Beyond Darwin: *Coral Reef Research in the Twentieth Century*

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Of all earth's phenomena, coral reefs seem best calculated to excite a sense of wonder. ... Tiny plants and animals are their builders. Their architects are the giant ocean and the restless wind.

Roger Revelle[2]

Coral reef science became an identifiable research specialty only within the lifetimes of people nearing the end of their scientific careers now—at the close of the second millennium. Of course, research was done on reefs earlier, but much of that, such as the famous debate on the importance of subsidence in reef growth, and particularly its role in the formation of atolls,[3] was based on inference rather than on the extensive empirical research that has come to characterize reef science. Perhaps more telling is the fact that those who did work on reefs before the latter twentieth century did not term themselves coral reef scientists. For example, Sir C. Maurice Yonge, whose name is closely linked with the early days of reef science, was trained as—and would undoubtedly have labeled himself—a malacologist.

Coral reefs, which may be the most diverse marine communities in the world (summarized, e.g., by Wilkinson and Buddemeier,[4] and by the Committee on Biological Diversity in Marine Systems[5]), are biogenic structures, the framework of which is formed primarily by some calcifying algae[6] as well as the cnidarians for which the reefs are named. Calcium carbonate skeletons produced by these organisms create a habitat for an array of other marine plants and animals, some of which contribute skeletal materials to the reef, others of which erode the reef structure, and still others of which simply live on, within, or beside it.[7] Coral reefs have been in existence since Jurassic, or possibly Triassic, times, with a gap in the Cretaceous and early Tertiary.[8]

Fossil coral reefs occur throughout the world, many on dry land. Living reefs, by contrast, are confined to tropical and some subtropical seas, from slightly above sea level to a maximum depth of perhaps 100 m, but only a few tens of meters in most places.[9] Until recently, living reefs were widely perceived to lack much economic value,[10] whereas at the turn of the 20th century, fossil reefs, which had previously been largely of academic interest, gained economic value because some hold important petroleum reserves.[11] These contrasts help explain why geological research on coral reefs predated biological. Indeed, Darwin's interest in reefs was far more geological than biological.[12] One significant biological legacy of this history is that taxonomy of reef-forming corals was based until recently almost entirely on attributes of their skeletons, which fossilize, rather than on their soft tissues, which do not.[13]

Most research on living reefs until the early 20th century was by exploring expeditions, which were undertaken with sponsorship of European governments largely in the interests of commercial possibilities. The Danish-sponsored expedition to the Arabian Peninsula in 1761-1767 was among the earliest such ventures, and its emphasis on exploration of coral reefs was ahead of its time. Its naturalist, Peter Forsskål (a Swede), is credited with having described 151 species of fishes, sixty-two species of arthropods, and 138 species of other, mostly marine, invertebrates, despite having died in the third year of the expedition. Taxonomic descriptions were assembled mainly from his notes, although some specimens, mostly fish, made it back to Denmark.[14] Many coral reef species collected on subsequent expeditions were described by museum-based taxonomists from specimens that were gathered and preserved by people who were not taxonomists at all, or at least not taxonomists of the group in question. There were not always natural history data or drawings from life to supplement the typically colorless specimens that were often deformed after long storage. (This perpetuated the need to kill corals to identify them; indeed, it was far easier to ship dry skeletons than wet-preserved ones, with the result that relatively few coral specimens in most natural history museums possess their tissues.)

For research beyond this sort of inventory, scientists must go into the field: sustained study of the ecology or behavior of coral reef organisms requires at least dwelling quarters for scientists; physiological research, for example, also requires laboratories.[15] Among the first scientific facilities devoted to such studies of living coral reefs was the Tortugas Marine Laboratory, established in 1902 in Florida.[16] Its location at relatively high latitude, near the limits of reef growth, was typical of many early facilities that sacrificed biologically favorable settings for relatively easy access by scientists, and to communications, medical care, supplies, etc.

Not only do coral reefs flourish in greatest profusion in the equatorial tropics, but the diversity of reef organisms is far greater in the Indo-Pacific than in the Caribbean.[17] The remoteness of most Indo-Pacific reefs from traditional scientific centers compounded the logistical problems of their study. Early on, the alternative to easy access by scientists was prolonged stays by them in remote places. The Royal Society's Great Barrier Reef Expedition of 1928-1929, headed by C. M. Yonge, differed from earlier expeditions both in taking scientists to the field, and in headquartering them at a single site, where most of their research was done. Fifteen scientists comprising the core group were joined by nearly as many others for short periods. They made long-term observations and did experiments during a span of nearly thirteen months on Low Isles, at 16°23'S, 145°34'E, about 70 km north of Cairns, Queensland. Yonge's narrative of the expedition,[18] including a financial accounting and discussion and photographs of housing and boats, is the lead paper in the resulting multi-volume proceedings. He also wrote a semi-popular account of the expedition.[19]

By contrast, the Palao Tropical Biological Station at Koror (in what is now Belau) was among the earliest permanent research facilities for study of coral reefs at truly equatorial latitudes in a place with rich reefs. The Japan Society for the Promotion of Scientific Research established this laboratory in 1934. The first number of the "Palao Tropical Biological Station Studies," which contained six papers, was issued on 30 March 1937; the last (Volume II, number 4), containing papers numbered 61-66, was issued on 20 May 1944, although the station closed in 1943. The twenty-nine Japanese scientists who did research there formed the Iwayama Club, which met twenty-nine times from 1938 until 1987, and produced the "Journal of the Iwayama Club." In a mimeographed letter dated 15 December 1993, enclosed with number 18 of the journal, Sigeru Motoda wrote: "the members of the club are now getting quite old, almost all now over eighty years old. We cannot expect they still have interest to continue the journal. This number will be the last issue. We must say now 'Sayonara.'" This journal is a treasure for historians, if number 18 is typical; it contains articles (all in Japanese) on technical issues and reminiscences such as "From Palau," "From diary in Palau and curious animals in Palau," and "Remembrance of the Palao Tropical Biological Station." Motoda himself died in 1995.[20]

Although these large undertakings, driven by national concerns,[21] produced what are probably the best-known studies on Indo-Pacific coral reefs during the years between the world wars, they were not the only venues for research involving corals and reef inhabitants. Two examples of contemporaneous efforts, seemingly initiated by individuals, were in what was then the Dutch East Indies, at the Laboratorium voor het Onderzoek der Zee,[22] and in Egypt at the Marine Biological Station of Al-Ghardaqa.[23]

The same sort of political imperative that led the Japanese to establish a coral reef research laboratory on the islands with which Japan had been entrusted by the League of Nations after World War I led the US government to carry out similar projects on those same islands after they had been entrusted to the US by the United Nations after World War II. Comprehensive biological, geological, and oceanographic surveys were carried out by scientists from various American governmental and private institutions before, during, and after the American atom bomb tests (as support for coral reef research was later to be linked to nuclear testing in French Polynesia). Although some of the research was in preparation for the tests, and some was to assess their effects, much was not of immediate or direct military or economic interest.[24] For example, drilling by Harry Ladd on Enewetak Atoll in 1952 resulted in striking basalt beneath about 1300 m of carbonates,[25] resolving a long-standing conundrum, and prompting Ladd to erect a sign beside the bore hole "Darwin was right!"[26] A field station on Enewetak for research on coral reefs, which came to be operated by the University of Hawaii, continued into the 1980s, well after weapons testing had ceased. The enormous volume of scientific data generated was published in a variety of outlets. A large number of early papers dealing with geology, geophysics, oceanography, and biology was published as US Geological Survey Professional

Paper series 260 (introduced by Revelle).[27] The *Atoll Research Bulletin* was a direct outgrowth of the proliferation of data; the first number was published in 1951, number 347 contained a brief history of the journal and an index to its contents during the preceding forty years,[28] and the journal continues to be published.

A scientific field may be considered to have become identifiable as an academic entity when it has sufficient practitioners to hold regular large congresses, to form a society, and to create enough research to merit publication of a journal. By these criteria, coral reef science is very young, indeed. The First International Symposium on Corals and Coral Reefs was held under the auspices of the Marine Biological Association of India at Mandapam Camp, 12-16 January 1969. It was attended by seventy-two scientists from eleven countries, and resulted in a proceedings volume of 591 pages.[29]

Many reckon reef science as such to date from the Second International Coral Reef Symposium, held 22 June to 2 July 1973, and chronicled in the symposium's two-volume, 745-page proceedings.[30] As Mather points out, the symposium did not cause the leap in research nor the ferment in concepts about coral reefs that were occurring in the early 1970s, but the venue and structure of the program were consciously planned to highlight and take advantage of them.[31] The inspired idea to hold it aboard the passenger ship *Marco Polo*, cruising the Great Barrier Reef, resulted in one of the great scientific conclaves ever held, in the opinion of most people who attended it. Not only was the setting eminently appropriate to the subject matter (formal sessions held during a couple of days' cruising were interspersed with excursions to reefs for a day or two at a time), but the format made for interaction and camaraderie since a person could not attend only long enough to present a paper, as senior people too often do. In fact, because coral reef science was in its infancy, there were few senior people then. But the core of today's coral reef science seniors is derived from the 264 scientists assembled aboard the *Marco Polo*.

The International Society for Reef Studies was formed in 1980, and its journal, *Coral Reefs,* first appeared in 1982.[32] The Seventh International Coral Reef Symposium, held in 1992 in Guam, was attended by about 800 people, and resulted in two volumes of papers totaling 1240 pages, authored by 504 scientists.[33] The year 1996 saw the Eighth ICRS in Panamá, with more than 1300 attendees, and publication of the 15th volume of *Coral Reefs.*

Scientific interest in coral reefs during the 1970s, 1980s, and 1990s is reflected not only in a society, a journal, and an increased number of reef scientists, but by a growth in the number of relevant field facilities, courses of study, international projects, etc. Examples are provided by Kinzie,[34] Mather,[35] and Salvat[36] for the Caribbean, Australia, and France, respectively.

The emergence of coral reef science during the latter part of the 20th century would not have been possible, in my opinion, without two developments that permitted access to coral reefs by a large number of scientists who could make repeated, detailed observations through relatively long periods of time and/or at many sites. A technical innovation essential to the science as now practiced was SCUBA (self-contained underwater breathing apparatus) diving.[37] Although some reefs exist below depths at which SCUBA is safe and/or practical, before the development of SCUBA diving, scientists could visit only the shallowest reef habitats for meaningful periods of time. Invented in the early 1940s by Cousteau and Gagnan,[38] SCUBA was not widespread before the 1970s, when sport diving gained popularity. Participation by many thousands of sport divers has driven development of increasingly safe, light-weight, affordable, and durable equipment that can be purchased and serviced throughout the world.

The advent of frequent, relatively inexpensive air travel to places that had previously been accessible only at considerable expense of time and money allowed a proliferation of scientific field facilities where reefs thrive. As for SCUBA diving, scientists alone could not have supported this development. Indeed, the growth in sport diving, in my opinion, is intimately linked to improved access to reef sites: as numbers of divers has increased, so has demand for attractive, exotic diving destinations, and as the number of tropical facilities accommodating divers has grown, so has the number of divers. Scientists have gained from this development—a substantial proportion of the field stations for research on coral reefs are located, by design or coincidence, near resort facilities that cater to SCUBA divers, presumably for logistical reasons but also because many reefs that attract scientific attention are attractive to sport divers. Ironically, the access that makes their study possible has resulted in the concern that at least some coral reefs may be visited by more people than they can tolerate,[39] but this has produced an awareness of reefs on the part of the public that has created a demand for knowledge about them that has contributed to a recognition of the need for the discipline of coral reef science.

Coral reef science is rooted in both geology and biology (and increasingly involves management) as reflected, for example, in the makeup of the editorial board of *Coral Reefs*, and the contents of the *Atoll Research Bulletin*. Field studies on living coral reefs that became possible during the twentieth century have affected the work of nearly all reef scientists, even those whose own research is laboratory-centered or focused on fossils. Such rigorous, empirical research has permitted the emergence of coral reef science as an identifiable scholarly endeavor. ■

Notes

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