Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 1

The R/V Alpha Helix Expedition: A retrospective analysis of a milestone in coral reef research

C.F. D'Elia and A.R. Harris

University of South Florida St. Petersburg and USF College of Marine Science, 140 7th Avenue South
St. Petersburg, FL 33701, USA

Abstract. The most comprehensive study of a coral reef undertaken until that time, the *Symbios Expedition*, was conducted in 1971 by an interdisciplinary team of ecologists and oceanographers. The study site was at Enewetak Atoll, Marshall Islands, and the *R/V Alpha Helix* along with shore-based facilities provided laboratory and logistical support. Many coral reef researchers are aware that this team-oriented research program made significant contributions to the understanding of coral reef metabolism and function, but the expedition itself has not been documented formally for historical purposes. Here, to assess *Symbios'* published results, we used *Citespace II*, a public domain that provides information visualization methods, bibliometrics, and data mining algorithms in an interactive visualization tool for extraction of patterns in citation data. We found that *Symbios* research results have had a significant scientific impact. Our review of historical reference materials and extensive interviews suggests some of the reasons for the expedition's success: a good science plan, strong and adaptative leadership that emphasized collaborative research, and excellent logistical support lines.

Key words: coral reef, ecosystem metabolism, nutrients, history of science, citation analysis.

Introduction

In the spring of 1971, an interdisciplinary team of marine researchers gathered at Eniwetok Atoll (now "Enewetak"), Marshall Islands to conduct the most comprehensive study of a coral reef undertaken until that time. This expedition resulted in significant advances in the understanding of coral reef metabolism and ecological function.

The name of the expedition, *Symbios*, was chosen as a metaphorical reference both to the symbiotic relationships that characterize coral reefs and to the symbiotic relationships that the late Dr. Robert E. Johannes, the Chief Scientist and driving force behind the expedition, thought should occur among scientists in ecological research. In retrospect, *Symbios* seems to be a clear demonstration of the importance of a well executed collaborative, interdisciplinary approach to undertaking scientific research. Our review shows that this expedition is now regarded as a significant contributor to our understanding of coral reef metabolism and ecological function.

The idea for the *Symbios* Expedition was developed jointly by Robert E. Johannes and Lawrence R. Pomeroy, who were colleagues of Dr. Eugene P. Odum in the University of Georgia's Institute of Ecology. Odum was a renowned pioneer in the field of ecology who, with his equally regarded brother, Howard T. Odum, conducted a remarkable study of coral reef metabolism at Enewetak in the Marshall Islands (Odum and Odum 1955; see also Barile 2004, who has provided a retrospective analysis of the Odums' study). The Odums' monumental monograph notwithstanding, relatively little was known in the 1960s about community metabolism of coral reefs, and Johannes and Pomeroy saw the value of building on the Odums' work. Their aim was to gather an interdisciplinary team of scientists to assess the community metabolism of an entire atoll. The initial objectives of *Symbios*, as presented in the original grant proposal to the U.S. National Science Foundation (NSF), are summarized in Table 1.

Table 1. Initial *Symbios* Proposal Objectives

1. Monitor changes in [chemical and biological] characteristics of seawater as it moves from the open ocean across the windward reef at site one and from the lagoon across the leeward reef at site two.
2. Conduct biological surveys across both reef transects to establish what species may exert quantitatively significant influences on nutrient and/or energy flux in these communities.
3. Determine the effects of the addition of nitrogen and phosphorus on reef community metabolism.
4. Measure changes in oxygen, nitrogen, and phosphorus levels in water flowing across the reef before and after the removal of the large reef herbivores (and coincidentally, the removal of large amounts of nitrogen and phosphorus).

In 1969, with the advice of Dr. W.J. Wiebe and others, Johannes and Pomeroy began the immense task of planning the expedition. According to the

original proposal, the expedition was to take place at Ant Atoll in the Caroline Islands because Enewetak was deemed too small and ill-equipped for such a large operation. As it turned out, it was logistical difficulties with Ant Atoll that led to the switch to Enewetak Atoll, in what was then the U.S. Trust Territory of the Pacific. Logistical support there was better, partially because of the Eniwetok Marine Biological Laboratory (EMBL), supported by the U.S. Atomic Energy Commission (AEC) and directed by Dr. Philip Helfrich.

The expedition was planned as a two-month-long deployment. The *R/V Alpha Helix* (Fig. 1), an NSF-supported research vessel operated by the Scripps Institute of Oceanography (SIO), would remain docked and be used as a floating. An additional group in a shore party would occupy facilities abandoned after the end of the nuclear weapons testing program a little more than a decade before.

Figure 1: The R/V Alpha Helix at Japtan Island pier, Enewetak Atoll. (Photo courtesy S.B. Betzer).

The arrangement worked very well. The ship served as sleeping and eating quarters for half of the scientific party. The ship's laboratories were modern and adequately equipped. Thanks to the creative expertise of the ship's chief electrician, Merle Post, a cable running from the ship provided power to shore buildings, which were used as additional laboratories, and eating and sleeping quarters for the shore party. Thus, the ship's scientific and logistical capabilities were strongly leveraged for a larger scientific party.

The complex logistics of the operation were supported either with direct funding or logistical support from the NSF, the AEC, the SIO, the Janss Foundation, and others. In interviews, *Symbios* participants point to the ingenuity and diligence of Helfrich, Johannes, Pomeroy, and the ship's crew for ensuring the success of the expedition despite the logistical obstacles presented by gathering a 23-person research team (Table 2) in a remote location to carry out such an enormous task.

Table 2. *Symbios Expedition* Scientific Party

Participant	**Role and Home Institution**
Robert E. Johannes[1]	Expedition PI & Chief Scientist; Professor, University of Georgia
Lawrence R. Pomeroy	Expedition Co-PI; Professor, University of Georgia
William J. Wiebe	Professor, University of Georgia
Robert A. Kinzie, III	Postdoc, University of Georgia
James Alberts	Postdoc, University of Georgia
Christopher F. D'Elia	Graduate Student, University of Georgia
William Sottile[1]	Graduate Student, University of Georgia
Michael E.Q. Pilson	Professor, University of Rhode Island
Nelson Marshall	Professor, University of Rhode Island
Susan B. Betzer	Graduate Student, University of Rhode Island
Gregory Telek[1]	Graduate Student, University of Rhode Island
Philip Helfrich	Professor, University of Hawaii
Stephen V. Smith	Postdoc, University of Hawaii
Judy L. Meyer	Graduate Student, University of Hawaii
James E. Maragos	Graduate Student, University of Hawaii
Kenneth L. Webb	Professor, Virginia Institute of Marine Science
William D. DuPaul	Graduate Student, Virginia Institute of Marine Science
Ariel Roth	Professor, Loma Linda University
David Crabtree	Graduate Student, Loma Linda University
James A. Marsh, Jr.	Professor, University of Guam
Robert I. Clutter	Research Scientist, South Pacific Islands Fish. Devel. Commission
Lawrence R. McCloskey	Postdoc, Woods Hole Oceanographic Institution
J. Morgan Wells	Research Scientist, Wrightsville Marine Bio-Medical Laboratory

[1]Deceased

This expedition has, until now, neither been documented for the historical record, nor has its impact on the field been evaluated through citation analysis, which involves the use of citation data for "the construction and application of a wide range of 'bibliometric' indicators of the 'impact,' 'influence' or 'quality' of scholarly work" (Moed 2005). This is not surprising, because scientists, whose primary interest is in the original research they conduct, rarely concern themselves with such things. Thus, we are typically left with only vague notions as to the scientific accomplishments of a given project and the factors that contributed.

The present project aims to paint a picture of the *Symbios Expedition* from its conception and execution through how its scientific results influence our present understanding of coral reefs. We show how its participants now perceive it and most importantly, how *Symbios* science has affected science in general in the last 35 years. As an exercise in the history of science, we hope this

project not only provides better documentation of the *Symbios Expedition*, its successes and the factors that enabled to them, but also leads to other similar studies for other research efforts.

While this project has scholarly aims, we hope that it may also come to the attention of the lay public and students interested in coral reef science.

Approach and Methods

This project had two components, the first being to provide historical documentation using traditional approaches, and the second being to conduct a citation analysis of *Symbios* publications and to assess their scientific impact. (Space limitations here will require us to report on these more fully elsewhere.)

We collected reference materials such as maps, ship logs, and research publications for historical documentation and to gain insight into the logistics of the expedition. Much of this was already in the SIO Library's Archives. The rest will be contributed to that collection. We also gathered from participants over 1600 photos taken during *Symbios* or related to *Symbios*. These provide insight into the living and working conditions of the expedition and help to demonstrate the social dimensions the participants experienced. Finally, we interviewed *Symbios* participants who added detail, perspective, and color to the historical record, and give insight to the reasons for the success of the expedition. Eleven interviews were conducted and transcribed. Participants were asked a series of similar questions but did not have them in advance, nor did they see the interviews conducted for the other participants. For example, we asked each individual what they thought the most significant scientific results of the expedition were, so that their answers could be compared to the results of the citation analysis. Transcripts were made of each interview.

We used citation data and network analysis tools to provide a quantitative understanding of the impact of the science of *Symbios* on scientific understanding. We first assembled a reference list of all papers we could identify that were uniquely or partly the result of research conducted by *Symbios* participants. Both peer-reviewed and non-peer-reviewed literature were included. Using the *ISI Web of Knowledge* (WOK*)*, we compiled citation counts for all peer-reviewed publications that were direct results of the expedition. Unfortunately, book chapters and other non-peer-reviewed publications are not as well covered by the WOK and were not included. The refereed *Symbios* publications were used for analysis of citation frequency and persistency, based on total citation counts and the years in which those citations occurred.

Citespace II, a network visualization tool developed by C. Chen at Drexler University, was used to create citation networks of *Symbios* publications and also to help determine if *Symbios* publications constituted pivotal points in coral reef literature. To create a network, we imported all the resulting publications of a general search into *Citespace II,* and allowed the program to determine which publications were turning points in the literature (pivotal points) based on when, where, how often, and by whom the publication was cited.

Results and Discussion

As was noted above, our approach to assessing the *Symbios Expedition* involved both the more qualitative approach of interviewing participants with the quantitative approach of doing the citation analysis. We felt that this would give us a way to gauge participants' impressions of the scientific accomplishments of the expedition with a wider measure of its impact on the scientific literature.

Oral Interviews. Interviewed participants were in consensus about several key facets of *Symbios*. First, all concluded that the expedition made major contributions to the understanding of the nitrogen cycle and metabolic function of coral reefs. This was verified by citation analysis (see below). Second, those interviewed felt strongly that the interdisciplinary, team approach to research embodied by *Symbios* was a critical characteristic that contributed greatly to Symbios' productivity. Third, the leadership of the late Dr. Robert E. Johannes was frequently cited as a major factor in fostering the scientific vision, cooperative spirit and interdisciplinary collaboration of Symbios. Moreover, interviewees noted that Johannes inspired younger scientists and graduate students, and made a concerted effort to involve women in a major marine science expedition, which was not characteristic at the time. (We believe that the two women who participated in the expedition were likely to have been the only women to have lived on the atoll in the 25-year interval since the Marshallese were expatriated in 1946.) Finally, participants also noted that Pomeroy and Helfrich played essential leadership roles as well.

Although Johannes had died before this retrospective project began, we were fortunate in obtaining an oral interview with him conducted by Dr. Jan Saap. While Johannes did not reflect on the administrative and leadership issues he encountered at all phases of the expedition, it is readily apparent how his enthusiasm for the *Symbios* science was "infectious."

Most interviewees felt that while the scientific objectives of *Symbios* were clearly defined and adhered to throughout the course of the expedition, good communication among participants allowed for "mid-course changes" to improve sampling protocols or take advantage of serendipitous discoveries. The two-month duration of the expedition allowed researchers to modify and repeat field experiments - another major reason cited for the expedition's success. Regular team meetings were held to assess progress and make necessary adjustments. Thus, when flux studies showed reef nitrogen export rates consistent with unexpectedly high rates of nitrogen fixation, it was decided to obtain by rush order the necessary supplies to measure nitrogenase using the acetylene reduction method. Given the logistical support offered by the AEC such as biweekly flights to Enewetak, it was feasible to obtain such critical supplies quickly and for individuals who were not part of the scientific party to join the expedition for a short interval. Thus several scientists from the University of Hawaii also came to conduct shorter complementary studies.

The excellent logistical support provided by SIO, NSF and AEC were mentioned by most interviewed as essential features that enabled *Symbios*' overall productivity. Because Helfrich also directed the AEC's EMBL, he had excellent relationships with key AEC managers in Washington and was able to facilitate logistics.

The other most significant reason for success, according to *Symbios* members, was the fact that the expedition was organized as a team effort, with individuals from widely varying academic backgrounds. At that time, team-oriented ecological studies were uncommon. Pilson said this of the team approach to *Symbios*, "Having a common objective where everybody was there to achieve a goal [was important] and people bring there own interests, their own perspectives to that. But they all wanted to see the enterprise succeed. So there's a certain natural dynamic when people are all keen on making it work." Helfrich said that it was crucial "being able to bring together a lot of scientists, each of whom had a little bit different perspectives and angles on a study like this, and seeing the dynamics of those scientists in the field together." Meyer said the following about of the need for working as an interdisciplinary team in ecological research, "It seems to me that if we are to understand the complexity of the world around us we need to have that diversity of approaches and understanding of the systems. They're complex systems and it's really hubris to think that only one person can truly understand them."

One of the remarkable features of *Symbios* was that it gave younger scientists, including the senior author of this paper, an incredible opportunity to work in a stimulating research environment with top-notch mentors. Meyer, for example, went on to a very distinguished career in stream ecology at the University of Georgia. In her interview, she cited *Symbios* as an important experience in her scientific development and networking that gave her confidence later on. Dr. Susan B. Betzer, on the other hand, said that she learned from *Symbios* that a research career in the ocean sciences was not for her. While she later finished her Ph.D. at the University of Rhode Island (and did include *Symbios*-based research in her thesis), she ultimately obtained an M.D. degree from the University of Miami and still is a practicing physician.

Citation analysis. As we noted above, the participants had their impressions of what the highest impact research conducted was. Citation analysis gave us an opportunity not only to reconcile their impressions with an objective metric, but also allowed us to gain a broader profile of the impact of *Symbios* research.

Symbios participants published nine peer-reviewed papers that related not only to the expedition's major goals but also other topics (Table 3). Many more non-peer-reviewed papers were also published, but they do not lend themselves to citation analysis because they are not well represented in ISI WOK databases.

Table 3. Publications or theses using data from *Symbios* (full citations appear in References).

Betzer (1972)	Pilson and Betzer (1973)
D'Elia (1977)	Pomeroy et al. (1974)
D'Elia (1974)	Smith and Marsh (1973)
Johannes et al. (1972)	Smith (1973)
Johannes and Gerber (1974)	Webb (1975)
Helfrich and Allen (1975)	Wiebe et al. (1975)
Knutson et al. (1972)	

Fig. 2 is a *Citespace II* network created using topic search terms *coral** and *nitrogen*. All publications and corresponding citation data resulting from a Web of Knowledge search using those terms were imported into *Citespace II*, and then analyzed to produce the citation network shown. Nodes represent publications and links represent citations. Rings within nodes represent citations received within time intervals; the larger the node, the more citations it has received from other publications in the network. Pivotal points that are *Symbios* publications or authored by *Symbios* members are noted, with *Symbios* publications noted in bold text. Citation counts

showed high citation rates for all publications, including 738 total citations for these refereed publications.

We do not have sufficient space to report on this topic fully here, but many of the *Symbios* papers are still cited over three decades after publication. Our analysis also showed high persistence for *Symbios'* refereed publications with a mean of 16 citations per publication since the year 2000.

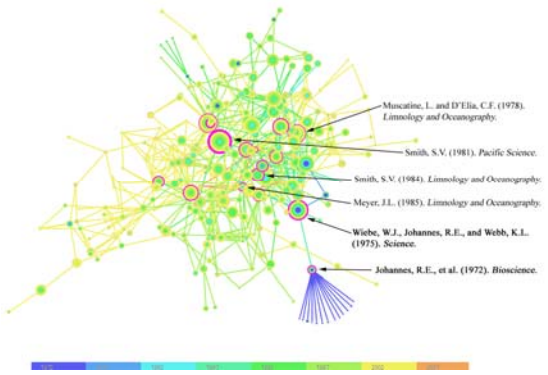

Figure 2. Citespace II network created using topic search terms coral* and nitrogen. (From Harris 2007).

The significant role of serendipity in scientific discovery is also apparent. One unexpected finding was that "Coral Chronometers…," Knutson, Buddemeier, and Smith's 1972 paper on growth bands in corals was the most highly cited publication, largely because of present interests in climate change that were unanticipated in 1971. Smith was only one of two *Symbios* members interviewed that mentioned that paper as a significant result. The research on which it was based was not a core activity of the expedition and was rather done "on the side," as were several other notable *Symbios* publications.

We believe that formal retrospective assessments of research productivity ought to be done more often. Most importantly, such studies provide useful documentation of the value of publicly funded research and the importance that serendipitous discoveries play in basic science. We also encourage more formal study into how large research projects are conducted and managed. Clearly, the team-oriented research of *Symbios* benefited from excellent conceptual and ongoing leadership, good administrative and logistical services, flexible adaptation to changing needs and opportunities, and a remarkably cooperative and team-oriented scientific party. We believe that the *Symbios Expedition* serves as a useful positive example for others to emulate in the future.

Acknowledgments

We thank SIO Archivist Deborah Day, Jan Saap and *Symbios* participants who helped. R.E. Turner and W.J. Wiebe made comments on the manuscript. C. Chen of Drexler University helped with us use the *CiteSpace II* program. Michael Reeve of the NSF's Division of Ocean Sciences provided a modest but critical amount of funding (NSF OCE 0500134) for this project.

References

Barile PJ (2004) Comments on "Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll" [Ecological Monographs 25 (3) (1955) 291-320]. Ecological Modelling 178:51-57

Betzer SB (1972) Copper metabolism, copper toxicity, and a review of the function of hemocyanin in *Busycon canaliculatum*. Ph.D. Dissertation, University of Rhode Island. 133 p

Chen C (2006) Citespace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. J Am Soc Inform. Sci. 57:359-377

D'Elia CF (1977) Uptake and release of dissolved phosphorus by reef corals. Limnol Oceanogr 22:301-315

D'Elia CF (1974) Aspects of the phosphorus flux of scleractinian corals. Ph.D. Dissertation, University of Georgia. 115 p

Harris AR (2007) The R/V Alpha Helix Symbios Expedition: A retrospective analysis of a milestone project. Honors Thesis. USF St. Petersburg. 27 p

Helfrich P Allen PM (1975) Observations on the spawning of Mullet *Crenimugil crenilabis* at Enewetak Marshall Islands. Micronesica 11:219-225

Helfrich P and R Ray (1987) Research at Enewetak Atoll: A historical perspective. in DN Devaney, ES Reese, BL Burch, P Helfrich (eds) *The Natural History of Enewetak Atoll*. US Department of Energy, pp 1-16

Johannes RE et al. (1972) Metabolism of some coral reef communities – A team study of nutrient and energy flux at Eniwetok. BioScience 22:541-543

Johannes RE Gerber R (1974) Import and export of net plankton by an Eniwetok coral reef community. Proc. 2nd Int Coral Reef Sym 1:97-104

Moed HF (2005) *Citation Analysis in Research Evaluation*. Springer. Dordrecht, The Netherlands. 347p

Knutson DW, Buddemeier, RW and Smith SV (1972) Coral chronometers - seasonal growth bands in reef corals. Science 177:270-272

Odum HT Odum EP (1955) Trophic structure and productivity of windward coral reef community on Eniwetok Atoll. Ecol Monogr 25:292-320

Pilson MEQ Betzer SB (1973) Phosphorus flux across a coral reef. Ecology 54: 581-588

Pomeroy LR Pilson MEQ Wiebe WJ (1974) Tracer studies of the exchange of phosphorus between reef water and organisms on the windward reef of Eniwetok Atoll. Proc. 2nd Int Coral Reef Sym 1:87-96

Price DJD (1965) Networks of scientific papers. Science 149:510-15

Smith SV Marsh JA (1973) Organic carbon production on windward reef flat of Eniwetok-Atoll. Limnol Oceanogr 18:953-961

Smith SV (1973) Carbon dioxide dynamics - record of organic carbon production, respiration and calcification in Eniwetok Reef Flat community. Limnol Oceanogr 18:106-120

Webb KL DuPaul WD Wiebe W Sottile W Johannes RE (1975) Enewetak (Eniwetok) Atoll - Aspects of nitrogen cycle on a coral reef. Limnol Oceanogr 20:198-210.

Wiebe WJ Johannes RE Webb KL (1975) Nitrogen fixation in a coral reef community. Science 188:257-259