due to mortality in the last 30 years, the coral population as a whole may not be able to recover. In contrast, the Flower Garden Banks located in the Gulf of Mexico still support ~50% or higher coral coverage, despite regional stressors.

It was obvious that there is a much different situation with available coral larvae and subsequent recruitment rates in the Western Pacific versus the Florida Keys, when one sees how many more coral recruits attach to structures like those deployed in the Pacific by Dr. Michael Moore's Eco Reefs company. The reefs sure do not seem recruitment limited in that part of the world. Eco Reefs' artificial reefs are ceramic (better for recruitment than most cements), diver deployed, may be anchored on a slope, and resemble acroporid architecture (reminiscent of a 58 pound 'snowflake'). Dr. Moore showed results from two large projects in Northern Sulawesi (Bunaken Island) and some amazing video of 18 months of growth on an artificial Eco Reef deployed at a site that had been dynamited to resemble an underwater desert in the 1960's. Dr. Margaret Miller, a colleague of Dr. Alina Szmant's, gave a detailed presentation of her team's frustrating efforts to collect gametes from scleractinians in the Florida Keys and get them to successfully fertilize. She credited rainfall as a culprit; destroying gamete viability through osmotic shock. In contrast, Steve Gittings, in a Question and Answer session commented that they hardly had to do anything at Flower Garden Banks to get high fertilization rates, except put the gametes in a bucket of sea water with some antibiotics.

It was exciting to learn of the efforts of Dr. David Gilliam's students near Southeastern Florida's coast with coral nurseries, type 2 Portland cement, gorgonian and barrel sponge transplantation techniques. They had high survivorship with 350 transplanted corals of opportunity representing 17 species of coral.! Billy Causey, Manager of the Florida Keys National Marine Sanctuary (FKNMS), and Dr. Steve Gittings, 1992-1998 Manager of the Flower Garden Banks NMS and currently Science Manager for NOAA's National Marine Sanctuary Program, both had excellent presentations. The audience heard repeatedly that there are still over 500 boats running aground per year in the Florida Keys (used to average over 600 per year before the 1990 law allowed government/taxpayers to collect from the owners/insurance companies of the vessels for restoration/mitigation of the damaged corals). One positive effect of the national (U.S.A.) 1990 law, according to Billy Causey, is that there was only one grounding of a large vessel (greater than 50 meters length) from 1990-1996 in the FKNMS. He also believed that there has been a subtle change in attitude such that people are starting to view ship groundings more as 'ecological disasters' and less as 'maritime disasters'. The audience was presented with many detailed case studies on large and small groundings and the efforts to restore coral reefs in the Florida Keys. Usually large gouges in the reef crest get filled with limestone boulders; lift bags are deployed by divers to right massive coral heads so that they are 'jelly side up'. The attorney for NOAA's Office of General Counsel in Washington DC, Sharon Shutler, gave a very interesting talk on her approach and coordination with other Washington DC government agencies -- they try to incentivize with escalating penalties over time, so that the responsible party will choose quick intervention by divers and biologists to start collecting and righting broken corals. An intriguing aspect of putting a dollar value on coral reef damage is that one cannot have the claim extended into perpetuity. Although the coral head that the errant ship killed may have taken five centuries to grow, the government may amortize damage over an artificial 37 year schedule. The other artificial aspect of computing monetary restitution for ecological damage is the tenuous premise that current scientific knowledge has a reliable capability to restore a living coral reef. The term "coral reef restoration" might be more accurately phrased, "coral reef mitigation". However, there seemed to be strong consensus that scientists can learn from failed attempts, though authors may sometimes be timid to publish lessons learned.

An unexpected presenter was Dr. Rebecca Vidra from Duke University who made attendees examine their ethics in ecological restorations via an audience case study exercise. She is a Mellon Postdoctoral Fellow and a terrestrial ecologist. The "shock and awe" seminar, the final talk of the day, was given by Dr. Les Kaufman from Boston. He made some outstanding points about misleading generalizations; i.e., those 'damn damselfishes' -- showing that ecological interactions with the corals depend on which species of damselfish and where on the reef one is studying the interaction. During the final discussion session, led again by Mr. Precht, a distinguished gentleman in the audience made several astute comments, challenging 1) why don't biologists set aside ten percent of the grounding site in a restoration project as a control for future monitoring and better science; (2) why don't researchers harvest some of the 'precious genetic few' colonies who survive a coral pandemic that kills over 90% of a species, and (3) he warned the group that some of the negative points in International Coral Reef Initiative (ICRI)'s 2005 resolution, formulated at their general meeting in the Seychelles, against reef restoration efforts, could effect funding of future restoration efforts and Non-Government Organizations (NGOs), although that may not have been their intent. This resolution is on the ICRI homepage (http://www.icriforum.org/) under ICRI News.

Overall, the science presented at the meeting was sound, we all benefited by the lateral views to terrestrial windows and mistakes made there, but also by the brief sense of history, and how new the science of coral reef restoration is and where it is heading.

Pacific Islanders' Awareness of Responsibility

The globalization of the economy, the cosmopolitan mixing of cultures, the depletion of fish and other resources, and the ability to make transactions globally over the internet rather than face-to-face all contribute to greater anonymity and loss of a sense of responsibility for the citizens of the world. The factors that are causing the accelerating deterioration of coral reef systems are ecological, economic, technological, cultural and conceptual feedback mechanisms (2004, BioScience 54: 1021-1027) that cannot be damped without a restoration of responsibility and political will. In small villages, or in families, each person recognizes responsibilities to the group in resource management. As populations grow, the sense of personal responsibility is lost. Each individual, anonymous in the crowd, focuses on getting his or her share (Garret Hardin's Tragedy of the Commons). Malcolm Gladwell, in "The Tipping Point" 2002, provides anecdotes from anthropological studies of hunter-gatherer societies, and from military, industrial, and religious organizations, that indicate people perceive responsibility when part of a group of less than about 150 people, but tend to become anonymous and more concerned for their share than their responsibilities when in crowds of over 150. An infamous example of this concept is the stabbing death of a young lady on the streets of densely populated New York City. At least 38 citizens observed the attack which took place over a period of half an hour, but none would call the police by telephone (A.M. Rosenthal, "Thirty-Eight Witnesses" 1964).

Citizens of many Pacific islands have felt the influence of globalization and the power of the world economy. But some have been close enough to their cultural roots to recognize the deterioration of individual responsibility with population growth. Due to the size of their islands, they perceive the entire ecosystem with a more holistic understanding of the interaction of human and environmental processes. At the 8th USCRTF meeting in Puerto Rico, October 2002, the delegates from various jurisdictions were asked to prioritize the problem areas for coral reefs in order to most effectively implement the National Action Plan and National Action Strategy to conserve coral reefs. The American Samoan delegation recognized human population growth as the ultimate cause for the proximate factors or signs ("symptoms"), such as overfishing, sedimentation, coastal development and land-clearing, pollution, recreational overuse, and probably the ultimate cause for the increase in disease, climate change and coral bleaching. As Peter Craig (National Park Service at American Samoa) wrote, "We can talk about environmental issues until we're blue in the face, but unless we address the underlying causes of these problems [human population growth], we will continue to face environmental problems of increasing severity." Unfortunately, the groups that compiled the resolutions and priorities in the National Action Strategy dismissed the input from American Samoa and focused on the previously established program of ameliorating the signs ("symptoms").

Lelei Peau, Chair of CRAG (Coral Reef Advisory Group to the Government of American Samoa) did not accept this dismissal. CRAG has been very active in bringing the problem to the attention of the people of American Samoa, in order to stimulate positive action. I read an article in the Samoa News of 8 July 2005 entitled "Overpopulation cited as our most pressing problem by CRAG". Peter Craig has written a number of articles, (at least 5), in the local newspaper, and developed a booklet for American Samoan public schools.

As former Lieutenant Governor of American Samoa, the present Governor Togiola Tulafono focused on the population issue. He chaired a Population Implementation Committee that assessed population impacts in the Territory and developed actions to deal with future effects. The rate of consumption of water and other necessities per capita were calculated in consideration of the rate of population growth and the limits to the island ecosystem. Islanders can see the top of the mountain and the ocean in one view, and they can feel the distance across the sea for the supply of resources if they mismanage. They are more aware of the root causes of degradation of their ecosystem processes.

In our offices in Honolulu, Silver Springs, and Washington DC, we are buffered from the immediate severity of the problem. We can earn our daily living by analyses of data from monitoring and mapping by satellite imagery, and we can go to the grocery store when we are out of fish or other food. The grocery stores are part of a global system and if the resources are depleted in one area, we can buy from other less-developed areas. When we give it any thought, we sometimes consider that we might eventually run out of new places to deplete. But since we go to the grocery store, and it is the job of the wholesaler to find new sources, we can focus on our studies of proximal factors and leave it to the grocery stores to find the fish to purchase. We propose large-scale long-term plans such as NEON or GOOS which will monitor environmental changes for decades. These programs have large-scale, long-term value, but they should not detract focus from immediate problems requiring immediate action. When reviewing nearly all of the same proximal causes of coral-reef degradation 30 years ago, Bob Johannes (1975, E.J. Ferguson Wood and R.E. Johannes (eds.) Tropical Marine Pollution. Elsevier, page 51) wrote "They measure and we weep."

In a recent large-scale 5-year research plan for a government agency,

it was encouraging to see a list of "key socioeconomic research questions for coral ecosystems". But then these questions were approached in a superficial manner "The role of social science in coral ecosystem management is to: (1) determine how society is currently choosing to use coral reef ecosystems, and (2) estimate the social and economic costs and benefits of those uses from and ecosystem perspective…" Just as with monitoring effects of climate change over the next few decades, these are perfunctory approaches to documenting and measuring the problem rather than investigating the causes. More important questions are how this use of coral-reef resources is changing with the rapid growth in human populations, how uses of coral reef resources are affected by global movements of humans, mixing of cultures and loss of traditional cultural integrity, globalization of economics and advances in technology. The globalization of the economy and the mixing of cultures are undermining the local control of resources and thereby undermining responsibility. These are as profound and immediate global issues as global climate change for coral-reef ecosystems (although climate change is probably the more immediate and severe problem in polar regions).

Pacific Islanders often have a good understanding of their ecosystem and attempt to manage global problems by local action. In 1997/98 seawater warming severely affected coral reefs in Palau. Citizens of Palau observed that many of the corals, especially *Acropora*, turned white and died during the seawater warming. Algae were replacing the living coral. It may be that some citizens of Palau felt that the problem of global warming was beyond their capabilities to handle. But the Vice President of the Republic of Palau, who is now the President, Mr. Tommy Remengesau, Jr., advised the citizens on practices that might facilitate the recovery of corals. He published this advice in an article in the local newspaper. He asked the people to avoid taking herbivorous reef fishes for food because the herbivores are important for survival by keeping the algae controlled and thereby facilitating recruitment of juvenile corals. He also asked people not to step on the few remaining nearshore living coral colonies, because in doing so they will damage the broodstock for recovery of coral populations. Like marine reserves, these small-scale actions will not stop global warming, but they might at least facilitate replenishment of coral populations and they could focus and secure a perception of community and responsibility among the stakeholders. The renovation of traditional community awareness of responsibility may be the most effective path to coral reef management.

A byproduct of human population growth and technology is the global economic demands that can overwhelm local control of marine resource harvest. If a village community controls local harvests, the villagers are likely to protect breeding stocks in consideration of future harvests. If they cannot control extraction by outsiders, then they are more likely to feel they may as well harvest them anyway. If they do not take them, someone else will (the "tragedy of the commons" of Garrett Hardin).

Pacific Islanders such as Palauans, Yapese, and Hawaiians traditionally have local control over marine resources. The Palauan Marine Protection Act of 1994 prohibits export of any marine invertebrates from coral reefs unless grown by aquaculture. All reef invertebrates and most reef fishes during their breeding seasons must be consumed locally for subsistence or in local restaurants. Local control of reef resources dampens the overwhelming influence of the global economic demand.

The Pacific island governments are often established in a traditional culture in which the chief has the power to accomplish things efficiently. This encourages political will. Following two afternoons of public hearings in which the local Samoan population protested the depletion of their fisheries resources by a small group of commercial fishermen using modern technology, the Governor of American Samoa created on Friday afternoon an Executive Order to stop fishing with modern technology (scuba and nightlights) the following Monday morning. The temporary ban would be in place until the issue is decided with public hearings and legislative debates. This is the opposite procedure to that in in the more cosmopolitan and westernized Guam where the concern with overfishing needed to be addressed in public hearings before any action was taken to establish marine reserves. The public hearings continued for 14 years, during which time the catch per unit effort decreased by 78% (0.69 to 0.15 kg h^{-1}).

To restore individual responsibility in times of globalization, and the buffering effects of modern society, is a daunting goal. Is there any hope? Over the past few years on some Pacific Islands there has been a restoration of community-based resource management and resistance to global economic domination. Vanuatu recognizes customary marine tenure of villages in its constitution and Independent Samoa recognizes village regulations concerning its nearshore fishing grounds as legal bylaws. When the local community is given authority to make management decisions, political will and motivation for responsible management might be restored.

FELLOWSHIP REPORTS

Nitrogen isotopic analysis of coral skeleton: Reconstructing Historical Great Barrier Reef Water Quality

Guy S. Marion
Centre for Marine Studies
The University of Queensland
Brisbane, QLD 4072, Australia
g.marion@uq.edu.au

Collaborating Authors

Ove Hoegh-Guldberg, Centre for Marine Studies, The University of Queensland

Stacy D. Jupiter, Earth and Marine Sciences, The University of California- Santa Cruz

Malcolm T. McCulloch, Research School of Earth Sciences, The Australian National University

David Mucciarone, Dept. of Geological and Environmental Sciences, Stanford University

Robert Dunbar, Dept. of Geological and Environmental Sciences, Stanford University

Background

Since Europeans first settled the Queensland coast that lines the 2,300km-long Great Barrier Reef (GBR), land use has been transformed for agricultural expansion, urban and port development, and wetland reclamation. Using a variety of approaches, recent studies estimate that the resultant total nutrient delivery into the GBR Lagoon has increased 2 to 4 fold since European arrival (1860)[1, 2], and sediment export has jumped by a factor of 4 to 10[3, 4]. The annual nitrogenous pollution flux into the GBR Lagoon is an estimated 43,000 tons, with sediment flux totaling 14 million tons[1]. Yet our knowledge of how pre-impacted, "pristine" water quality compares with present day conditions, at least with regards to nutrient concentrations and sources, is based on modeled estimates with varying degrees of uncertainty.

This project establishes a geochemical proxy technique for empirically identifying annual to centennial variability of nitrogen sources in tropical coastal oceans. The technique is applied in the agricultural Mackay region of the central GBR, and involves analysis of the nitrogen isotopic composition ($\delta^{15}N$) of organic matter (OM) preserved within the reef-building *Porites* coral skeleton. Comprising less than 0.01% of coral skeleton by weight, crystalline-bound OM accumulates continuously in long-lived *Porites*, reflecting the ambient $\delta^{15}N$ regime and providing a context for identifying end-member pollution inputs[5].

Nitrogen isotopes in coral skeleton

The natural abundance ratio of stable nitrogen isotopes ($\delta^{15}N$) is a useful tool for tracing isotopically distinctive nitrogen sources and biogeochemical cycling in the marine environment[6]. $\delta^{15}N$ refers to the relative abundance of ^{15}N to ^{14}N in a biochemical sample and is reported as the per mil deviation (‰) relative to the isotopic ratio of N in air ($\delta^{15}N$=0‰). Generally, biological processes alter $\delta^{15}N$ via a kinetic affinity for transformations involving the lighter isotope. This is manifested by a stepwise $\delta^{15}N$ enrichment (+3.5‰) between adjacent trophic levels due to excretion of depleted (low $\delta^{15}N$) detrital matter [7].

Symbiotic corals are reliable indicators of the ambient chemical environment, and numerous studies related enriched $\delta^{15}N$ values of coral tissues to gauge human-derived pollution stress in the tropical marine environment[8, 9, 10]. More recently, skeletal nitrogen isotopic analysis was proposed as a way to pinpoint historical variability of oceanic $\delta^{15}N$ [5, 11]. In Bali, Indonesia, Marion et al. found that the introduction of isotopically light chemical fertilizers during the Green Revolution of the early 1970s produced a significant, 30 year decline in coral skeletal $\delta^{15}N$. The authors attributed the decline to rapid increases in isotopically depleted fertilizer use, from 0 tons/yr in the late 1960s to >58,000 tons in 2000[5]. The technique demonstrated that near-shore coral reef skeletons in Bali record isotopic signals of fertilizer and sewage-rich runoff dating back to 1970.

Coral $\delta^{15}N$ technique development

The current project further develops methodologies for analyzing nitrogen isotopes in coral skeleton and applies the technique using *Porites* cores collected from the GBR. To compare isotopic variability caused by different OM extraction methods, five powdered, homogenized *P. lutea* standard specimens were subsampled repeatedly (n=226). In all, a total of 42 unique combinations of oxidizing reagents, acid types, and separation techniques were tested. A 220-year old *Porites* skeletal sample was included in the study to assess preservation of nitrogen isotopes over centennial timescales. Based on these results, optimum techniques were selected that allow rapid sample preparation at relatively high precision (1SE = 0.3‰-0.5‰; Marion et al. in prep). The fidelity with which coral $\delta^{15}N$ reflects perturbation in the ambient environment was tested using small GBR *Porites* colonies that had previously been subjected to a daily ammonium addition (36 uM) regime during the Enrich-

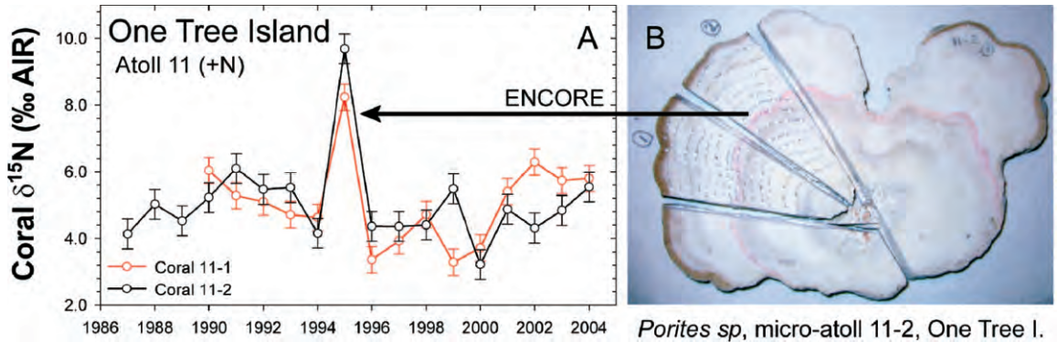


Figure 1. Nitrogen isotopic ($\delta^{15}N$) profiles (A) of *Porites lobata* colonies that were stained with Alizarin Red (B) in Jan. 1995 and deployed into incubation units as part of the Enrichment of a Coral Reef Experiment (ENCORE). The elevated $\delta^{15}N$ values (A) visible in colonies 11-1 (red) and 11-2 (black) reflect assimilation of isotopically enriched DIN from the ambient micro-atoll pool water.

ment of a Coral Reef Experiment (ENCORE)[12]. Skeleton deposited during enrichment phases (1995-96) of the experiment (identified by the Alizarin Red stain, Figure 1b) is highly $\delta^{15}N$ enriched (Fig. 1a), suggesting that rapid biological assimilation of ^{14}N following NH_4Cl addition to the micro-atolls resulted in enriched remnant water DIN $\delta^{15}N$. The high $\delta^{15}N$ was assimilated by the corals and reflected in the skeletal record. Taken together, these studies support that organic $\delta^{15}N$ reflects the ambient ocean chemistry, and is well-preserved in coral for at least 220 years (Marion et al, in-prep).

The Pioneer River Catchment of Mackay, QLD

In order to assess how topsoil erosion, sediment efflux, and the leaching of fertilizer-derived nitrogen (nitrate and particulate N) have altered N-related water quality in coastal GBR waters off Mackay, an integrated catchment to coral reef isotopic study was conducted. The Mackay region is centered at 21°7'S, 149°14' E, with a mean annual rainfall of 1665mm, falls within the "dry tropics" band of central Queensland (Fig. 2a-b). The region's largest catchment, the Pioneer River, drains an area of 1570 km^2 and is characterized by highly variable annual flows (807,917 ± 725,829ML) that peak between the summer months of October and March. Between 1910 and 1990, nitrogen-based fertilizer consumption increased 10-fold (to 5490 tones N) in the Pioneer catchment[13]. The area of sugar cane harvested is 117,000 hectares, representing one third of the total Queensland harvest.

To distinguish terrestrially-derived nitrogen inputs from the measured range of oceanic $\delta^{15}N$ in the Mackay region (5‰-6‰), particulate nitrogen was analyzed in water samples collected from representative end-member sites (n = 17) located throughout the Pioneer catchment (Fig. 2a). In the upstream tributaries, and in irrigation and river waters adjacent to cane lands, particulate $\delta^{15}N$ values are low (1-4‰). Generally, synthetic nitrogenous fertilizers, as well as cyanobacterial N-fixation, introduce isotopically low DIN and particulate N (~0‰) into waterways, reflecting their atmospheric source of nitrogen [14, 15]. Concentrations and $\delta^{15}N$ values are progressively higher downstream (6‰-12‰), and reflect a combination of: 1) biogeochemical cycling of fluvial nitrogen species during passage to the rivermouth, and 2) accumulation of enriched end-member inputs from the densely populated coastal lands. For example, DIN and particulate $\delta^{15}N$ in wastewater from septic systems and primary-treated sewage typically exceed 10‰ due to rapid microbial transformations including nitrification, ammonia volatilization and denitrification[16]. Collectively, these results indicate that the nitrogen isotopic composition of particulate nitrogenous phases that enter Mackay coastal waters is distinct (>8‰) relative to the background oceanic N regime. We hypothesize that: 1) decreasing inshore to offshore coral $\delta^{15}N$ values will reflect reduced exposure to terrestrially-derived nitrogen inputs, 2) time-resolved coral core $\delta^{15}N$ data will correlate temporally with instrumental Pioneer River discharge data, and 3) coral $\delta^{15}N$ will exhibit a long-term enrichment reflective of the onset of land-clearing and increased N flux in terrestrial run-off.

Coral $\delta^{15}N$ records of coastal water quality

Land-based river runoff contributes ~30% of all new N inputs into the central GBR Lagoon each year, dominating the coastal nitrogen regime[17]. To explore the spatial and temporal influence of terrestrial N inputs into near shore Mackay waters, *Porites sp.* replicate coral cores (50 to 170cm long) were drilled from shallow (<5m) reefs and coral communities found between 5km and 50km offshore of the Pioneer river mouth (Fig. 3a). High-resolution measurements of coral skeletal luminescence (δ = 490nm), which reflects freshwater river discharge into the GBR (Fig. 3b), indicate that inshore (Round Top I.) reefs are regularly exposed to Pioneer River discharge. Flood plumes can extend at least 33km offshore into the mid-shelf GBR (Keswick I.) in all but drought-bearing years, and

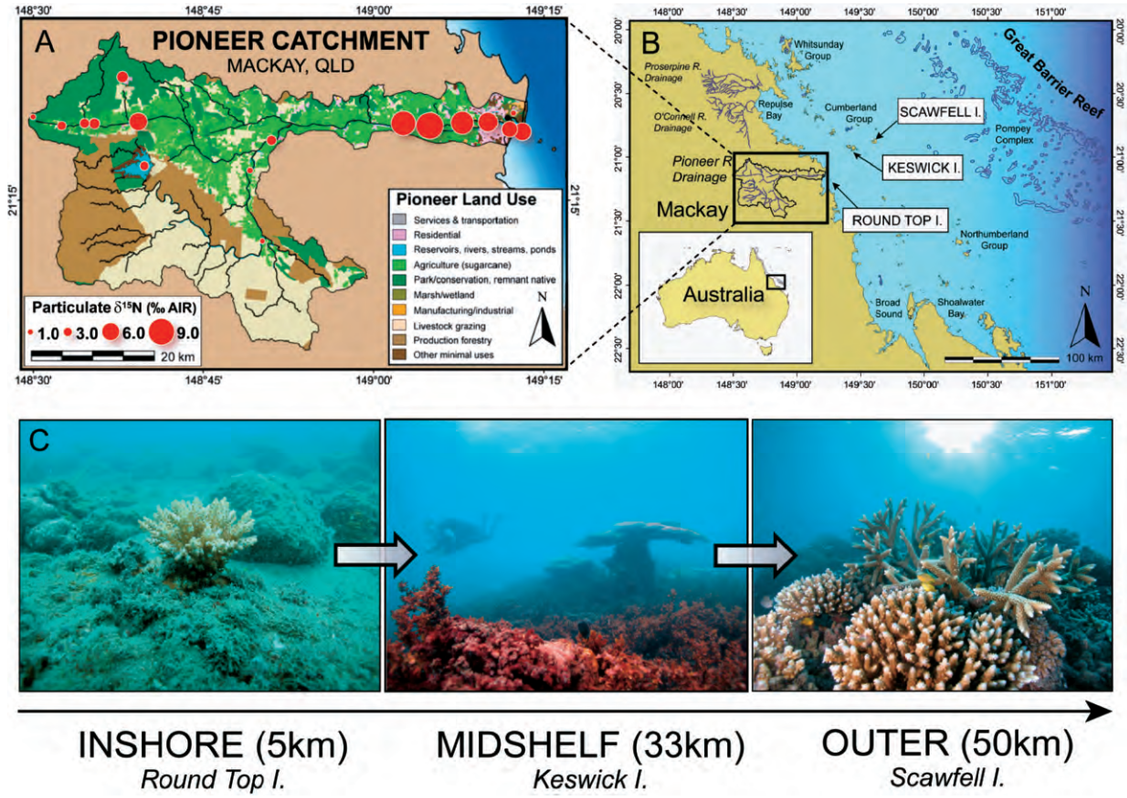


Figure 2. The Mackay Whitsunday region of the central Great Barrier Reef, Australia. Biogeochemical cycling of fluvial particulate $\delta^{15}N$ (red circles) in the Pioneer Catchment (A) produces a distinct (enriched) isotopic signal in flood waters. This signal is traced in long-lived Great Barrier Reef corals collected along a distance gradient from the Pioneer River mouth (B). Inshore and midshelf coral reefs (C) exposed to terrestrial runoff are sediment laden and algal overgrown while non-exposed, outer-midshelf reefs are healthy and support diverse marine communities.

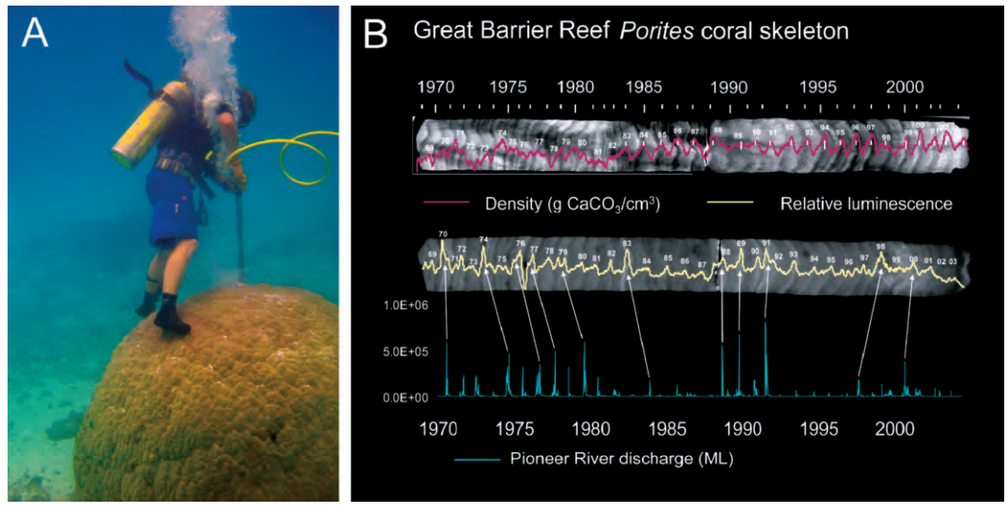


Figure 3. Pneumatic core drilling from a massive *Porites sp.* coral, whose carbonate skeleton records change in the coastal chemical environment (A). High resolution records of seasonally-dependent skeletal density (purple) overlaid on an x-ray image (top slab- B) and coral luminescence intensity (yellow) overlaid on a photograph taken under black light (bottom slab- B). Annually occurring density bands are used to assign dates to chronological time series data, and luminescent banding is used to identify floods and periods of low-salinity stress.

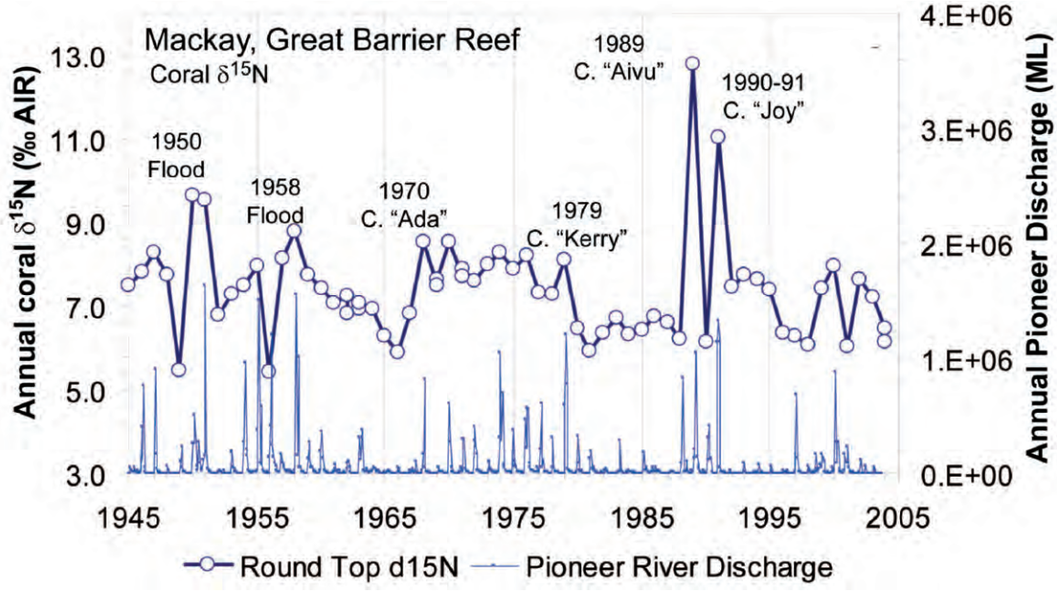


Figure 4. Coral core data from the inshore GBR (Round Top I.) provides a 59 history of δ^{15}N variability in Mackay coastal waters. Coral δ^{15}N is positively related to Pioneer River discharge, reflecting the flood-associated efflux of anthropogenic waste nutrients into the GBR Lagoon. The cyclonic floods of 1989 and 1991 resulted in the highest observed δ^{15}N values since 1945.

extend up to 50km offshore (Scawfell I.) every three to five years following major floods. Not surprisingly, the distribution and abundance of coral reef species vary dramatically across the Mackay transect (Fig. 2c). The inshore reefs are characterized by highly turbid waters (visibility frequently ranges from 0 to 5m), widespread macroalgal and sediment blanketing, low fish biomass, and encrusting / massive hard coral species. In contrast, the reefs fringing Scawfell Island, located 50km offshore, have clear waters (typically yielding 10 to 25m of visibility) and intact, healthy hard and soft coral communities that exhibit high species diversity typical of an oligotrophic, offshore GBR environment.

Nitrogen isotopic records reconstructed from three inshore (RTC, RTF, RTH) and two midshelf (KIC, SCC) coral cores reveal consistent spatial and temporal trends. Average coral skeletal δ^{15}N values decrease with increasing distance from land, ranging from elevated values (8.0±0.2‰) in the three inshore (Round Top I.) corals, to oceanic values (3.6±0.5‰) by the outer mid-shelf (Scawfell I.). Between 1945 and 2004, inshore coral δ^{15}N is positively correlated with river discharge (Fig. 4), with maximum recorded values occurring during the major floods triggered by Cyclones "Aivu" (1989) and "Joy" (1991). One inshore coral δ^{15}N record (RTH) that predates European-style land use change (~1860) indicates that the expansion of coastal agriculture and fertilizer use in Mackay has dramatically increased river-borne nitrogen efflux into the GBR Lagoon relative to "pristine" baseline conditions (Marion et al. in prep). The Keswick I. coral (33 km offshore) recorded enrichments of land-derived nitrogen, particularly during major flood years (e.g. the cyclones-driven floods of 1974 and 1991), that probably contribute to the high proportion of macroalgal cover evident at this site. By contrast, Scawfell I. (50 km offshore) coral δ^{15}N is unresponsive to river discharge, even during years when major flood plumes reach the reef (inferred from coral luminescence). This suggests that phytoplankton blooms deplete all biologically-available nitrogen by >50km offshore, regardless of the magnitude of the flood. Of the three sites sampled, Scawfell Island fringing reefs have the highest coral cover and diversity.

Preliminary Conclusions

The recent discovery that organic matter preserved in long-lived *Porites* coral skeleton reflects past pollutant sources offers tantalizing new opportunities to explore relationships between long-term land use change and coastal coral reef ecosystems. In the Mackay region, multi-decadal coral δ^{15}N records (1945-2005) collected from a lateral transect of reefs extending from 5km to 50km offshore show clear flood-associated signals of anthropogenically-enriched nitrogen inputs. While freshwater flood plumes reach reefs located 50km offshore (Scawfell I.) every three to five years, coral δ^{15}N values from this site are consistently low and isotopically unrelated to Pioneer River discharge, indicating that terrestrially-derived inorganic and particulate nitrogen species are fully depleted by <50km off the coast. A coral record dating back

to the late-1800s indicates that the onset of significant N-loading in the coastal environment initiated post-1950. Various endogenous (technique related) and exogenous (riverine and coastal biogeochemical cycling) processes can cause non-source related fractionation of the terrestrial source $\delta^{15}N$ and must be accounted for when interpreting coral isotopic results (Marion et al. in-prep). A synthesis report will explore the impact of post-European land use on Great Barrier Reef health (assessed by photo transect data) in the Mackay Region by comparing coralline tracers of nitrogen provenance ($\delta^{15}N$) and sediment discharge (trace metals) with remote sensing-derived records of riparian vegetation and mangrove loss in the Pioneer Catchment, which has suffered a 32% net loss of riparian area since 1972 and a 22% net loss of tidal mangroves since 1948[18].

Acknowledgements

The author would like to thank ISRS/TOC for the Graduate Research Fellowship that enabled the start of this project. Joint sources of funding include the PADI Foundation, GBRMPA, The Richard & Rhoda Goldman Foundation, the University of Queensland, and the Australian Research Council (Linkage Grant # LP0560896 to OHG for Mackay research).

References

[1]Furnas M (2003) Catchments and Corals. Australian Institute of Marine Sciences, Townsville (334)

[2]Brodie JE, Mitchell AW (2005) Nutrients in Australian tropical rivers: changes with agricultural development and implications for receiving environments. *Marine and Freshwater Research* 56: 279-302

[3]Neil DT, Orpin AR, Ridd EV, Yu BF (2002) Sediment yield and impacts from river catchments to the Great Barrier Reef lagoon. *Marine and Freshwater Research* 53: 733-752

[4]McCulloch M, Fallon S, Wyndham T, Hendy E, Lough J, Barnes D (2003) Coral record of increased sediment flux to the inner Great Barrier Reef since European settlement. *Nature* 421: 727-730

[5]Marion GS, Dunbar RB, Mucciarone DA, Kremer JN, Lansing JS, Arthawiguna A (2005) Coral skeletal delta N-15 reveals isotopic traces of an agricultural revolution. *Marine Pollution Bulletin* 50: 931-944

[6]Owens N (1987) Natural variations in 15N in the marine environment. *Advances in Marine Biology* 24: 389-451

[7]Minagawa M, Wada E (1986) Stepwise enrichment of 15N along food chains: further evidence and the relation between 15N and animal age. *Geochim Cosmochim Acta* 48: 1135-1340

[8]Sammarco PW, Risk MJ, Schwarcz HP, Heikoop JM (1999) Cross-continental shelf trends in coral d15N on the Great Barrier Reef: further consideration of the reef nutrient paradox. *Marine Ecology-Progress Series* 180: 131-138

[9]Heikoop JM, Risk M, A. V. Lazierb, E. N. Edingerb, J. Jompad, V. Limmonb, Dunnb JJ, Browne DR, Schwarcz HP (2000) Nitrogen-15 Signals of Anthropogenic Nutrient Loading in Reef Corals. *Marine Pollution Bulletin* 40: 628-636

[10]Swart PK, Saied A, Lamb K (2005) Temporal and spatial variation in the delta N-15 and delta C-13 of coral tissue and zooxanthellae in Montastraea faveolata collected from the Florida reef tract. *Limnology and Oceanography* 50: 1049-1058

[11]Hoegh-Guldberg O, Muscatine L, Goiran C, Siggaard D, Marion GS (2004) Nutrient induced perturbations to 13C and 15N in symbiotic dinoflagellates and their coral hosts. *Marine Ecology-Progress Series* 280: 105-114

[12]Koop K, Booth D, Broadbent A, Brodie J, D. Bucher, D. Capone, J. Collf, Dennison W, Erdmann M, Harrison P, Hoegh-Guldberg O, Hutchings P, Jones G, Larkum W, O'Neil J, Stevens A, E. Tentori, Ward S, Williamson J, Yellowlees D (2001) ENCORE: The Effect of Nutrient Enrichment on Coral Reefs. Synthesis of Results and Conclusions. *Marine Pollution Bulletin* 42: 91-120

[13]Pulsford J (1996) Historical Nutrient Usage in Coastal Queensland River Catchments Adjacent to the Great Barrier Reef Marine Park. Great Barrier Reef marine Park Authority, Townsville (68)

[14]Kendall C (1998) Tracing nitrogen sources and cycling in catchments. In: Kendall C, McDonnell JJ (eds.) Isotope Tracers in Catchment Hydrology. Elsevier Science, USA (pp 519-576)

[15]Udy JW, Dennison WC, Long WJL, McKenzie LJ (1999) Responses of seagrass to nutrients in the Great Barrier Reef, Australia. *Marine Ecology-Progress Series* 185: 257-271

[16]Heaton T (1986) Isotopic studies of nitrogen pollution in the hydrosphere and atmosphere: a review. *Chemical Geology* 59: 87-102

[17]Furnas MJ, Mitchell A, Skuza M (1997) Shelf scale nitrogen and phosphorus budgets for the Central Great Barrier Reef (16–19 S). *Proceedings of the 8th International Coral Reef Symposium*: 809-814.

[18]Jupiter S, Potts DC, Phinn S, Duke N (in-press) Natural and anthropogenic changes to mangrove distributions in the Pioneer River Estuary (QLD, Australia). *Wetlands Ecology and Management*

Elizabeth H. Tyler

Report on the results of the study and use of the funding awarded Surface Microbial Communities Of Reef-Building Corals

Reia Guppy
PhD Candidate
September 2006

Since the 1970's, there has been an explosion in not only the number of diseased corals, but also the number of different diseases observed on corals on a global scale. Coral reef ecosystems are undergoing unprecedented rates of change which may be linked to global climate change effects,[1,2] as well as local and regional environmental impacts.[3] At the organismal level these diseases are created by shifts in microbial communities. Since ecosystem function is dependent on microbial processes, and the effects of even small environmental changes may be reflected and magnified within the microbial community over a relatively short time span,[4,5] the use of microbes as possible indicators for environmental change or pollution is promising. In order to determine if microbial changes in a coral reef environment could be used as potential indicators for pollution/environmental change, this study examined the surface layer mucus (SLM), bacterial community on two important Caribbean reef-building corals (the common brain coral *Diploria strigosa* Dana 1848 and the star coral *Montastraea faveolata* Ellis and Solander 1786). The monitoring of these SML microbes may represent a non-destructive means of determining coral response to environmental change.

Thus far, the study of microbial diversity on coral reefs has concentrated largely on changes associated with coral diseases.[6] It has been found that a more diverse microbial community exists in the SML of diseased versus healthy corals;[7,8] but it is not known to what extent this increased diversity reflects a cause and/or an effect of the disease process, or why coral diseases have become more prevalent. This differential microbial diversity between healthy and diseased corals suggests that there is a change in the ability of corals to physically and/or chemically defend themselves against potential pathogen(s). Reasons for this change may be: (1) the physical mucus barrier being compromised, such as in fish bites, creating a point of access for invasion; (2) changes in the mucus composition, leading to the variation of the nutritional value, and so too the survivorship of the microbes on the SML; or (3) changes in the effectiveness of antimicrobial chemicals produced by the corals against potential pathogens. Regardless, it is first necessary to understand the dynamics of the SML microbial community on healthy corals before there can be a clear understanding of the mechanisms leading to the initiation and progression of disease and the associated impacts on coral populations.

This is the first study to explore how the bacterial communities on coral SML change over multiple spatial scales, time, and (indirectly) with varying environmental (water quality) conditions. The overlying goal was to characterize the structure of the SML communities and to determine the extent to which they are affected by environmental stress. The coral SML bacterial communities on *Diploria strigosa* and *Montastrea faveolata* were examined, then compared to biofilm and water column bacterial communities, and analyzed against water quality conditions. With the receipt of an ISRS Fellowship in 2003, I was able to successfully conduct my research on the Caribbean island of Tobago. There I was able to collect coral mucus swabs, water filters and nutrient data at eight reef sites of varying anthropogenic impact over a 6-month sampling period. Culture-independent molecular techniques were used to analyze samples to obtain DNA fingerprints of the bacterial communities from Tobago, as well as those samples collected from Puerto Rico and Mexico.

Following a biogeographical approach, the coral SML microbial communities were examined both spatially and temporally. Comparisons of the SML bacterial communities between host species offered some indication if these communities were randomly formed, biologically (host) controlled, environmentally controlled or a combination of biologically and environmentally controlled. Results suggested that the microbial communities developed following deterministic processes more than stochastically (passive settlement). Concurrent examination of the SML microbial communities both in the water column and also in a settler community (biofilm) allowed for additional information on the settlement dynamics. Although the biofilm and SML communities showed greater overlap to each other compared to the water column communities, multiple culture-independent methods indicated that the SML not only supports a distinct community, but also that the SML provides a unique niche for settlement.

As in all biogeographical studies, spatial scale is an important consideration, particularly when concerned about potential influencing factors. Therefore, four spatial scales were examined in the study following a hierarchical sampling regime: intra-colonial, inter-colonial (intra-reef), inter-reef, and inter-country (Tobago, Puerto Rico, and Mexico). Changes in SML microbes over time offers indirect information on microbial community and SML turnover, thus spatial sampling of the coral SML also extended across six months covering

two seasons (the wet and dry). Variations between host at each spatial level, month and season sampled were observed, where the driving or controlling factors appeared to be a combination of host and environment. It was found that the apparent magnitude of their contribution differed at each spatial level.

Coral mucus dynamics are not well understood.[10] It is likely that changes in the production/sloughing dynamics due to changing environmentalconditions, the coral host physiology would result in a subsequent change in bacterial community. Under this assumption, to facilitate the understanding of how the coral SML microbial communities develop over time, the changes in the microbial diversity on a developing biofilm was followed over five days, and comparisons were drawn from the diversity levels of the SML microbial communities found in both host species. Results were evaluated against three possible modes of development of these communities in the SML. For *D. strigosa* and *M. faveolata*, the associated microbial communities suggested that the rate of SML loss was less than that of bacterial community development, therefore SML loss was most likely a gradual process with only the loss of the outermost surface allowing the bacteria trapped in the mucus to continually develop. Continual seeding from the water column and other sources could possibly account for the temporal differences.

Examining corals under varying conditions of stress is also important in looking at the SML microbial communities, as it is under these conditions that coral mucus properties can change thereby allowing invasion of more potent diseases into the SML or decreased resistance to existing pathogens. Stress to corals can result from a number of sources, such as changes in seawater temperature, salinity, turbidity, and water quality. In the Caribbean, particularly the southern island of Tobago, 'pollution' is mainly from runoff and ill-treated sewage, and therefore water quality was considered as the primary source of stress, especially since seawater temperature and salinity varied little over the months that sampling occurred. Besides these anthropogenic influences, Tobago is highly influenced by the discharges from the Orinoco River in Venezuela. As a result, strong seasonal differences in water quality were correctly predicted, as well as nearshore/offshore gradients. However, correlations between the water quality and the SML microbial diversity were difficult to determine, possibly complicated by the relatively small spatial scales investigated and the overall well-mixing of waters around Tobago.

The support from ISRS/TOC (£ 5,500) came directly before I started my field sampling, 9 months after I had started my PhD. It covered all of my fieldwork expenses, including two international return flights between Newcastle (UK) and Trinidad, and local travel between Trinidad and Tobago. Customs costs for importing chemicals, boat and diving costs, hiring of a local dive assistant, lodging, as well as food expenses were covered by support from ISRS. Without this invaluable support, I would have been unable to conduct such an extensive research project. Thus this award has played a tremendous role towards the completion of my degree, and in preparing me for what the future may bring. I have recently finished my PhD, and have already secured a position as a research associate at Newcastle University, working in an area that is an extension of my PhD research, looking more closely at the coral SML under specific stress conditions. After this, I hope to continue working on finding an alternate bioindicator(s) of pollution that will be useful in small island states, such as Tobago. I also intend to become involved in tertiary education, which will allow me the opportunity to impart my knowledge and experience to others, in the hopes of encouraging the youth of our country towards a greener pasture.

References

[1]Hoegh-Guldberg O (1999). Climate change, coral bleaching and the future of the world's coral reefs. Marine and Freshwater Research, 50: 839-866.

[2]Harvell CD, Mitchell CE, Ward JR, Altizer S, Dobson AP, Ostfeld RS, and Samuel MD (2002). Climate warming and disease risks for terrestrial and marine biota. Science, 296: 2158-2162.

[3]Jordán-Dahlgren E, Maldonado MA, and Rodríguez-Martínez R (2005). Diseases and partial mortality in *Montastraea annularis* species complex in reefs with differing environmental conditions (NW Caribbean and Gulf of México). Diseases of Aquatic Organisms, 63: 3-12.

[4]Paerl HW, Dyble J, Moisander PH, Noble RT, Piehler MF, Pinckney JL, Steppe TF, Twomey L, and LM Valdes (2003). Microbial indicators of aquatic ecosystem change: current applications to eutrophication studies. FEMS Microbiology Ecology, 46: 233-246.

[5]Manini E, Luna EM, and Danovaro R (2004). Benthic bacterial response to variable estuarine water inputs. FEMS Microbiology Ecology, 50: 185-194.

[6]Rosenberg E and Ben-Haim Y (2002). Microbial diseases of corals and global warming. Environmental Microbiology, 4: 318-326.

[7]Cooney R, Pantos O, Le Tissier MDA, Barer MR, O'Donnell AG, and Bythell JC (2002). Characterization of the bacterial consortium associated with black band disease in corals using molecular microbiological techniques. Environmental Microbiology, 4: 401-413.

[8]Frias-Lopez J, Zerkle AI, Bonheyo GT, Fouke BW (2002). Partitioning of bacterial communities between seawater and healthy, black band diseased, and dead coral surfaces. Applied and Environmental Microbiology, 68: 2214-2228.

[9]Pantos O, Cooney RP, Le Tissier MDA, Barer MR, O'Donnell AG, and Bythell JC (2003). The Bacterial Ecology of a Plague-Like Disease Affecting the Caribbean coral *Montastrea annularis*. Environmental Microbiology, 5 (5): 370-382.

[10]Brown B and Bythell JC (2005). Perspectives on mucus secretion in reef corals. Marine Ecology Progress Series, 296: 291-309.

Rare Insights into Evolution

T. Richards - Marine Biology PhD Student – ISRS Recipient 2005

Speciation and extinction occur cryptically in corals. Rare species (those with a restricted distribution), are expected to be at the forefront of these evolutionary changes. While rare species are often in the spotlight in the context of conservation and biodiversity, the factors that limit their distribution are unknown. Focus on rare coral species using recently developed genetic tools promises to provide answers to many basic evolutionary questions.

Corals are considered to display a widespread distribution, due to the open water environment; yet up to 35% of *Acropora* corals have a restricted distribution. Corals with a restricted distribution initiate a series of perplexing evolutionary questions: Are they young and in the process of expanding their range? Are they old and at the end of their taxon cycle? Are they remnants of ancestral populations that were formerly widespread? Are they hybrids? Are they genetically eroded and vulnerable to extinction? Are isolated populations connected? Can they persist? Our research aims to use new advances in coral genetics to bring these questions together into the most comprehensive investigation of rarity ever performed in the marine environment.

This investigation into rare coral species was stimulated by recent surveys of the remote Rongelap Atoll in the Northern Marshall Islands (Pacific Ocean). Fieldwork in this isolated location revealed one new species of *Acropora* coral and many rare species were recorded in the Pacific Ocean for the first time. Along with other rarity hotspots around the globe (such as Indonesia and Papua New Guinea and the Red Sea), the coral population of Rongelap Atoll provides the ideal opportunity to test hypotheses about the age, origin and threatened status of rare species.

The evolutionary history (phylogeny) of the genus *Acropora* has been established using morphological characters (skeletal form and structure). This is supplemented by a molecular phylogeny, which is based on only a small subset of the entire genus. There are a number of discrepancies between the two phylogenies. Species currently hypothesized to be closely related to ancient species in the morphological phylogeny may be more recent in origin according to the molecular phylogeny. Species restricted to the Western Indian Ocean and Red Sea are considered the most ancestral within the morphological phylogeny (this is also supported by fossil records), while species restricted to the Caribbean are suggested to be the most ancestral in the nuclear tree of the molecular phylogeny. Rare species are suggested to be the most recently derived in the morphological phylogeny however the position of rare *Acropora* species remains unresolved within the molecular phylogeny.

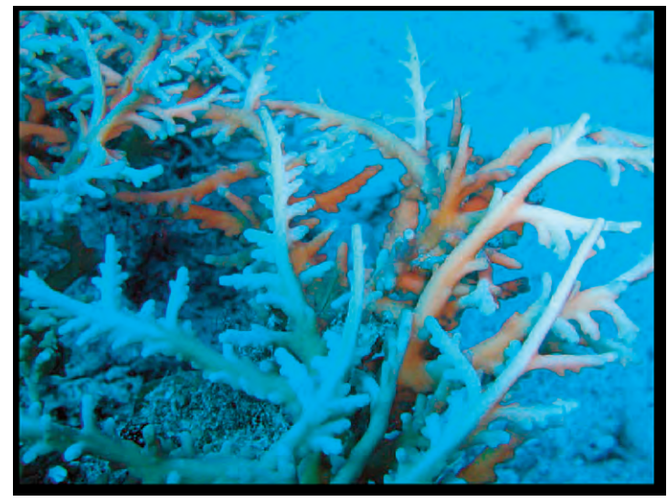


Figure 1. The most recently described new species of Acropora - *A. rongelapensis* (described in 2004 from the Marshall Islands by the author) is at the heart of an evolutionary debate.

One outstanding challenge to understanding the evolution of new species within the Genus *Acropora* has been that in genetic terms, we have no real idea of what a coral species is. Cryptic species, syngameons (groups of species that exchange genes) and morphological plasticity within and between species have provided a major challenge to coral taxonomists. The apparent complexity in *Acropora* structure and the suggestion that the same morphologies may have independently evolved more than once in *Acropora* evolution has lessened the integrity of morphological phylogenies.

It is now clear that baseline population genetic studies are fundamental to advancing the evolutionary debate for corals. Using genotyping technology the extent of genetic variation can be determined for a species across its entire range. By using the extent of variation within a common and widespread species as a benchmark, coral species can be defined in genetic terms. Applying this strategy to investigating the genetic variation in rare species will enable an interpretation of rare species integrity to be made for the first time. This research will be the first global-scale application of genotyping technology in coral science; and will provide information valuable information at to the threatened status of corals.

Molecular phylogenies offer a robust portrayal of a species evolutionary history. Single-copy Mitochondrial and Nuclear gene markers have been found to provide useful data for reconstructing species-level phylogenetic relationships in corals. The mitochondrial control region

rns-cox3 and the highly polymorphic Pax-C 46/47 Intron are the most valuable. Populations of rare and closely related corals will be screened in this project using sequences from these regions and placed into the existing molecular phylogeny to investigate divergence patterns relating to rarity or commonness. If rare species are recently derived they are expected to occur within a terminal position on the cladogram. If rare species are derived from ancient lineages they are expected to occur in a near-basal position in the cladogram.

The amount of sequence divergence within and between species reveals a lot about species ancestry. Low amounts of sequence divergence between morphologically distinct species may represent a recent common ancestry. Alternately, species that diverged from each other a long time ago are expected to exhibit high levels of sequence variation. Different morphs within a single species may represent local adaptation with occasional hybridization and backcrossing. Generally however, as a species expands its range- the newly colonized area carries only a subset of the alleles from the parent population (i.e. significantly lower genetic diversity); hence the ancestry of a species can be traced.

Information from rare corals also offers insights into the origin of biodiversity. The classic view of marine evolution is that a large proportion of recently evolved genera occur within high diversity regions of the Central Indo-Pacific. The consensus view amongst coral biologists seems to have been that new species are likely to have arisen within this "Centre of Origin" through different types of speciation. According to this view, relatively advanced species are characteristic of the centre of diversity and their more primitive relatives are characteristically found towards the periphery of coral reef ranges.

Many rare species within the genus *Acropora*, are completely absent from the Indo-Pacific Centre of Diversity and occur only at higher latitudes. Morphological phylogenies suggest these species are closely related to ancient lineages. In this case, rare populations in peripheral locations may represent relict populations and may harbor the original source of genetic diversity. "Taxon Cycles" have been used to explain the process whereby older taxa are excluded from their preferred habitat, being forced to survive in marginal, less desirable habitats, and finally becoming peripheral endemics and ultimately extinct. However, this theory remains untested within the molecular phylogeny for *Acropora* corals.

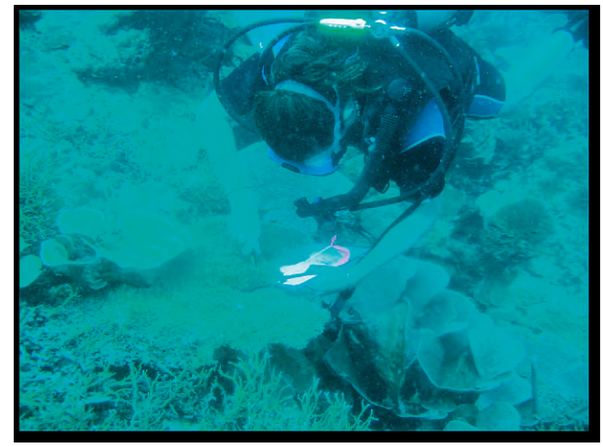


Figure 2. The author collecting molecular samples of *Acropora jacquelineae,* a rare species that is restricted to the Central Indo-Pacific.

Rather than being excluded from the preferred habitats, an alternate theory suggests that rare species may be remnants of ancestral species whose range was fragmented by vicariance events such as sea-level changes. As a result of isolation, incipient speciation leads to rapid diversification. Some evidence of this remains in modern-day species distributions as some rare *Acropora* species specialize in deep, protected habitats (e.g. *A. elegans* on deep vertical faces; *A. russeli* on deep sandy slopes). The apparent habitat signature of rare *Acropora* corals may reflect the persistence of these habitats during glacial sea level falls however their age and origin have not been established within the molecular phylogeny.

The question of whether rare corals can persist is dependant upon the ability of coral species to respond to change, and this is determined by levels of genetic variation and also the extent of genetic connectivity. Until recently, the genetic tools required to estimate genetic structuring and long-range gene flow were not available for corals. A large number of polymorphic microsatellite loci have recently been characterized that promise to advance this debate greatly.

Population genetic studies have previously focused on limited geographic ranges and little latitudinal genetic differentiation was detected in corals along the GBR in earlier studies. However, recent work shows unexpected genetic structuring in several species. If genetic connectivity is low, rare species may be particularly susceptible to local or global extinction, and widely distributed species will effectively consist of heterogeneous assemblies of locally-adapted genotypes and suffer cryptic genetic erosion. Conversely, if connectivity is high, locally adaptive effects will be unimportant on the broader scale, and damaged areas may be effectively recolonised via long-range dispersal. However, the amount of connectivity between isolated populations of rare species is unknown.

Overall, there are a number of important evolutionary insights contained within rare species that may help to explain observed distribution patterns. Funded by the International Society of Reef Studies Fellowship Program, this research will substantially advance our scientific knowledge of critically important issues such as genetic variability, structure and connectivity which are central

to the conservation of coral reefs. It will provide a molecular basis for the evolution of biodiversity and provide a scientific basis for the management and conservation of coral reefs both locally and globally. Given the threats currently facing coral reefs, and the novelty of the proposed approaches, this research will give us rare insights into evolution.

Flexibility under environmental disturbance: Will coral reefs be able to recover?

Eugenia Sampayo
Centre for Marine Studies (CMS),
University of Queensland,
St. Lucia, QLD 4072, Australia.

Coral reefs and stress

The persistence of reef building corals is determined by the symbiosis between the coral host and symbiotic algae (*Symbiodinium* spp.), where each component determines the success of the complex. Environmental disturbances, such as global climate change, can disturb the finely regulated balance between coral and algae, and as a result the symbionts may be expelled from the host tissue (becoming white or bleached) and the entire coral colony may die. Large scale bleaching events in addition to other factors, such as pollution, nutrient run-off and overfishing, have lead to a serious decline in the health of coral reefs. Many believe that coral reefs now face serious decline as mass bleaching events and other stresses are predicted to increase in severity and frequency over the next 30 years[1].

The response of corals to bleaching has been found to vary among coral genera and geographic location, indicating that both the host and symbiont determine the stress-response[2]. The algal symbionts have been shown to have variable physiologies, and "same host-different symbiont" combinations may have a variety of tolerance limits[3,4,5]. Additionally, bleaching tolerant hosts are found in areas where the majority of the population is highly affected[6]. Unfortunately, very little information is available as to how or why these individuals resist or cope with environmental stress as opposed to those that die.

Genetic variability

Since the advent of molecular techniques a variety of genetic markers have been used to uncover an enormous diversity of algal symbionts within coral and non-coral hosts (i.e. clams and anemones) [7,8,9,10]. Studies on the algal component have mainly focused on geographical and community level diversity, phylogeny and evolution within the genus *Symbiodinium*. Now, the focus is slowly changing to assessments of flexibility and persistence of the symbiosis. Here, the use of the highly variable ITS2-region was tested to detect variability in host-symbiont combinations on a local scale. Given that symbiont availability and host-specificity determine what combinations of host and symbiont will be successful, three major objectives were to determine (a) if multiple host-symbiont combinations exist within a single host; (b) if these are influenced by local environmental gradients; and (c) if these associations are flexible over time and under altered conditions.

Host-symbiont associations

Three ubiquitous species of corals, viz. *Stylophora pistillata*, *Pocillopora damicornis* and *Seriatopora hystrix*

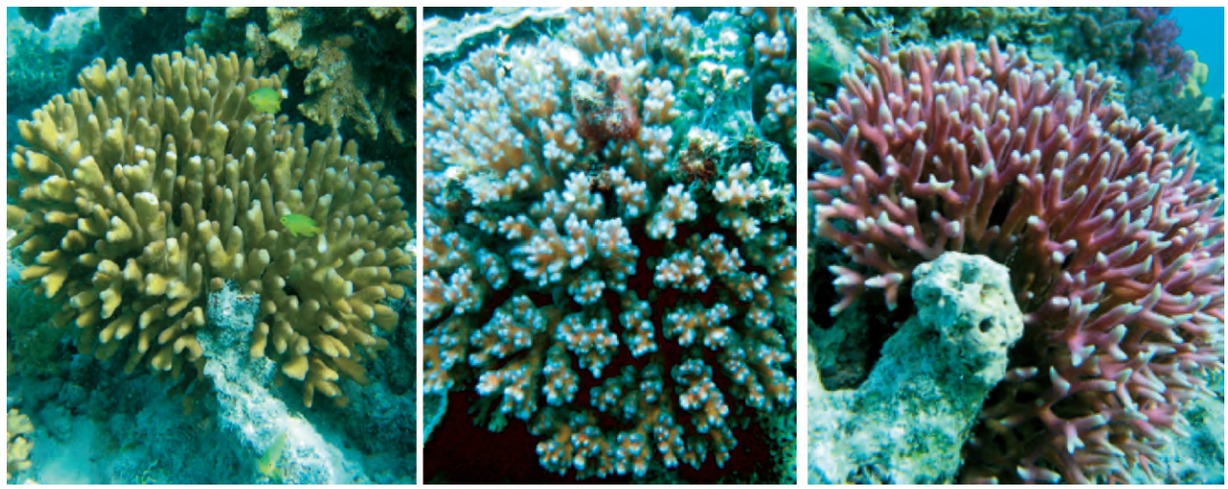


Figure 1. From left to right: *Stylophora pistillata, Pocillopora damicornis, Seriatopora hystrix.*

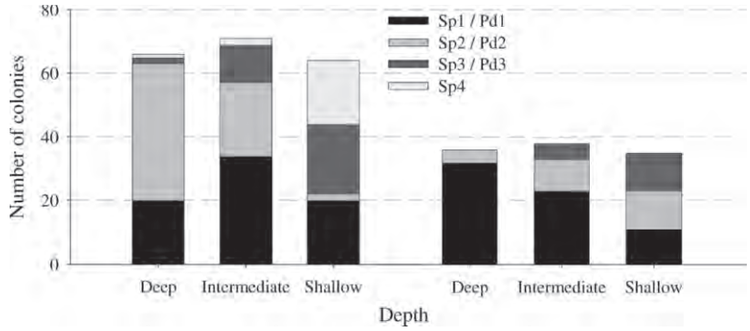


Figure 2. Host-Symbiont combinations with depth at Heron Island (GBR). Note that *S.pistillata* and *P.damicornis* symbionts are not equal even though depicted in similar colours.

(Figure 1), were subjected to a broad sampling regime at multiple depths on two locations around Heron Island (Great Barrier Reef, GBR). Pocilloporid corals at this particular geographic location are generally reported to host Clade C symbionts. Each examined species of coral harbored a group of symbionts specific to the host and there was no 'cross-over' of symbionts between species of coral. Both *S. pistillata* and *P. damicornis* colonies associated with respectively 4 and 3 different symbiont types, but were restricted to a single symbiont type per colony. Within these two host species there was a strong relation of symbiont types with depth (Figure 2). *Stylophora pistillata* had one symbiont type (Sp2) dominant in deep (>15m) and two in shallow reef areas (2-7m). *Pocillopora damicornis* displayed the same pattern with one deep (Pd1) and two shallow symbionts (Pd2 and Pd3). Each host species therefore appears to associate with its own symbiont community, where each occupies a specific niche within the distribution of the host.

S. hystrix, even though it belongs to the same family of corals, was remarkably faithful to a single symbiont type that occurred at all depths and locations, indicating that this symbiont type may have a wide tolerance within the distribution range of the host. Alternatively, associations could be a factor of initial uptake of the symbionts, a process that for these corals species occurs through maternal inheritance. In this instance, the parent colony is thought to faithfully pass on its symbionts to their offspring, in this manner ensuring continuance of a successfully established symbiotic relationship.

Flexibility of the symbiosis

It has been suggested that corals may be able to change their symbiont communities over time, and this theory has especially gained interest with the increase of stress related degradation of coral reefs. If corals are able to form multiple associations with a variety of symbionts, this would enable them to have a certain level of flexibility in response to environmental disturbances. As shown above Pocilloporid corals can associate with a multitude of symbionts within a single host population and a large-scale transplantation experiment was undertaken to test whether the presence of multiple established associations would facilitate the ability of corals to change their symbiont communities under altered environmental conditions. Fragments from multiple colonies were moved from shallow to deep environments and vice versa (Figure 3), and have been monitored for a period of two years. Symbiont communities before initiation of the experiment were significantly different

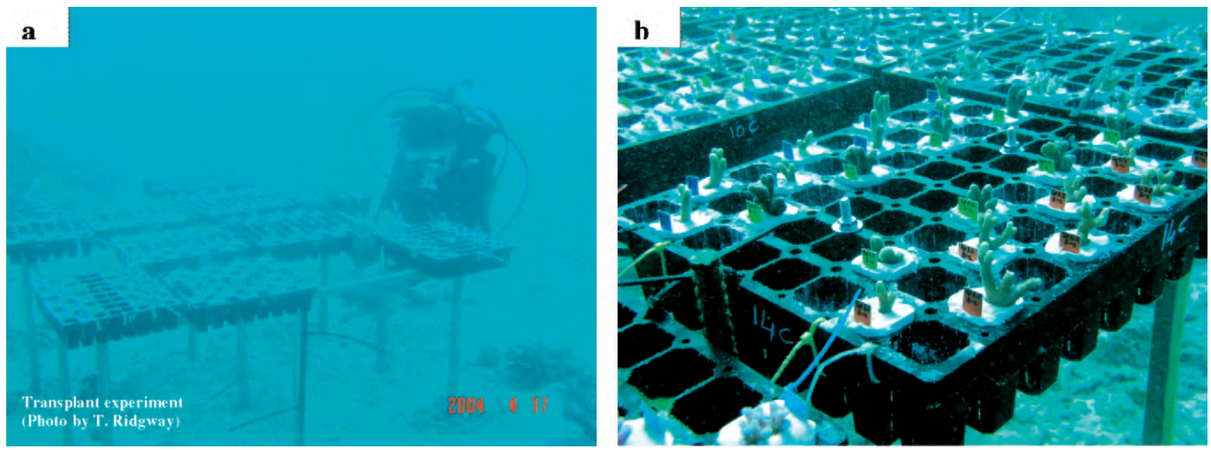


Figure 3. Transplant experiment with (a) seedling trays attached to a metal frame and (b) coral fragments securely attached with underwater cement.

between depths (as in figure 2) and light levels in the deep are generally 8-10% of that in the shallow.

Preliminary results indicate that even though 'shallow' symbionts are generally not found in deep reef zones (and vice versa), adult colonies did not change their symbiont compositions over a period of two years. Small scale fluctuations were observed shortly after transplantation but each individual colony retained its original symbiont, regardless of the fact that this symbiont appeared to be sub-optimal to the new environment. Transplants are still in the field for continued collections and the effect of symbiont type on growth, bleaching sensitivity and tissue thickness are still to be analyzed.

Conclusions

To date most studies have focused on biogeography and phylogeny within the genus *Symbiodinium* [7,8,9,11,12]. From these, some ecological relevance can be inferred about the function of particular symbiont types, but without a thorough understanding of the level of flexibility in the coral symbiosis, we cannot accurately predict how corals will react to certain stressors and levels thereof. Here, it was demonstrated that each host studied from the family Pocilloporidae have multiple options in their symbiotic partnership and that these are optimized to local environmental conditions. This suggests that corals may have the potential to optimize their performance to a wider environmental range than previously thought. However, transplantation experiments for these species showed that associations are fixed and new combinations of host-symbionts may not easily be established for adult colonies. Alternatively, novel combinations of host and symbiont may be formed in early life stages or arise from rare associations within the population, each of which have not been studied but may result in a symbiosis with different tolerance limits. The conclusions from this study must therefore remain limited to the species studied, and other species of corals may not be able to associate with multiple symbionts. Some species associate with a multitude of symbionts suited to cover particular environments over the full range of their distribution, whereas other species may associate with a single symbiont that has a wider tolerance range. There are many possibilities, all influenced by a huge variety of both external and internal factors, and this indicates the importance to study these associations in depth so we can more accurately understand the intricacies involved in the persistence of a successful symbiosis.

As coral reefs are critically endangered by both local and global factors, it is imperative that management shifts in response to focus on ecosystem and global processes rather than individual species[10]. Management should therefore not only focus on sustainable use of coral resources, but also the protection of areas that are important for the persistence and recovery of damaged zones. This study aims to develop an understanding of the level of flexibility in the coral symbiosis, and the finding of multiple options in the symbiotic partnership suggests that corals may have the potential to optimize their performance to a wider environmental range than previously thought. A greater understanding of the symbiotic options, coupled with large scale monitoring efforts, reef connectivity, and assessment of larval competence will enable management programs to evaluate which regions are most valuable in terms of sustaining reef health and the capacity to act a sources of resistant recruits to recolonize damaged zones. These strategies will become increasingly important to model and manage the resilience of coral reefs as we move into a period of rapidly changing climatic conditions.

Acknowledgements

This project has been jointly funded by the ISRS, PADI foundation, Project Aware to Eugenia Sampayo and Australian Research Grants to Ove Hoegh-Guldberg.

References

[1]Hoegh-Guldberg, O (1999). *Mar. Freshw. Res. 50: 839-866.*

[2]Marshall, PA and Baird, AH (2000). *Coral Reefs 19; 155-163.*

[3]Baker, AC (2003). *Annu. Rev. Ecol. Evol. Syst. 34: 661–668.*

[4]Iglesias-Prieto, R and Trench, RK (1997a). *Proc. 8th Int. Coral Reef Sym. 2: 1319-1324.*

[5]Iglesias-Prieto, R and Trench, RK (1997b). *Mar. Biol. 130: 23-33.*

[6]Edmunds, PJ (1994). *Mar. Biol. 121: 137-142.*

[7]LaJeunesse, TC (2002). *Mar. Biol. 141: 387-400.*

[8]LaJeunesse, TC (2001). *J. Phycol. 37: 866-880.*

[9]Baker AC, Rowan R, Knowlton N (1997). *Proc. Int. Coral Reef Symp*., *8th*, *Panama, 2:1295–300.*

[10]Rowan, R and Powers, DA (1991). *Mar. Ecol. Prog. Ser. 71: 65-73.*

[11]Rodriguez-Lanetty, M, Hoegh-Guldberg, O (2003). *Mar. Biol. 143: 501–509.*

[12]Loh WKW, Loi T, Carter D, Hoegh-Guldberg O (2001). *Mar. Ecol. Prog. Ser. 222:97–107.*

An Interdisciplinary Appraisal of Community-based Marine Resource Management of a Traditional Fijian Fishing Ground (*qoliqoli*)

Annette Mühlig-Hofmann
PhD candidate
March 2006

Attempts have been made to comprehensively highlight successes and failures of community-based marine resource management (CBMRM), but with little rigorous assessment of what the conditions of long-term success are. Fiji represents a unique case because its customary fishing-rights areas (*qoliqoli*) constitute a form of dual ownership, establishing a theoretical connection between indigenous owners and central government for management purposes, often facilitated by local non-governmental organizations (NGOs). However, this so-called cooperative co-management approach has not been uniform across Fiji; different levels of government, NGO and community involvement are present, creating a source of confusion and disputes. One issue of a revision of the present constitution is whether indigenous *qoliqoli* ownership should include both the marine resources and the seafloor, the latter being currently owned by the state.

To predict what consequences a planned devolution of full *qoliqoli* ownership and thus management rights to local authorities might have on the communities and their *qoliqoli*, this study took a critical look at customary tenure and CBMRM initiatives, perceptions of them by the people primarily concerned, the forces driving their evolution and their impact on marine resource use.

Besides fishing logbooks, the usefulness of basic social scientific methods (incl. semi-directed interviews, focus groups, life history interviews and participant and non-participant observation) was tested for a specific community setting and assessed for a more integrated and interdisciplinary approach to CBMRM. Research was conducted mainly in four communities sharing the same *qoliqoli* on Gau, an undeveloped and un-investigated offshore island in the Lomaiviti Group of Islands, around 80 km's east of the capital Suva.

This interdisciplinary approach proved especially valuable as each method disclosed different information and perceptions crucial for CBMRM to work in the long run. An inclusion of participant and non-participant observation into CBMRM research in the region is suggested.

In addition to the methodological approach, this research provided useful detailed insights into a case-study community setting with specific management needs and circumstances. It underlined that the country never had a formal co-management arrangement with uniform national guidelines. The present decentralized responsibility in Fiji in terms of coastal marine resource management cannot (yet?) be classified as co-management. Rather, it is a parallel arrangement between government and rural communities, the latter carrying the biggest responsibility for their resources. The government relies on the local governance and self-regulation skills of the coastal fishing communities, mainly due to lack of funds and personnel capacity; their struggles and challenges would otherwise be much greater.

However, the communities cannot from their present structure and skills deal with the increasing pressure on their resources by themselves. Knowledge of the different possibilities, practices and sustainable management regulations remain scarce. Resource owners, like government officials, often still do not have the means to quantify the impacts and pressures on the fishery. Hence, they require (and ask for) input from outside agencies in the form of biological, environmental and conservation education, as well as help in planning, monitoring, evaluation and enforcement.

Management measures have been implemented on Gau (e.g., tabu areas), and perceptions of people towards them were generally positive. However, the *qoliqoli* and the resources within remain under heavy usage, and it is unclear whether the present management efforts will have a sustainable effect towards conservation and restoration of reefs and the related fishery. More knowledge on the local resources is needed; the fishing logbooks should be one way to provide this. Improving local biological surveying in quality and quantity would improve monitoring data. CBMRM structures still remain too fragile at this point, depending wholly on very few people involved, and varying strongly between communities and islands. For more sustainability and success, the management efforts have to reach deeper into the community. CBMR managers and researchers have to look more to the everyday life of people. Focusing on a specifically developed research methodology (e.g., including various social groups); specific environmental conditions (e.g., deforestation activities; social and natural history of the island); specific combinations and characteristics of people involved (e.g., community structures and hierarchies), and on their specific perceptions.

This study thus also emphasizes the importance of social interaction and information exchange between official agents and local communities for CBMRM. For many factors crucial for a CBMRM and conservation regime to be successful, improved transport and communication are the keys. These factors include the need to:

- discover and explore ways for input from outside agencies in the form of biological, environmental and conservation education as well as help in planning, monitoring, evalua-

tion and enforcement (such as 'local marine advisers');
- find ways to (re-)establish and maintain a strong bond between communities and official agents, based on continuity, community consensus and trust;
- improve ways to monitor projects, grant their continuity and make marine conservation and education matters of everyday life for the communities;
- find ways to sustainably improve the connections between communities of the same islands, amongst islands and between urban and rural areas.

Whether devolution will come sooner or later – connections to the main island Viti Levu and the capital Suva with its organizations and institutions will have to be improved first. The communities generally need and want a closer collaboration with these official counterparts – and the planned return of ownership has to be used for good co-management and not only to release pressure from already overwhelmed government departments. Only then, under such an improved system, a decentralization of owning rights would be recommendable, as the possible benefits could be fully put into use. Above all, the island communities would be closer linked to their government, ministries and NGOs, and thus have better chances to have access to the much-needed sources of information.

Consequently, to estimate the magnitude of effects of the proposed devolution of owning rights (and thus responsibility) it will be crucial to rigorously define the conditions, regulations, rights and responsibilities that will be attached to the full *qoliqoli* ownership, and decide whether legal protection (such as that existing for the native lands) is a realistic aim for Fiji's coastal marine areas. Fiji will have to think very carefully about a return of full qoliqoli ownership under the new constitution in order not to end up in a situation where the government and other institutions use the situation as an excuse for not providing any more extension work, help or assistance to the 'independent' rural island communities. Hence, how high the risks following a devolution will be for the marine resources, the subsistence lifestyles and the livelihood of the people concerned, will depend on these conditions and regulations. Under the present situation, a nationwide devolution of ownership would therefore not be recommendable - not without any established and continuous strong correspondence between government and NGO officials, and the (especially rural island) communities.

In conclusion, it can be said that for a complex, de-centralised, multi-stakeholder management system to work, such as that planned in Fiji, the communities perceptions are of increasing importance. A more holistic ecosystem-based approach to CBMRM in Fiji becomes vital, including an increased focus on core individuals, their respective influence (e.g., community leaders), knowledge and character. Long-term research and assistance, based in the communities, is recommended to detect the specific concerns and integrate them into the CBMRM process. More information for decision-making and more support for empowering the communities in terms of ecological understanding and enforcement of measures are required – and wanted by the communities – for strengthening the present local management regime. Only if these could be guaranteed while handing back the full owning rights to the traditional authorities under a new constitution, could a real step forward towards CBMRM be taken. Without organising these forces, however, Fiji will not be able to maintain its natural marine resources.

At this point, I am approaching the completion of my degree for PhD at the University of Newcastle upon Tyne (UK). The ISRS/TOC Fellowship was the principal source of funding for the field research period of the thesis. The award, which I received in spring 2003, has thus played a key role in my research course and career. When I applied for the ISRS/TOC award, I had already started the degree, but so far had only secured funding for my living costs for two years (which later got extended by a third year) by a German foundation. The funds for doing any field research were hence very limited. The news on the positive decision of ISRS/TOC on my application were therefore the true beginning of my PhD; with this secured, a longer period of field work in Fiji in the South Pacific could be planned, essential for the objectives of my thesis.

Being in this way able to conduct my fieldwork in Fiji, I collected data in local island communities, mainly on the offshore island of Gau in the East of the Republic. From April 2003 to November 2004, I spent 18 months in Fiji, based in Suva at the University of the South Pacific, from where the trips to Gau were planned.

The support from ISRS/TOC (US$ 8,600) covered the largest part of this fieldwork. This included one international return flight from England, my research permit application fee for two years, two Fijian language classes in Suva, all inter-island flights and boat travels between the villages and islands visited for my study, lodging in the communities, and the interpreters' salary. In addition, the necessary tools for the preparation and conduct of my research could be provided for, encompassing printing, copying and laminating, buying maps and a voice recorder (for interviews). This support has been invaluable – without it, the thesis could not have been completed. I therefore feel honoured to have received this award and am tremendously grateful for this opportunity. After finishing my PhD, I hope to continue working in the interdisciplinary field of protection, conservation and management of living coastal marine resources, for the environment and the people using and/or depending on them.

Allowing macroalgae growth forms to emerge: use of an agent-based model to understand the growth and spread of macroalgae in Florida coral reefs

Aletta T. Yñiguez
National Center for Coral Reef Research (NCORE)/ Marine Biology and Fisheries
Rosenstiel School of Marine and Atmospheric Science
University of Miami

Introduction

Macroalgae are important yet largely overlooked components of the coral reef ecosystem. They play their own roles in coral reefs, ranging from providing the base in the trophic food chain, to giving settlement cues to coral larvae, and even helping cement the reef framework. Currently, the increasing abundance of fleshy macroalgae on reefs has been a cause of much concern. This has been termed a "phase-shift" wherein coral abundance has declined and given way to macroalgae. This can have large impacts on ecosystem health and function as well as the socio-economics of coral reefs. However, there is surprisingly little known about the basic population and community biology of these coral reef macroalgae. Yet such information is important in understanding the mechanisms of their spread on coral reefs. To investigate these mechanisms, it is potentially instructive to borrow a page from macroalgal invasive species studies and focus on how these indigenous macroalgae grow and occupy space explicitly on the reef and the factors affecting these processes.

Morphological plasticity and the use of space

Space to grow, live and feed is of primary importance to organisms, and for sessile species such as macroalgae and many benthic invertebrates in reefs, this is especially true. From our perspective, quantifying and potentially forecasting the amount of space taken up by certain organisms is important. However, instead of just asking *how much* space is occupied by which organisms, we can also ask *how* is space occupied by these organisms? Getting at the *how* allows us to explore structural properties that can have consequences for biotic and abiotic interactions and provides the potential for distinguishing characteristics of the organism that can help forecast its space utilization, and then scale up to the spatio-temporal distribution of how much it can occupy.

Investigating *how* macroalgae occupy space is relevant because of a key characteristic that most of them (and many reef benthos) possess: morphological plasticity. A large number of macroalgae exhibit non-deterministic phenotypically plastic growth that enable them to have different morphologies under different conditions. Knowledge on the variety of forms macroalgae have under varying conditions, can give us information about the environment they are experiencing, the potential effect on other organisms and environment itself, as well as a trajectory of growth.

The clonality and plasticity of growth in many macroalgae and plants have important implications for their ability to occupy and spread along the substrate. Lovett-Doust[1] coined the terms "guerilla" and "phalanx" growth strategies to describe the two extremes in the continuum of clonal plant growth and space exploration. Species with a guerilla growth form as the name implies, have widely spaced and scattered ramets. On the other hand, the ramets of phalanx species grow closely together and advance through space like a front. There exists a rich literature on the relation of plant/invertebrate clonal morphology and growth with respect to their ecology and evolution[2, 3]. However, apart from a few studies[4, 5] this approach has not been adapted in the marine realm.

This project used a combined modeling and experimental approach in order to investigate the three-dimensional growth of dominant macroalgae in the Florida Reef Tract. Through my model **SPREAD** (***SP***atially-explicit ***RE***ef ***A***lgae ***D***ynamics), the influence of light, temperature, nutrients and disturbance on how macroalgae grow and occupy space are being investigated, while preserving their key characteristics of clonality and morphological plasticity and allowing their growth patterns to emerge. The growth and morphology of these macroalgae can give important insights into the environmental conditions affecting them if we know more about their responses, as well as allow us to forecast potential space occupation patterns[6, 7].

The Model: SPREAD

Conceptual framework: capturing the biology of macroalgae

SPREAD is intended to understand the link between the growth and plasticity of macroalgae to their spatio-temporal dynamics. This means that the model needed to capture the main factors affecting how macroalgae grow and die in response to relevant environmental factors. Figure 1 shows a simple conceptual diagram of the model. The main features of this model are 1) forcing functions composed of light, temperature, nutrients, space and the "internal state" of the algae modules; 2)the algae modules responding to, or based upon these functions, and building up an "individual" algae; and, 3) the interactions of these modules through resource competition for light and space. In keeping with their mod-

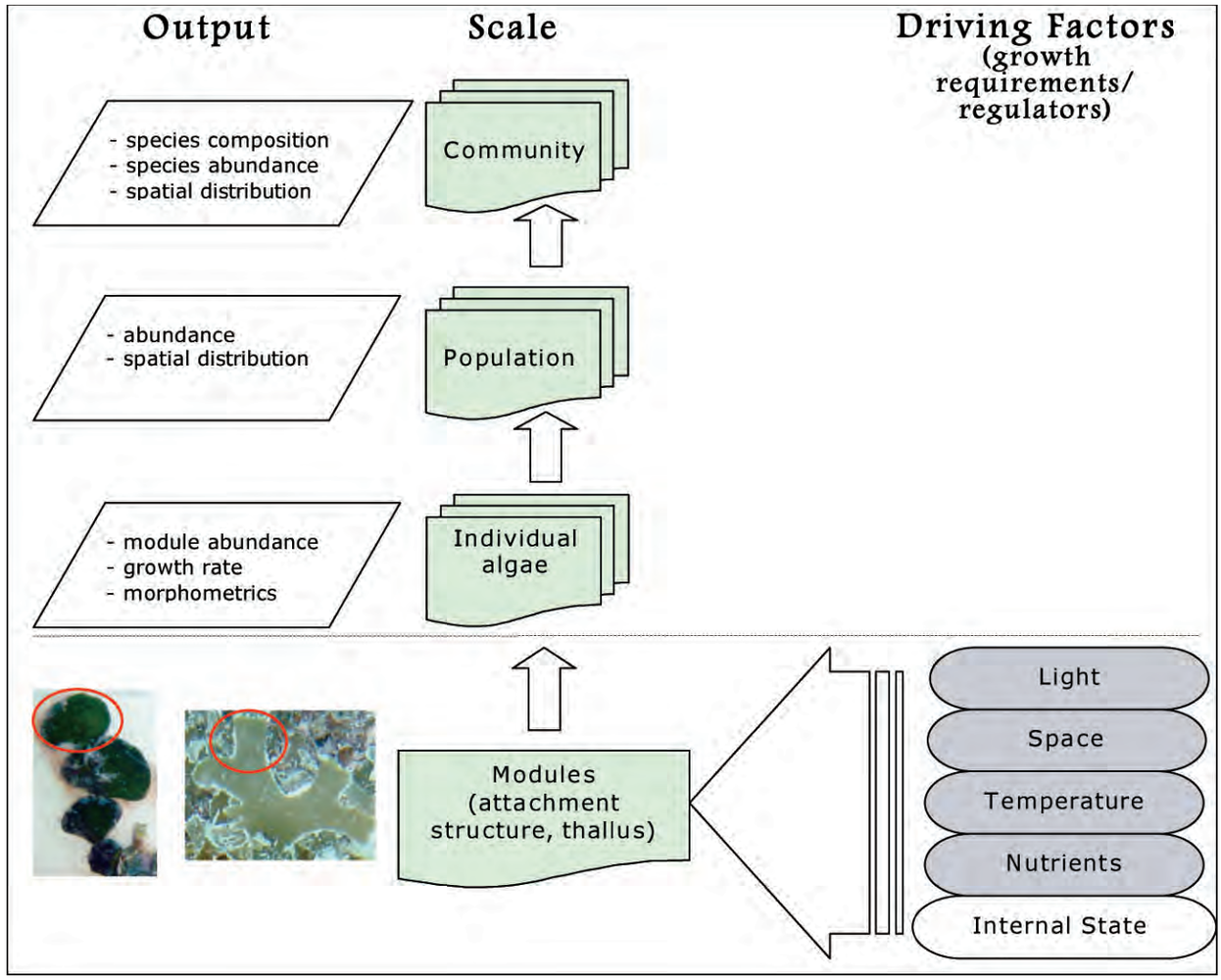


Figure 1. Conceptual diagram of the agent-based model for reef macroalgae dynamics. Pictures of *Halimeda tuna* and *Dictyota menstrualis* illustrate their respective thallus module.

ular and clonal characteristics, and the questions being addressed in this study, it was important to model at the level of the algae modules. From these local interactions, the population and community level properties will emerge which allows us to explore the mechanisms involved in forming these patterns.

Model species

Species belonging to the genera *Halimeda* and *Dictyota* are two of the dominant macroalgae found in the Florida Reef Tract[8, 9] as well as many reefs around the Caribbean. They can represent 77-99% of the macroalgal biomass in the Northern Florida Reef Tract[9].

The body of these two genera is composed of two primary structures: a rhizoidal cluster, or attachment structure, and the thallus. Both also exhibit modular and clonal growth. Their rhizoids and thalli grow through the iteration of fundamental units hence their modularity. The iterating units of the thalli are the calcified segments for *Halimeda* and linear segments for *Dictyota*. *Halimeda tuna* and *Halimeda opuntia*, two commonly found species in the Florida Reef Tract, both grow on hard substrate. *Dictyota* spp. can use pavement, coarse sand and other living organisms (epiphytism) as substrate. The morphological plasticity in these *Halimeda* and *Dictyota* species lean towards the more subtle end of the spectrum rather than dramatic differences in form. The most plastic of these species is *Halimeda opuntia* which has two recognized forms. One form is composed of oval segments that grow into a highly compact shape. The second form (*f. triloba*) has trilobed segments and longer inter-segment distances which result in loose clumps. *Dictyota* spp. can grow both in an upright and prostrate manner with growth forms ranging from upright compact to horizontal sparse ones. These *Halimeda* and *Dictyota* species also produce fragments which survive and reattach to produce ramets (potentially indepen-

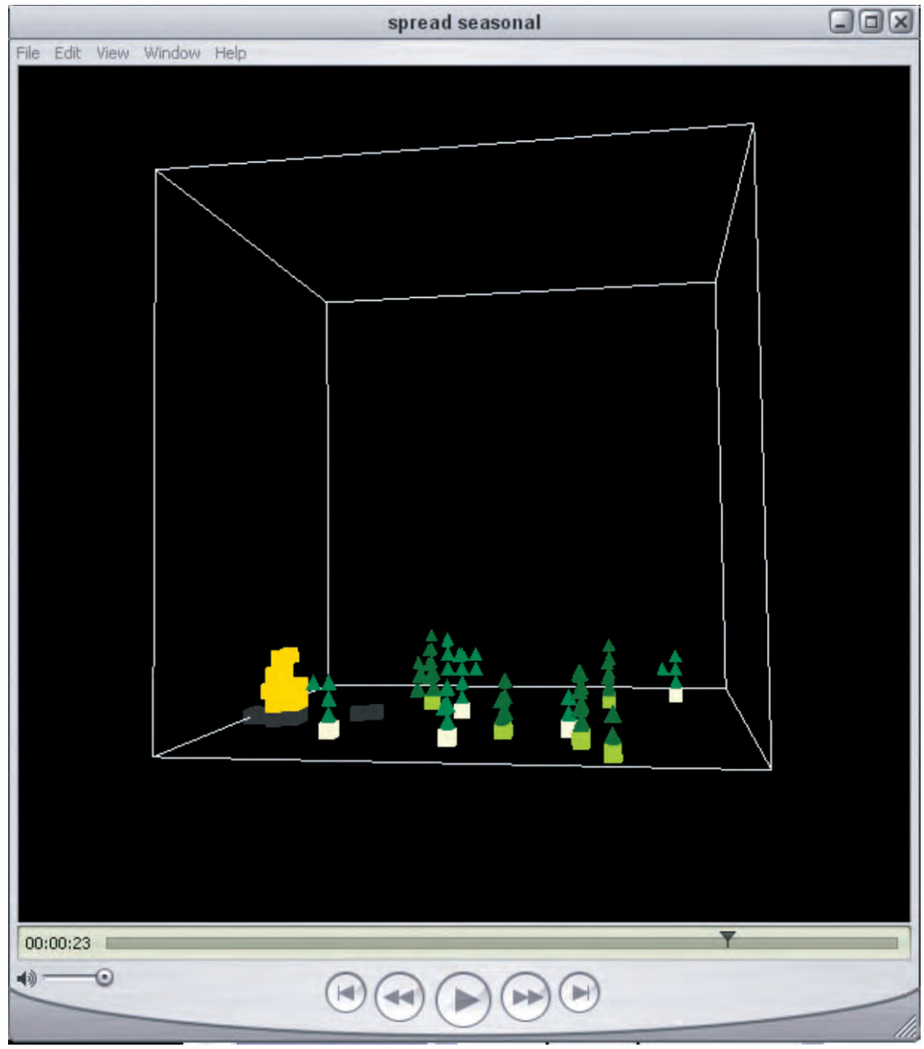


Figure 2. Visual output of SPREAD showing representations of *Halimeda tuna* (Base: Thallus:), *Halimeda opuntia* (Base: Thallus:), *Dictyota* sp. (Base: Thallus:) growing in a 3D grid.

dent units). This clonality is an important part of their life histories, allowing them to persist and disperse.

Model Implementation

Software platform

The model was implemented using the object-oriented programming language Java. Rather than starting from scratch, I extended Mason (http://cs.gmu.edu/~eclab/projects/mason/), a discrete-event multiagent simulation library core developed by the Evolutionary Computation Laboratory and Center for Social Complexity at George Mason University. Java and Mason allowed for easy translation of concepts into a 3-dimensional grid agent-based model.

Space

The stage upon where the algal modules interact was modeled as a three-dimensional grid space (Figure 2). The bottom of this space represents the reef substrate and the length and width of one cell is equivalent to one centimeter.

Factors and processes

The light regime was modeled using the Lambert-Beer equation $I_{depth} = I_0 e^{-k(depth)}$ (I_{depth} = irradiance at depth, I_0 = surface irradiance, k = attenuation coefficient) wherein cells at the same level (equivalent to depth) experience the same light values expressed as Photosynthetically Active Radiation (PAR). Light data from field sampling and the SEAKEYS program (http://www.keysmarinelab.org/seakeys.htm) were used. An algal module can shade another below it based on the species' transparency coefficient.

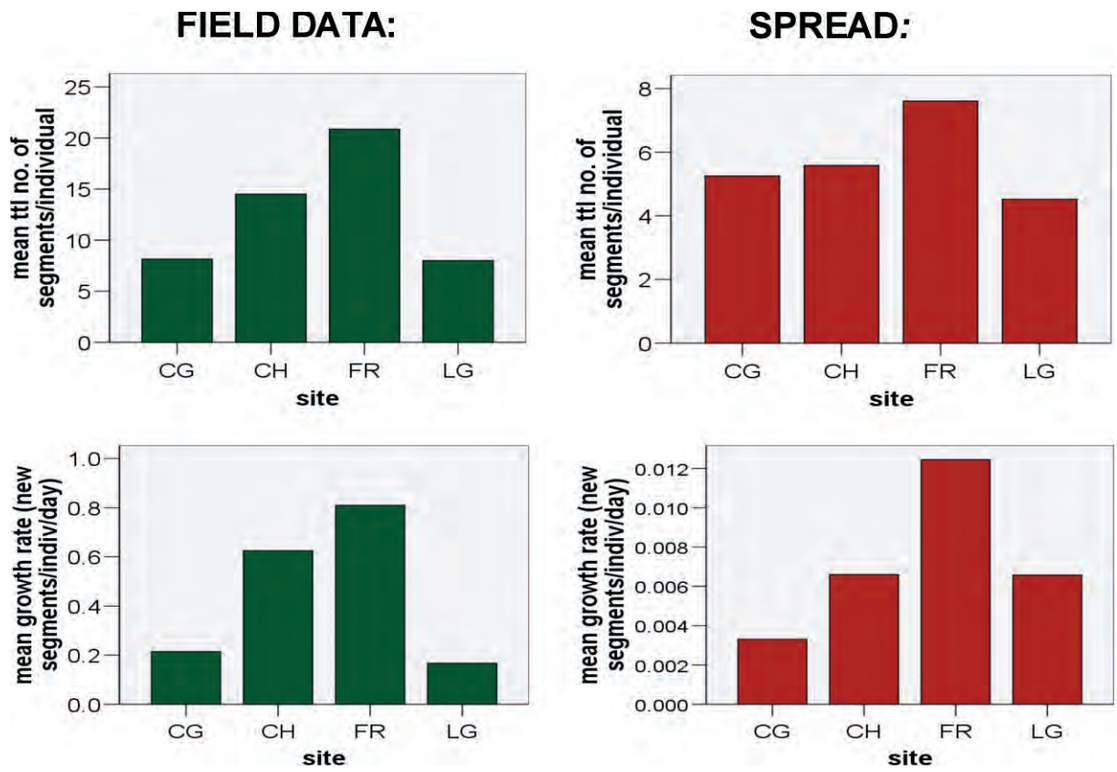


Figure 3. Mean total number of segments per *Halimeda tuna* individual and mean new segments per individual per day (growth rate) at the four study sites where the two graphs on the left are from the summer 2005 field sampling and the two graphs on the right are data from the model SPREAD. CG: Coral Gardens, CH: Cheeca, FR: French Reef, LG: Little Grecian.

The temperature is equal at all depths and cells in the modeled space and only varies with season (temporally). Temperature data came from my own field sampling and the Florida International University's Southeast Environmental Research Center (http://serc.fiu.edu/wqmnetwork/).

The nutrient regime is only coarsely represented as low, ambient and enriched. This is again equal at all depths and cells in the modeled space and can be varied temporally.

The growth of each algal module is a central process that is iterated at each time step of the model. This is governed by the probability of the module producing another module and is dependent on availability of a cell to grow into the light, temperature and nutrient conditions of the cells surrounding it:

$$P(\text{growth}) = P(\text{growth}_{light}) \times P(\text{growth}_{temperature}) \times P(\text{growth}_{nutrients})$$

Mortality of the modules can occur as fragments wherein a number of modules are removed from the individual algae, or as the whole individual algae.

SPREAD VS. Reality

One of the means to test and validate agent-based models such as SPREAD is to compare the emergent patterns from the model to those found in the real world[10]. One of the patterns that I have initially looked at is the growth of *Halimeda tuna* in four reefs in the Florida Keys during the summer of 2005 and I compared these with the model outcome.

Following the growth of Halimeda tuna

I tagged about 20 individuals of *Halimeda tuna* in each of four sites in the Florida Keys: Cheeca and Coral Gardens (inshore patch reefs), and Little Grecian and French Reef (offshore spur and groove reefs). I followed them for 4-5 weeks using digital photos which I later analyzed for the following growth metrics: total number of segments, new segments, segments lost, epiphyte load, height, width, number of axes, maximum branch order.

The results showed that French and Cheeca tended to have greater number of segments per individual as well as greater segment production rates (termed as growth rate) while Coral Gardens and Little Grecian had lower values.

Comparing field data to model outcome

I ran SPREAD for each site using site-specific depth, light values (surface irradiance and attenuation coefficient) and summer temperatures. Nutrient levels were set at ambient and together with mortality levels were the same in all sites. Surface irradiance and temperature were varied randomly each time step (day) using a normal distribution. Each scenario was allowed to run for 100 days and repeated 20 times. Similar measurements as those from field sampling were obtained.

Comparing the main *Halimeda tuna* morphometrics from SPREAD to the summer 2005 field data showed that they were similar (Figure 3). Little Grecian, a shallow (3.2m) reef experiencing relatively higher light intensities, had the lowest growth rates compared to the other sites while the deepest reef (7m), French (with accompanying lower light intensities), had the highest growth rates and individuals with more segments. The *H. tuna* growth rates and number of segments in the two shallow but turbid patch reefs were in the middle of the two offshore sites. These patch reefs experienced light intensities that were also in between the two offshore sites.

Past studies on *H. tuna* populations at Conch Reef, Florida Keys have hypothesized that light and photo-inhibition[11, 12], and/or nutrients[13] could be driving morphological differences between populations. These initial results from SPREAD indicate that the variation in light regime seemed to be enough to simulate the growth patterns found in these reefs sites. *H. tuna* in the relatively shallow and clear waters of Little Grecian may be experiencing the effects of photo-inhibition while French experiences better light conditions for growth while the inshore patch reefs, though shallow are experiencing intermediate conditions due to turbidity.

Conclusions and Future Work

Using an agent-based model approach enables the capture and emergence of macroalgal growth forms that have important implications in terms of spatial occupation and spread in the coral reef substrate. The model SPREAD allows for the modularity, clonality and morphological plasticity of *Halimeda* and *Dictyota* spp., the dominant macroalgae in the Florida Keys. It revolves around the iteration of macroalgal module production in response to light, temperature, nutrients, and space availability, and this process builds the individual algae, then the population, in a patch of reef substrate.

Preliminary results from the model show that SPREAD can closely reproduce growth patterns of *Halimeda tuna* in Florida reefs. Initial explorations also illustrate its use in potentially teasing out mechanisms and factors responsible for the growth patterns observed. Further simulations will be run and compared to more field data to investigate the relative effects of combinations of factors, the dynamics of the two other macroalgae (*Halimeda opuntia* and *Dictyota* sp.), and the translation of individual growth to horizontal spread.

Acknowledgments

Funding for this study came from NCORE-EPA, ISRS/OC Fellowship, and Project Aware. Fulbright-Philippines DA and UM Maytag Fellowship provided my finances to pursue my Ph.D.

References

[1]Lovett Doust, L. 1981. Population dynamics and local specialization in a clonal perennial (*Ranunculus repens*): I. the dynamics of ramets in contrasting habitats. The Journal of Ecology 69:743-755.

[2]Cook, R.E. 1985. Growth and development in clonal plant populations. *In:* Jackson, J.B.C., L.W. Buss and R.E. Cook (eds) Population Biology and Evolution of Clonal Organisms, New Haven, Yale University Press, pp. 259-296.

[3]Jackson, J. B. C., and A. G. Coates. 1986. Life cycles and evolution of clonal (modular) animals. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 313:7-22.

[4]Collado-Vides, L., G. Gómez-Alcaraz, G. Rivas-Lechuga and V. Gómez-Gutierrez. 1997. Simulation of the clonal growth of *Bostrychia radicans* (Ceramiales-Rhodophyta) using Lindenmayer systems. BioSystems 42:19-27.

[5]Collado-Vides, L. 2002. Clonal architecture in marine macroalgae: ecological and evolutionary perspectives. Evolutionary Ecology 15: 531-545.

[6]Cain, M. L., S. W. Pacala, J. A. Silander Jr., and M.-J. Fortin. 1995. Neighborhood models of clonal growth in the white clover *Trifolium repens*. The American Naturalist 145:888-917.

[7]Sintes, T., N. Marba, C. M. Duarte, and G. A. Kendrick. 2005. Nonlinear processes in seagrass colonisation explained by simple clonal growth rules. Oikos 108:165-175.

[8]Chiappone, M. and K.M. Sullivan. 1997. Rapid assessment of reefs in the Florida Keys: results from a synoptic survey. Proceedings of the 8th International Coral Reef Symposium 2: 1509-1514.

[9]Lirman, D. and P. Biber. 2000. Seasonal dynamics of macroalgal communities of the Northern Florida Reef Tract. Botanica Marina 43:305-314.

[10]Grimm, V., and S. F. Railsback. 2005. Individual-based Modeling and Ecology. Princeton University Press, New Jersey, 480 pp.

[11]Vroom, P. S., C. M. Smith, J. A. Coyer, L. J. Walters, C. L. Hunter, and K. S. Beach. 2003. Field biology of *Halimeda tuna* (Bryopsidales, Chlorophyta) across a depth gradient: comparative growth, survivorship, recruitment, and reproduction. Hydrobiologia 501: 149.

[12]Beach, K., L. Walters, P. Vroom, C. Smith, J. Coyer, and C. Hunter. 2003. Variability in the ecophysiology of *Halimeda* spp. (Chlorophyta, Bryopsidales) on Conch Reef, Florida Keys, USA. Journal of Phycology 39:633-643.

[13]Smith, J.E., C.M. Smith, P.S. Vroom, K.L. Beach and S. Miller. 2004. Nutrient and growth dynamics of *Halimeda tuna* on Conch Reef, Florida Keys: Possible influence of internal tides on nutrient status and physiology. Limnol. Oceanogr. 49(6): 1923-1936.

Symbiont stability following a coral bleaching event

Michael Stat

I received the student ISRS/Ocean Conservancy graduate fellowship in 2003. These funds were used to purchase molecular supplies for my research. The experiments that I performed required the use of expensive (molecular biology) resources that allowed me to complete my research investigating whether changes in the population of the coral endosymbiont, *Symbiodinium*, occurs in coral following a bleaching event. This question has direct relevance to the adaptive potential of coral in light of current and future changes in climate.

Coral endosymbionts are unicellular photosynthetic dinoflagellates that belong to the genus *Symbiodinium.* There are eight (A-H) divergent evolutionary lineages within the genus each of which contains multiple sub-clade genetic varieties.[1] The mutualistic symbiosis between coral and *Symbiodinium* is what enables the growth and formation of coral reefs.[2] A loss of the endosymbionts and/or their pigment results in a whitening of the coral colony, described as coral bleaching.[3] Coral bleaching can lead to reduced growth rate of the animal host and mortality. However, this biological trait may also present an opportunity for the coral hosts to change their complement of endosymbionts to ones more suited to the environmental condition that caused bleaching to occur.[4] This process of "adaptation" may occur by shifts in the abundance of existing endosymbionts, or the expulsion of existing types and acquisition of new ones from the ocean environment. Shifts in the abundance of coral symbionts due to seasonal variation and ontogeny of the coral host has been shown.[5,6] However, there are also several studies that have shown that the symbiotic interaction between anthozoans and *Symbiodinium* is stable.[7,8]

Table 1. Coral species, number of colonies sampled, and the number of observed colonies to have bleached.

Coral species	Number of colonies	Number of bleached colonies
Pocillopora	12	2
Porites cylindrica	16	
Montipora digitata	6	
Seriatopora hystrix	14	4
Stylophora pistillata	16	4
Lobophyllia corymbosa	13	
Favites abdita	16	2
Goniastrea favulus	15	3
Acropora millepora	13	5
Acropora palifera	15	2

To determine whether the symbiont population in coral changes following a bleaching event, colonies representing ten species were monitored before and after the coral bleaching event in 2002 in the Great Barrier Reef. Samples were taken from the same colonies during July 2001, January 2002 and August 2002. The coral species, number of colonies monitored, and those that had been observed to have bleached are presented in Table 1. To monitor whether changes in the population of *Symbiodinium* in each colony occurred, single strand conformational polymorphism (SSCP) was used to visualize the endosymbiont "fingerprint" at each time point based on the large subunit rDNA.

None of the populations of *Symbiodinium* in the corals monitored changed following the bleaching event in 2002. This points to a stable relationship between coral hosts and their symbiotic dinoflagellates over time and lends support to other studies that demonstrate a stable coral-symbiont relationship.

References

[1]Stat M, Carter D, Hoegh-Guldberg O (2006) The evolutionary history of *Symbiodinium* and scleractinian hosts - Symbiosis, diversity, and the effect of climate change. Perspectives in Plant Ecology, Evolution and Systematics 8:23-43.

[2]Muscatine L, Porter J (1977) Reef corals: Mutualistic symbioses adapted to nutrient-poor environments. Bioscience 27:454-460.

[3]Hoegh-Guldberg O, Smith G (1989) The effect of sudden changes in temperature, light and salinity on the population density and export of zooxanthellae from the reef corals *Stylophora pistillata* Esper and *Seriatopora hystrix* Dana. Journal of Experimental Marine Biology and Ecology 129:279-303.

[4]Buddemeier R, Fautin D (1993) Coral bleaching as an adaptive mechanism. Bioscience 43:320-325.

[5]Chen C, Wang J-T, Fang L-S, Yang Y-W (2005) Fluctuating algal symbiont communities in *Acropora palifera* (Scleractinia: Acroporidae) from Taiwan. Marine Ecology Progress Series 295:113-121.

[6]Little A, van Oppen M, Willis B (2004) Flexibility in algal endosymbionts shapes growth in reef corals. Science 304:1492-1494.

[7]Goulet T, Coffroth M (2003) Stability of an octocoral-algal symbiosis over time and space. Marine Ecology Progress Series 250:117-124.

[8]Rodriguez-Lanetty M, Chang S-J, Song J-I (2003) Specificity of two temperate dinoflagellate-anthozoan associations from the north-western Pacific Ocean. Marine Biology 143:1193-1199.

Partially protected marine reserves appear to support greater fish diversity

The literature assessing the effect of marine reserves has concentrated on No-Take Areas (NTAs), where all resource extraction is banned. However, marine reserves that allow some resource extraction are becoming common. I refer to this type of marine reserve as a Partially Protected Area (PPA), because it clearly defines their restrictions in comparison to No-Take Areas, but allows for a wide range of methods for managing resource extraction. PPAs can regulate gears (e.g. by banning destructive gears) and/or reduce fishing effort (by allowing access only to certain user groups or only at specific times).

In Tanzania, E. Africa, PPAs are the dominant form of marine reserve. All reserves designated before 1995 are under IUCN category II, which exclude exploitation. However all those designated since 1995 are under IUCN category VI (Managed Resource Protected Area; http://www.mpaglobal.org). The recent proliferation of PPAs in Tanzania has been prompted by the trend for community-based management, the failure of seven NTAs gazetted there in 1975[1] and historical and political factors.[2]

During my first field season in Zanzibar, Tanzania, I recognized this trend and wanted to assess whether PPAs had the ability to deliver conservation and fisheries benefits, particularly important because there had been little work assessing their impact. In 2003, I received a ISRS/TOC fellowship grant to assess the effect of a PPA on coral reef fish communities. I assessed the impacts of a PPA on the total density, biomass, mean length and species richness of commercially important fish and the total density, biomass and mean length of different fish trophic groups.

Menai Bay Conservation Area (MBCA) is one of six PPAs in Tanza-

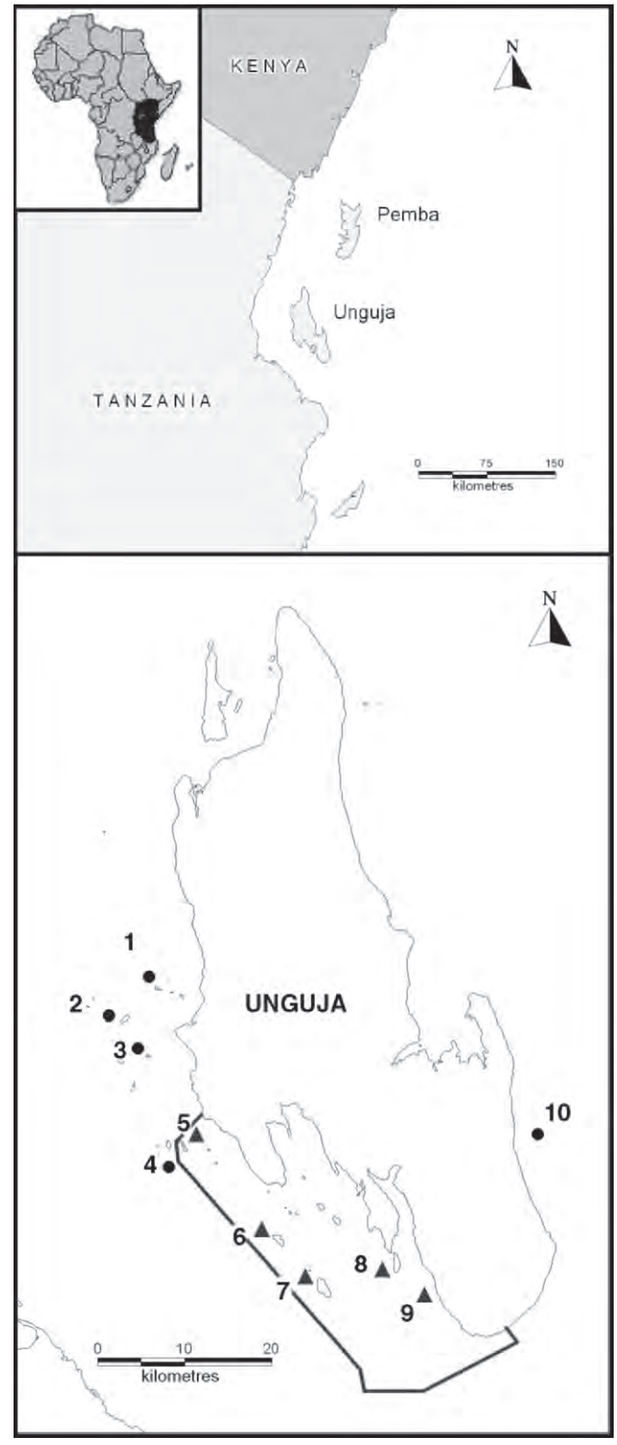


Figure 1. Map showing the location of Unguja Island, Zanzibar, Tanzania (East Africa), the location of the 10 reefs surveyed and Menai Bay Conservation Area. Partially protected reefs are triangles and unprotected reefs are circles. Line indicates boundary of Menai Bay Conservation Area. Reefs: 1, Changuu; 2, Bawe; 3, Pange; 4, Chawacha; 5, Tele; 6, Kwale; 7, Pungume; 8, Vundwe; 9, Kizimkazi; 10, Paje.

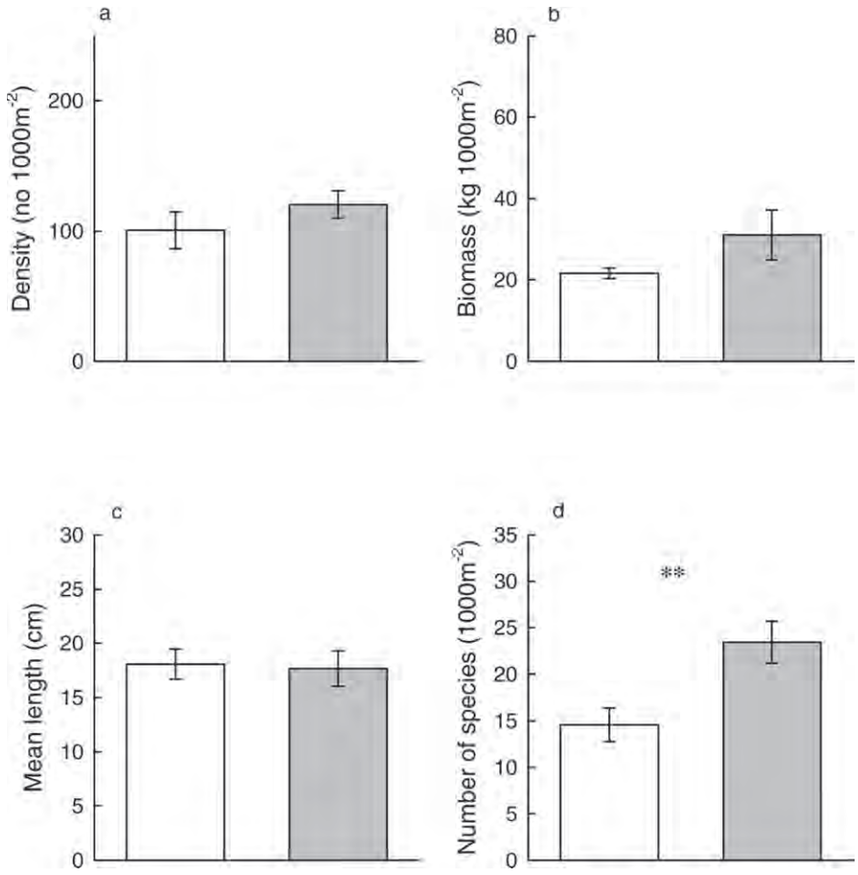


Figure 2. Means and standard errors of commercial fish (a) density, (b) biomass (c) mean length and (d) species richness, between unprotected (white) and partially protected (grey) reefs (** $P < 0.01$).

nia. It was gazetted in 1997,[3] and covers 470 km^2, comprising the southern end of Unguja island, which lies 35 km from the coast of Tanzania (Fig. 1). It contains no NTAs. Destructive fishing techniques (e.g. beach seines (juya in Kiswahili), dynamite, spear-guns and poisons) are prohibited following Fisheries Principal Regulations, which declared these gears illegal in Zanzibar in 1993.[3] However, due to limited finances and infrastructure, enforcement of these regulations outside managed areas is virtually non-existent (Jiddawi, pers. comm. 2006). Camping by visiting fishermen on islands in the Bay is also seasonally restricted.[3]

I used a study design and method similar to those used by previous studies finding greater commercial fish biomass, density, length and species richness in No-Take Areas.[4,5,6,7,8,9,10] I used standard Underwater Visual Census techniques (100 m x 10 m transects) to measure reef fish communities and habitat at five sites inside and five outside the PPA. Some of these sites were located in relatively remote parts of Zanzibar, and involved staying in small coastal villages and hiring local fishing boats. At each village, we turned up as a sort of travelling circus in a local Zanzibari bus, a 'dala dala', piled with buckets, rope, fuel cans, dive tanks and compressor.

As comparisons of marine reserves with unprotected sites need to be made cautiously, I corrected for the spatial proximity of sites, which would have been likely to influence community composition and the quality of reef habitat, using Mantel's tests. I found no effect of the PPA on the density, biomass or mean size of commercial fish (Fig. 2), or on any of the individual trophic groups. However I did find evidence for 60% greater fish species richness inside MBCA (Fig. 2). This substantial difference was significant even after correcting for spatial proximity and reef habitat.

Although not unequivocal, this is highly suggestive of a management effect. It is likely that a reduction in the use of destructive fishing gears inside the Bay has allowed retention of a greater number of fish species. Previous studies assessing different forms of PPA have only found effects on commercial fish populations, if at all. This has implications for the use of PPAs in conserving biodiversity, particularly in areas where destructive fishing gears are common.

Acknowledgements

I am very grateful to the ISRS and TOC for my fellowship, which paid for a whole field season (nearly five months) for myself and a research assistant, covering our flights, visas, research permits, boat hire, accommodation and subsistence. Thank you to the ISRS and TOC for setting up this fellowship and the donor who supported it. Funding for fieldwork is not often provided by studentships. The ISRS/TOC fellowship represents a critical source of fieldwork funding for Ph.D. students studying coral reefs.

Dr. Elizabeth Tyler
Visiting Researcher, Zoology
Department, Cambridge University
Downing Street,
Cambridge CB1 3EJ
etyler@ouce.ox.ac.uk

References

[1]McClanahan, T.R. (1999) Is there a future for coral reef parks in poor tropical countries? *Coral Reefs*, **18**(4), 321-25.

[2]McClanahan, T., Verheij, E. & Maina, J. (2006) Comparing the management effectiveness of a marine park and a multiple-use collaborative fisheries management area in East Africa. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **16**, 147-65.

[3]Sichone, W.A. (2000). Menai Bay Conservation Area: WWF-UK Annual Project Report. In, p 19. Commission of Natural Resources, Zanzibar, Tanzania.

[4]Jennings, S., Marshall, S.S. & Polunin, N.V.C. (1996) Seychelles' marine protected areas: comparative structure and status of reef fish communities. *Biological Conservation*, **75**, 201-09.

[5]Letourneur, Y. (1996) Influence of establishing marine reserves on fish populations: The case of Mayotte Island (western Indian Ocean). *Ecoscience*, **3**(4), 442-50.

[6]McClanahan, T.R. & Arthur, R. (2001) The effect of marine reserves and habitat on populations of East African coral reef fishes. *Ecological Applications*, **11**(2), 559-69.

[7]McClanahan, T.R., Muthiga, N.A., Kamukuru, A.T., Machano, H. & Kiambo, R.W. (1999) The effects of marine parks and fishing on coral reefs of northern Tanzania. *Biological Conservation*, **89**(2), 161-82.

[8]Roberts, C.M. (1995) Rapid build-up of fish biomass in a Caribbean Marine Reserve. *Conservation Biology*, **9**(4), 815-26.

[9]Wantiez, L., Thollot, P. & Kulbicki, M. (1997) Effects of marine reserves on coral reef fish communities from five islands in New Caledonia. *Coral Reefs*, **16**(4), 215-24.

[10]Watson, M. & Ormond, R.F.G. (1994) Effect of an artisanal fishery on the fish and urchin populations of a Kenyan coral reef. *Marine Ecology Progress Series*, **109**(2-3), 115-29.

DIARY

First Sclerochronology Conference

July 17–21, 2007, Hilton St. Petersburg, St. Petersburg, Florida, USA

Sclerochronology is used to reconstruct records of environmental and climatic change through space and time - it is the study of physical and chemical variations in the accretionary hard tissues of organisms, and the temporal context in which they formed.

Sclerochronology focuses primarily upon growth patterns reflecting annual, monthly, fortnightly, tidal, daily, and sub-daily increments of time entrained by a host of environmental and astronomical pacemakers. Familiar examples include daily banding in reef coral skeletons or annual growth rings in mollusk shells.

This conference is important because sclerochronology is such a multi-disciplinary pursuit, and yet lines of communication amongst researchers in this field are not very well-established so their goal is to promote communication and feature recent advances in sclerochronology.

For more information and registration:
http://conference.ifas.ufl.edu/sclerochronology/index.html

DEADLINE to register at reduced fee for NCER 2007 is Friday, March 31, 2007.

Reef Encounter No. 34, May 2007

Magazine of the International Society for Reef Studies

Editor William F Precht
Associate Editors Martha L Robbart and Beth Zimmer
prechtw@battelle.org

CONTENTS

Reef Encounter is printed on recycled paper by Allen Press Inc., 810 East Tenth, Lawrence, KS 66044, USA.

Cover image: A hawksbill turtle named “Curious George” at Windmill Beach in Guantanamo Bay, Cuba. Photo by Martha Robbart.

COPY DEADLINE FOR REEF ENCOUNTER 35 (due November 2007) is 15 September 2007

The **International Society for Reef Studies** was founded at a meeting in Churchill College, Cambridge, UK in December 1980.

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.

In order to achieve its aim, the Society has the following powers:

i. To hold meetings, symposia, conferences and other gatherings to disseminate this scientific knowledge and understanding of coral reefs, both living and fossil.

ii. To print, publish and sell, lend and distribute any papers, treatise or communications relating to coral reefs, living and fossil, and any Reports of the Proceedings or the Accounts of the Society

iii. To raise funds and invite and receive contributions from any persons whatsoever by way of subscription, donation or otherwise providing that the Society shall not undertake any permanent trading activities in raising funds for its primary objects.

The Society collaborates with Springer-Verlag in producing the quarterly journal Coral Reefs. This large-format journal is issued free of charge to all members of the Society, and concentrates on quantitative and theoretical reef studies, including experimental and laboratory work and modelling.