

A retrospective look at Guam's marine biodiversity

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Abstract—For marine biodiversity studies at Guam, note is made of early discoverers to the 1900s and the beginning of scientific investigations through World War II. Specific activities surrounding *Acanthaster planci* are noted as they led to the development of the University of Guam Marine Laboratory with comments on the Marine Lab's role in Guam and the Commonwealth of the Northern Marianas to the present. Former and current faculty, graduate students, and visiting researcher activities are reported.

Early Discoverers (1521 – 1790s)

Guam was visited by a number of early explorers; however, none of them wrote about the waters surrounding the island. Antonio Pigafetta, Magellan's chronicler, made very brief remarks related to the people of Guam (Skelton 1969). Five years later, Fray Garcia Jofre de Loaysa retraced Magellan's route with Andreas Urdaneta who briefly described people and weapons. Urdaneta returned in 1565 with Miguel Lopez de Legaspi, who took possession of the islands for the King of Spain. Urdaneta further reported on the people and their houses erected on stone pillars. Between 1600 and 1625 a number of Dutch expeditions passed through Guam, each adding little information about the islands and their inhabitants. In 1665, the galleon *San Damian* with Padre Diego Luis de Sanvitores returned to Guam, establishing the first permanent Spanish colony. Padre Sanvitores is remembered for the first study of the Chamorro language. William Dampier first visited in May 1686 and returned with Woodes Rogers in 1710 and upon leaving, took a proa (sailing canoe) with them back to England. Marion Crozet was so impressed with the breadfruit trees that he attempted to take some to the French Colonies; few survived.

In 1789 Spain sent its greatest "scientific" expedition to investigate Spanish America, the Mariana Islands, and the Philippines Islands. In February 1792 this expedition reached Guam under the control of Don Alejandro Malaspina with the corvettes *Atrevida* and the *Discubierto*. This was the first "scientific" expedition to cross the Pacific. The naturalists aboard were Antonio Pineda who recorded the zoology and geology, and Thadaeus Henke and Louis Nee who were to report on the plants. The expedition left Cadiz in July 1789, and, arriving at South America, Pineda left the *Discubierto* and crossed the Andes on foot to rejoin it in

Chile, collecting along the way. Saipan was sighted on February 11, 1792; on February 12 the ships landed at Apra Harbor and moved to Umatac, Guam, the following day (David 2000). Pineda walked along the west shore at Guam, crossing to Agana and returning along the east coast, having remained on the island for 12 days. He reported on the rivers, houses, people and commented on the coral at Umatac and noted sponges without reference to location (Mallada 1990). Pineda died shortly afterward in the Philippine Islands. Because of political reasons Pineda's papers, as well as those of the other participants of the Malaspina Expedition, were never published. More than 20,000 plant specimens, many from Guam, collected by Henke and Nee have been deposited in museums and herbaria throughout Europe.

Period of Scientific Exploration (1800s – 1890s)

With the ending of the trans-Pacific galleon crossings in 1815 and the advent of whalers entering the Pacific, more voyages of discovering were in the making, although ocean crossings were still a dangerous experience. Russian explorers were the first to cross the Pacific in number with their newly developed scientific instruments.

The first Russian to visit Guam was Otto von Kotzebue in the brig *Rurik* in November 1817 with Adelbert von Chamisso, a botanist, Johann Friedrich Eschscholtz, a naturalist and entomologist, and Ludwig Choris, an artist (Browning 1968). They reported on the geology of the island and the surrounding reefs. V. M. Golovnin with the ship *Diana* visited briefly (Wiswell 1974). Friedrich H. de Kittlitz collected bird specimens in March 1828 as the ornithologist aboard the *Senyavin*, captained by Fedor von Lutke.

Also during this time, the French sent a number of expeditions throughout the Pacific. Luis Claude Desaulses de Freycinet arrived at Guam with the corvette *Uranie* in March 1819. The botanist, Charles Gaudichaud-Beaupre, collected plants and zoologists J. R. C. Quoy and J. P. Gaimard described many species from Guam, including a number of land snails. They also described the first marine invertebrates from Guam, including four new species of gastropods and two species of salps, as well as something they named *Mariana rubrum*, new genus, new species, which they indicated as somewhat ascidian-like with attached, gelatinous, red-colored circular mass; however, examination of the original figure appears to look superficially like the egg mass of *Hexabranhus sanguineus*, an opisthobranch! The genus *Mariana* seems to have been lost in history, never having been reported since. Quoy and Gaimard also reported six crabs from Guam, one being new: *Thelphusa rotunda* (now *Discoplax rotundum*). They also reported *Pagurus latro* (now *Birgus latro*) with the common name "pagure larron", perhaps the source of the common name, robber crab. Additionally, they (Quoy & Gaimard 1824) added the sponge *Spongia lamellifera*, as well as *Pocillopora coerulea* (now *Heliopora coerulea*).

In 1828 Jules Sebatien Cesar Dumont d'Urville, commander of the corvette *Astrolabe*, visited Guam with the zoologists Quoy and Gaimard and P. Lesson, a pharmacist and botanist who assisted Dumont d'Urville. In January 1839, Dumont d'Urville returned to Guam in command of the *Astrolabe* and *Zelee* along with J. B. Hombron and C. H. Jacquinot, botanists and physicians.

Alfred Marche made extensive natural history collections during his two-year visit between 1887 and 1889. He collected mollusks, insects, fish, lizards, and minerals, as well as human skulls and implements. He is considered to have taken the first photograph of the islands and visited almost all the Mariana Islands during late 1888 where he photographed an eruption on Pagan (Cheng 1982).

1900s to World War II

On February 21, 1900, the U.S. Fish Commission steamer, *Albatross*, arrived at Apra Harbor during its "expedition to the tropical Pacific 1899-1900", leaving on February 25. During the visit Alexander Agassiz described the geology of Guam and photographed elevated limestone at Cabras Island and volcanic hills at Agana (Agassiz 1903). Rathbun (1907) noted that dredging and shore collecting were of secondary importance during the cruise; therefore, the decapod crustacean collections are not well represented. A total of 136 crab species were reported from the entire expedition; but only one species, *Ocypode ceratophthalma* (Rathbun 1907), and one holothurian, *Holothuria scabra*, (Clark 1920) were recorded from Guam, although the latter appears to have been erroneously recorded from the island (Paulay 2003).

William Edwin Safford, U.S. Navy Lieutenant, the assistant to the Governor of Guam between August 1899 and August 1900, wrote "The Useful Plants of Guam". In it he briefly discussed without specific names a few marine invertebrates (corals, crabs, mollusks) and describes the west coast reefs (Safford 1905).

In 1900 Alvin Seale, a field naturalist for Bishop Museum, made his first zoological collecting survey at Guam (Herre 1959). In addition to numerous fishes, he collected some 30 crustacean specimens and six echinoderms currently deposited in Bishop Museum. Additionally, he collected a single soft coral in 1900, which was not described until 1977 as *Sinularia vervoorti* by Verseveldt (1977).

Hans Hornbostel, a lieutenant at the U.S. Naval Hospital, collected material for the Bishop Museum between April 1922 and June 30, 1928. His writings were primarily archaeological in nature, especially work with the latte. More than 380 lots of invertebrate specimens remain in the Bishop Museum collection.

Pacific Vegetation Project

The U.S. Army Corps of Engineers initiated a number of surveys in Micronesia following the end of World War II. A survey of Saipan in September 1948

and mid-July 1949 resulted in a series of publications in Geological Survey Professional Paper, Volume 280. Part 4 was the "Submarine Topography and Shoal-Water Ecology" (Cloud 1959) in which 531 species of marine plants and animals are reported and the shoal marine habitats of Saipan were described.

A field party composed of members of the U.S. Corps of Engineers, U.S. Army, and U.S. Geological Survey were on Guam between 1951 and 1954. They produced the "Military Geology of Guam" (Tracey et al. 1959) and a series of studies assembled in Geological Survey Professional Paper, Volume 403. Chapter A was the general geology of Guam (Tracey et al. 1964); Chapter B, the marine geology (Emery 1962) primarily covered Cocos Lagoon floor, channels, reef surface, beaches, and rocky shores. Of special note was extensive work on the rimmed terraces with list of species collected from the rims. Chapter E is the larger Foraminifera (Cole 1963); and Chapter G, the fossil and Recent calcareous algae (Johnson 1964).

On January 23, 1960 the U.S. Navy Bathyscaph *Trieste* with Lt. Don Walsh and Jacques Picard descended to the bottom of the Challenger Deep, 200 miles southeast of Guam in the Mariana Trench, to a depth of 35,800 ft (11,033 m). Although they did not collect any biological specimens, they did observe a single flounder during the twenty minutes they rested on the bottom (Walsh 1979).

Acanthaster Times

In the early 1960s extensive predation by the crown-of-thorns starfish (*Acanthaster planci*) was noted on the Great Barrier Reef, the Ryukyus, and Micronesia. A population outbreak was first reported at Guam in 1967. An International Biological Programme (IBP) Technical Meeting on Conservation of Pacific Islands held at Koror, Palau and Guam in November 1968 adopted the Resolution on Starfish (RR-1) "in an attempt to understand and to control its current explosive increase and the consequent destruction of reef such as those on Guam, the Great Barrier Reef, and elsewhere" (Nicholson & Eldredge 1969). Richard Chesher joined the University's biology department in 1968 and took Sir Maurice Yonge and Thomas Goreau from the IBP meeting on a dive to view *Acanthaster* devastation. Shortly afterwards, Guam Senator Richard Taitano surveyed several sites and was able to obtain \$15,000 from the Guam Legislature for an emergency, six-month research program. In May 1969, R. Chesher traveled to California and visited the Westinghouse Ocean Research Laboratory which resulted a month later in the U.S. Department of Interior's designating \$250,000 for a Micronesian survey to obtain the status of *Acanthaster* populations. Nearly 60 scientists were briefed on Guam in July 1969 and organized into 10 teams which traveled to all the districts of the then Trust Territory of the Pacific Islands. On August 15, 1969 the field studies were completed and the scientists were debriefed. The final Westinghouse report was finished on October 15, 1969 (Chesher 1969a) and a 12-minute movie "Search for the killer starfish" was screened. This whirlwind event drew worldwide

attention to the problem and to Guam (Chesher 1969b). Dive teams were organized throughout Micronesia to monitor the status of *Acanthaster*. R. T. Tsuda convened a workshop at the University of Guam in March 1972 to bring all the Micronesian players together to review their findings on history and control, biology, and past and present status (Tsuda 1972). This led to a symposium—Biology and Ecology of the Crown-of-Thorns Starfish, *Acanthaster planci* (L.)—at the 2nd Pacific Science Inter-Congress at the University of Guam in May 1973 attended by several scientists from around the world [see *Micronesica* 9(2), 1973, for Proceedings]. All these activities spawned a number of research projects. Masashi Yamaguchi, a visiting investigator from Japan, began life history studies. On August 9, 1972, he celebrated the first birthday of his efforts with an invitation, which read, “The juveniles have grown about 100 times in diameter and 100,000 times in weight in the first year.” Research, surveys, control efforts continued during periodic outbreaks in Guam and Micronesia. Charles Birkeland served on the Australian “Advisory Committee on Research into the Crown-of-Thorns Starfish” and in 1990 co-authored with John S. Lucas, “*Acanthaster planci*: Major Management Problem of Coral Reefs”, the definitive work on the subject (Birkeland & Lucas 1990). A history of coral reef science as based around the crown-of-thorns starfish has been prepared by Sapp (1999).

Role of the UOG Marine Laboratory

Backtracking a little in order to explain the history of the Marine Laboratory, the Micronesian Area Research Center was originally proposed to be an umbrella research organization for all University of Guam (UOG) research and was first initiated in 1967. At the beginning the Marine Laboratory was operated through the Science Building under the leadership of Robert S. Jones. Ground was broken for the Marine Laboratory building in February 1970. In February 1971, R. S. Jones, R. H. Randall, H. Kami, and R. Struck of the Marine Laboratory and Guam Fish and Wildlife Division traveled to Maug, Agrihan, and Anatahan aboard the U.S.N. *Grasp*. They collected fish and corals primarily, as well as some algae and other invertebrates. This trip began a series of UOG Marine Laboratory expeditions to the northern islands of the Marianas. Three trips were made on the privately owned ketch *Wanderer* by University faculty and others; in April 1971 they visited only Pagan; in June 1971 and July 1972 they visited several islands. During these cruises algae, terrestrial plants, invertebrates (mostly opisthobranch mollusks), and fish were collected.

The National Marine Fisheries Service R/V *Townsend Cromwell* cruised through the entire archipelago in April and October 1971, taking depth and temperature measurements which form the basis for a report on the physical oceanography of the area (deWitt 1972). deWitt also listed 35 known Japanese and Russian hydrographic cruises conducted in the area between 1936 and 1968.

In January 1975 the UOG Marine Laboratory held the first of two trips throughout the entire archipelago aboard the schooner *New World*. The major

objective was a broad-based marine survey; the group included L. G. Eldredge and nine UOG students. During July of the same year, the *New World* again sailed throughout the islands (Eldredge 1975). This time L. G. Eldredge was joined by S. Amesbury (University of Guam), E. A. Kay and C. Lamoureux (University of Hawaii), and M. V. C. Falanruw (Yap Institute of Natural Science), and five students (Ronck 1975). This second trip included some detailed terrestrial investigations (Fosberg et al. 1975). The marine algae were reported by Tsuda & Tobias (1977a, 1977b).

As evidence of expanding support for the marine programs at UOG the Western Society of Naturalists convened the 1st International Symposium on Indo-Pacific Tropical Reef Biology on Guam in June 1976. This was followed a decade later with the 2nd International Symposium on Indo-Pacific Marine Biology in June 1986 [see *Bulletin of Marine Science* 41(2)]. The Republic of China-U.S. Cooperative Science Seminar, "Cultivation and utilization of economic algae" was held at Guam in June 1982 under the sponsorship of the U.S. National Science Foundation and the R.O.C. National Science Council (Tsuda & Chiang 1982).

In August 1976 the *Lindblad Explorer* with Sir Peter Scott and R. and V. Taylor aboard spent one day at Maug. In a report to the Resident Commissioner, they sight recorded 113 species of reef fish and recommended that the island be protected (Lindblad Expedition 1976). A similar report followed their 1977 visit (Lindblad Expedition 1977).

The Pacific Deep Benthos Survey investigated deep-water corals between Guam and Saipan in October 1973 by R. Grigg from the University of Hawaii and L. G. Eldredge. One eroded specimen of a precious coral was collected with the dredging mop, as well as numerous other invertebrates (Grigg & Eldredge 1975). Between May 1975 and May 1977, a series of deep-water shrimp trapping experiments were conducted at depth between 244m and 732m (Wilder 1979). Numerous crabs and gastropods were collected.

In conjunction with coastal studies R. Randall and L. G. Eldredge surveyed and created atlases for Guam (Randall & Eldredge 1976) and for Saipan, Tinian, and Rota (Eldredge & Randall 1980).

The Resource Assessment Investigation of the Mariana Archipelago (RAIOMA) was a five-year program begun in 1980 of the National Marine Fisheries Service, Southwest Fisheries Center, designed to "quantify the distribution and sustainable yield of insular fishery resources with commercial potential" (Polovina et al. 1985, p.19). The program covered the area from Santa Rosa Reef northward to Maug and to the west to include Pathfinder Reef and Arakane Reef. Six 40-day cruises were conducted on the R/V *Townsend Cromwell* between May 1982 and June 1984. The prime resources investigated were tuna, deepwater snappers and groupers, deepwater shrimp (*Heterocarpus* spp.), and akule or big-eye scad (*Selar crumenophthalmus*) (Polovina et al. 1985). Associated with RAIOMA was the "Assessment of Inshore

Marine Resources in the Mariana Archipelago” program organized by the Marine Laboratory which was designed to acquire information on selected resource stocks which may be potentially exploitable in the nearshore, relatively shallow waters. Resources to be investigated were benthic marine plants, reef corals, deepwater precious corals, nearshore zooplankton, and certain physical and chemical parameters of seawater. Three separate cruises—circle-island, 500 Fathom Bank, and Galvez and Santa Rosa Bank—were conducted around Guam during 1982 and 1983; another one to the northern islands between March 28, 1983 and April 12, 1983. This combined information provided a useful overview of resource distributions in the Mariana Islands (Anonymous 1984).

Beginning in 1972, Marine Laboratory staff members started a series of environmental surveys throughout Guam and Micronesia resulting in a number of Environmental Survey Reports and Technical Reports. Research efforts increased and numerous publications resulted (Smith 2001) on the biology and ecology of coral reefs, natural products, aquaculture and fisheries, and the taxonomy of marine flora and fauna.

In March 1981 a several UOG biologists visited Pagan under the auspices of the Commonwealth of the Northern Mariana Islands Coastal Resource Management Office to conduct a basic marine and terrestrial environmental survey. On May 15, 1981, the northern volcano violently erupted. In July 1981, a similar group of biologists visited Pagan again. The purpose of this trip was to record the impact of the May eruption on the environment. In April 1983 L. G. Eldredge returned to examine recovery of the marine environment from the effects of the eruption (Eldredge & Kropp 1985)

The Mariana Trough was the third vent system to be discovered. Six of the 28 submersible “Alvin” dives were held between April 7 and May 19, 1987 and discovered fields and active vents and vent communities at depths between 3,559 and 3,660 meters. Thirty species were recognized; 27 identified to species, including 23 new species, 8 new genera, and 2 new families. Among them the new species *Alviniconcha hessleri* is the first known example of a gastropod with symbiotic chemosynthetic bacteria (Hessler & Lonsdale 1991). During cruise 69 of the R.V. Sonne in mid-1990 investigating the Mariana back arc at Esmeralda Bank, two unique decapod crustaceans were collected; one was a new genus of callianassid and the other a grapsid already known from Japanese waters (Türkyay & Sakai 1995).

The 1990s

A biological expedition to the nine northern Mariana Islands in the Izu-Mariana Arc was conducted in 1992 by the Natural History Museum and Institute, Chiba, Japan, in cooperation with the Department of Natural Resources (CNMI) and the UOG Marine Laboratory. The close relationship between the biota of the northern islands and Japan was investigated, and many new taxa were identified. The shores of the northern Marianas are mostly volcanic and

have a flora and fauna different from the more southerly raised limestone islands and reef flats (Asakura & Furuki 1994). These studies led to an International Symposium on Natural History of the Izu-Ogasawara-Mariana Arc held at the Natural History Museum and Institute, Chiba, on February 11-12, 1994 where UOG staff members presented papers on corals (Randall 1995) and fishes (Donaldson 1995)

The 7th International Coral Reef Symposium was held at Guam under the sponsorship of the Marine Laboratory June 22-26, 1992 in coordination with the Committee on Coral Reef of the International Association of Biological Oceanographers and the International Society Reef Studies. C. Birkeland was Chair of the Organizing Committee and organized the scientific program. A series of public lectures took advantage of the coral reefs specialists attending the Symposium. The two-volume proceedings reflect the 31 sections of the Symposium itself; R. H. Richmond was the editor (Richmond 1993).

A focused effort was made in late 1990s to record additional species encountered in previously documented taxa and to survey major groups not systematically examined in the past. This effort received a considerable boost between 1996 and 2000 through five major biodiversity surveys funded by COMNAVMARIANAS (U.S. Department of Defense), Sea Grant, and the Insular Pacific Marine Research Program. Two of these focused on Apra Harbor (Eldredge & Paulay 1996; Paulay et al. 1997), one on the southern Orote-north Agat Bay (Paulay et al. 2001), one on the Pugua Patchreef-Haputo area (Amesbury et al. 2001), and one on island-wide non-indigenous species (Paulay et al. 2002). Taxonomic workshops were offered at the Marine Laboratory on sponges by Michelle Kelly, soft corals by Yehuda Benayahu, and ascidians by Gretchen Lambert.

Overview

Former and present Marine Laboratory faculty have contributed to numerous biodiversity studies: S. S. Amesbury (fishes), C. Birkeland (coral reefs), L. G. Eldredge (crustaceans and information), C. Lobban (algae), S. Nelson (freshwater studies), V. Paul (chemical ecology), G. Paulay (invertebrate studies), R. H. Richmond (coral reefs), R. Rowan (coral studies), B. D. Smith (mollusks) R. T. Tsuda (algae), and Research Affiliates P. J. Hoff and C. H. Carlson (opisthobranch mollusks). The Laboratory also collaborates with staff from the University's Department of Natural Sciences, Water and Environmental Research Institute of the Western Pacific, and the Agricultural Experiment Station. More than 450 research papers have been published by the faculty, students, and colleagues. Many of these papers have appeared in *Micronesica*, a journal of the University of Guam that had been edited by Marine Laboratory faculty for many years.

In addition to the work carried out in Guam and Micronesia, C. Birkeland and colleagues have studied the waters around American Samoa for more than

two decades, and extensive studies have been conducted in Palau by many Marine Laboratory Staff and in Taiwan by R. H. Randall.

More than 110 graduate students have completed Master of Science degrees, beginning in 1969. Many have contributed to biodiversity studies. Approximately a quarter of these M.S. students have gone on to complete Ph.D. degree programs around the world.

Since Guam's coastal waters had not been historically investigated in great detail, investigations by visiting scientists began in earnest in the mid 1980s and continue. Visiting investigators have taxonomically studied: algae (I. A. Abbott, W. J. Gilbert, K. Kumano, H. Itono), foraminiferans (J. J. Lee, S. L. Richardson), sponges (M. Kelly), soft coral (Y. Benayahu), sea anemones (D. Fautin), corals (P. W. Glynn), polychaete annelids (J. Bailey-Brock), mollusks (A. J. Kohn, P. Signor, J. D. Taylor, G. J. Vermeij), cave fauna (T. Kase, I. Hayami, Y. Kano), marine insects (L. Cheng), barnacles (K. Asami, Y. Hisatsune), other crustaceans (A. Asakura, A. J. Bruce, P. Castro, P. K. L. Ng, M. Takeda), crinoids (D. L. Meyer), holothurians (F. W. E. Rowe), and ascidians (C. and G. Lambert).

Specimens not identified at the Marine Laboratory itself were often sent to a worldwide cadre of experts for identification. These specimens and others are the basis of the collections make Guam one of the world's most well known islands.

The publications of the current and past faculty and staff and a list of the M.S. theses completed have been compiled by Smith (2001) and can be found at the UOG Marine Laboratory web site [<http://www.uog.edu/marinelab/>].

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