

ATOLL RESEARCH BULLETIN

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F. RAYMOND FOSBERG AND THE ATOLL RESEARCH BULLETIN 1951-1991

BY

EDITED BY DAVID R. STODDART

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Contents

	Page
David R. Stoddart: F. Raymond Fosberg and the <i>Atoll Research Bulletin</i> , 1951-1991.....	1
F. Raymond Fosberg: Ecological research on coral atolls.....	9
F. Raymond Fosberg: Pacific oceanic island biodiversity in a geohistoric perspective	13
Major publications of F. Raymond Fosberg on tropical islands and coral atolls: a selected list	19



F. Raymond Fosberg
June 1986

F. RAYMOND FOSBERG AND THE *ATOLL RESEARCH BULLETIN*, 1951-1991

BY DAVID R. STODDART¹

The first issue of the *Atoll Research Bulletin* was dated September 10, 1951. To date, in 1991, 354 numbers of the *Bulletin* have been issued in 78 separate volumes, containing more than 600 separate titles. Then, as now, the *Bulletin* has been edited by F. Raymond Fosberg, joined over the years by a small team of associates of whom the most active and prominent was the late Marie-Hélène Sachet. In good times and in bad, Ray Fosberg has guided this journal to be the central repository of information concerning the biota and ecology of reefs and reef islands in all three tropical oceans. In addition to this editorial achievement—and let no-one underestimate the prodigious amount of work it has involved by the small staff in Washington, D.C.—Ray is a botanist and conservationist of worldwide reputation and extraordinary productivity. To mark the anniversary of the *Bulletin* his co-editors decided to honor him with this special issue of papers on themes close to his central interests. This issue is therefore dedicated to him.

The record of the *Bulletin* has been documented in extraordinary detail in the comprehensive index compiled by Mary McCutcheon and published appropriately in 1991. She records in her introduction how the *Bulletin* grew out of the Coral Atoll Program of the Pacific Science Board, headed by the late Harold Coolidge, and the remarkable series of expeditions sponsored by the Program to representative atolls across the Pacific. As she records, it was Ray who first proposed the concept of a formal bulletin to record the preliminary results of these expeditions, and who was also responsible for suggesting its title.

The critical initiatives which led to the foundation of the *Bulletin* came with the Pacific Science Board expedition to Arno Atoll in the southeastern Marshall islands in 1950 and early 1951, and the convening of symposia in Washington on 12 January 1951 and in Honolulu 5-6 February 1951 (Coolidge 1951). The first paper published in the first issue of the *Bulletin* was Ray's summary statement on 'Ecological research on coral atolls' (Fosberg 1951). While many other specialists contributed to these meetings, this statement effectively determined the philosophy adopted by the *Bulletin*. Since the first issue is now extremely difficult to find, this paper is reprinted here.

The preliminary symposium papers in the first two issues were followed in 1953 by the *Handbook for Atoll Research*, termed the second preliminary edition (Fosberg and Sachet, eds. 1953). Thirty-two papers gave succinct yet detailed guidelines for work in geography, meteorology, geology, hydrology, soil science, botany, zoology, marine ecology, anthropology and expeditionary work. Although nearly forty years old, these papers, dating from a time when field science was simpler than it is today, can still be read with profit—not least the concluding papers ('Hints on how to live on a boat' and 'Hints on living under restricted camp conditions').

The earliest substantive issues of the *Bulletin* (3-11 and 15-17) were devoted to the results of the Arno Atoll expedition, in papers which often not only recorded field data but systematised existing knowledge in specific subject areas and provided models of field procedures. There followed the results of the second expedition in 1951 to

¹Department of Geography, University of California at Berkeley, Berkeley, California 94720, U.S.A.

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Onotoa Atoll, southern Gilbert Islands, including a widely-quoted paper by Preston E. Cloud, Jr. (1952); the third expedition in 1952 to Raroia Atoll, in the Tuamotus, including early versions of classic papers by Norman D. Newell (1954a, 1954b) together with major papers in anthropology and cultural ecology; partial results of the fourth expedition in 1953 to Ifalik Atoll in the central Carolines; and substantial reports on the fifth expedition in 1954 to Kapingamarangi Atoll in the southeastern Carolines (Niering 1956, Wiens 1956) which were to play a substantial role in the development of MacArthur and Wilson's (1967) influential theory of island biogeography.

These results, which generated a completely new appreciation of the diversity of atoll geomorphology, biotas and ecology across a wide geographic range in the Pacific, coincided with the beginning of the flood of publications, appearing serially as Professional Paper 260 of the U.S. Geological Survey, based on intensive studies of atolls in the southern Marshalls (notably Bikini, Enewetak, Rongerik and Rongelap) during 1946-1952. The 'wonderfully detailed descriptions' (Revelle 1954, v) of the surface geology and morphology of these atolls given by Emery, Tracey and Ladd (1954) did for the physical understanding of the surface features of atolls what the largely ecological reports in the *Bulletin* did for the understanding of the ecology.

Ray Fosberg was himself in the northern Marshalls in 1951 and 1952, detailing the geology, hydrology, soils, vegetation and floristics of 21 atolls: his *Military Geography of the Northern Marshalls* appeared in 1956. The *Bulletin* itself carried many of the scientific reports from this expedition—on the plants (Fosberg 1955), sediments and soils (Fosberg and Carroll 1965) and birds (Fosberg 1966). Ray returned to Bikini in 1985 (Fosberg 1988), and rounded out his work in the Marshalls with a review of their natural history in 1990.

The 1950s thus saw an expansion of coral reef research on a quite unprecedented scale, in which the Pacific Science Board and the *Atoll Research Bulletin* played a central role. I myself saw my first atoll and barrier reef in 1959, and met Ray and Marie-Hélène Sachet the following year. With the generation of so much new research one was very conscious that coral reef studies were at the frontier of science, and at a time when the flood of new publications had not yet become the almost unmanageable torrent it has now become. At that time Ray and Marie-Hélène were working as botanists for the U.S. Geological Survey from the National Academy of Sciences annex near the State Department. In 1966 they moved to the Department of Botany, National Museum of Natural History, Smithsonian Institution. Up to that date the *Bulletin* had been issued by the Pacific Science Board, but from issue 118 in November 1967 it has been published by the National Museum of Natural History. Ray formally reached retirement age in 1978, and Marie-Hélène died in July 1986; she had been associated with Ray in Washington since 1949. Ray asked me to join him as an editor in 1969, and Ian G. Macintyre of the Department of Paleobiology, National Museum of Natural History, in 1979. Mark M. Littler and Joshua I. Tracey, Jr. of the Smithsonian and Bernard M. Salvat, then of the Ecole Pratique des Hautes Etudes in Paris, joined the editorial board in 1987.

Ray had of course been introduced to Pacific reefs and islands many years before the *Bulletin* began. From 1932 to 1937 he was a graduate assistant in the Department of Botany at the University of Hawaii, where he began a long association with Harold St John and where he took his Master's degree in 1935. It was from Hawaii that he embarked as assistant to St John on the now legendary Mangarevan Expedition to central and eastern Polynesia in 1934 (Gessler 1937, 1943). He thus became one of a group of men—Anderson, Buck, St John, Zimmerman, Emory, Kondo, Stimson, Cooke—who have dominated terrestrial scientific studies in Polynesia, largely from Bishop Museum, for half a century. The expedition took him to many remote islands, including Vostok,

Flint, Oeno, Rapa, and Maria. Ray's knowledge of Henderson in particular was of critical importance when proposals for its development arose in the 1970s (Fosberg et al. 1983). But after he left Hawaii his Pacific interests were necessarily interrupted by the long war years, when he was diverted to economic botany in Andean South America. In 1946, however, he was appointed Botanist to the Micronesian Economic Survey, and began a long series of visits to the Marianas, Carolines, Marshalls and Ryukyus. Many of the early papers on the Marianas and Ryukyus were published by the Office of the Engineer, U.S. Army, Pacific, but more recently there have appeared massive checklists of Micronesian dicots, pteridophytes, gymnosperms and monocots (Fosberg et al. 1979, 1982, 1987), together with contributions to an ongoing *Flora of Micronesia* in *Smithsonian Contributions to Botany* (1975-).

Ray also has a wide knowledge of the vegetation of Caribbean coral islands, with visits to Alacran in 1961, the Pedro Cays in 1962, the U.S. Virgin Islands from 1970 onwards, the Belize reefs in 1971 and 1972, the Dry Tortugas in 1981. His Indian Ocean work included visits to the Maldives in 1956 and to the Seychelles and Aldabra in 1968 and 1971, and many times to Sri Lanka. All have resulted in substantial publications notably the *Flora of Aldabra and neighbouring islands* (Fosberg and Renvoize 1980). He published an extensive checklist of the plants of the northern Great Barrier Reef in 1991. He also found the opportunity to organise and co-edit with M.D. Dassanayake *A Revised Handbook to the Flora of Ceylon* beginning in 1980 and now entering its eighth volume.

Not least of his contributions to island studies was the compilation with Marie-Hélène Sachet of *Island Bibliographies* (nearly 600 pages in 1955) and its *Supplement* (over 400 pages in 1971). He also organized and edited a remarkable symposium on *Man's Place in the Island Ecosystem* (1963) at the Pacific Science Congress in 1961. His exhaustive study of the Pacific collections made by J.R. Forster on Cook's second voyage is close to publication. His book with Dieter Mueller-Dombois and Ross McQueen on the vegetation of Pacific islands is virtually complete.

This astonishing record says nothing of Ray's tireless work for conservation around the world, nor of his interests in the humid tropics, the vegetation of the Americas, mangroves or biogeography. Altogether the list of his published works contains over 600 items, and of these about ten percent have appeared in the *Atoll Research Bulletin*. And it is of course for Ray's great contribution to the *Bulletin* and thus to the establishment of coral reef science that we present this special issue. We hope that the papers here will all speak to Ray's special interests in coral islands and the tropical Pacific. Those on Washington and Suvarrow present data on vegetation history and distribution, respectively. That on the Marquesas recalls Ray's interest in the high islands of eastern Polynesia. The paper on the soils and plants of the northern Marshall Islands addresses the main concerns of his expeditions in that area, especially in 1951 and 1952 and on which he himself has published extensively. The paper on phosphate rocks of Tuvalu takes up the arguments advanced by Ray in two important papers in 1954 and 1957. The paper on Nukutipipi gives new information on a hitherto almost unknown atoll in the Tuamotus. The papers on ethnobotany and cultural ecology highlight an area of science which Ray has always insisted to be important. Sadly these papers cannot adequately represent the range of his interests—the collection includes nothing on taxonomic botany, for example, nor on conservation. Nor can it begin to represent the vast range of his colleagues and co-workers around the world, some of whom joined in a symposium in his honor at the INTECOL meeting in Yokohama in 1990, the proceedings of which will shortly appear in *Pacific Science*.

It has been a privilege for everyone associated with the *Bulletin* to have been able to work with Ray Fosberg over the years to make it a success. His co-editors are proud to be part of his team. And the *Bulletin* will undoubtedly carry many more papers from his pen.

Acknowledgments

Ian Macintyre helped greatly in assembling this issue, as indeed, over the years, did Marie-Hélène Sachet. We are all greatly in the debt of Mary McCutcheon for compiling the comprehensive *Contents Lists and Indexes* for the *Bulletin*.

References

- Cloud, P.E., Jr. 1952. Preliminary report on geology and marine environments of Onotoa Atoll, Gilbert Islands. *Atoll Research Bulletin*, 12, 1-73.
- Coolidge, H.J. 1951. Introduction. *Atoll Research Bulletin*, 1, 2.
- Dassanayake, M.D. and Fosberg, F.R., eds. 1980-. *A Revised Handbook to the Flora of Ceylon*. New Delhi: Amerind Publishing Co. Vol. 1 [and subsequent volumes].
- Emery, K.O., Tracey, J.I., Jr. and Ladd, H.S. 1954. Geology of Bikini and nearby atolls. *U.S. Geological Survey Professional Paper* 260-A, i-xv, 1-265.
- Fosberg, F.R. 1951. Ecological research on coral atolls. *Atoll Research Bulletin*, 1, 6-8.
- Fosberg, F.R. 1954. Soils of the northern Marshall atolls, with special reference to the Jemo Series. *Soil Science*, 78, 99-107.
- Fosberg, F.R. 1955. Northern Marshall Islands Expedition, 1951-1952. Land biota: vascular plants. *Atoll Research Bulletin*, 39, 1-22.
- Fosberg, F.R. 1956. *Military Geography of the northern Marshall Islands*. Tokyo: Intelligence Division, Office of the Engineer, Headquarters U.S. Air Force (Far East). 320 pp.
- Fosberg, F.R. 1957. Description and occurrence of atoll phosphate rock in Micronesia. *American Journal of Science*, 255, 584-592.
- Fosberg, F.R., ed. 1963. *Man's place in the island ecosystem*. Honolulu: Bishop Museum Press. 264 pp.
- Fosberg, F.R. 1956. Northern Marshall Islands land biota: birds. *Atoll Research Bulletin*, 114, 1-35.
- Fosberg, F.R. 1988. The vegetation of Bikini Atoll 1985. *Atoll Research Bulletin*, 315, 1-28.
- Fosberg, F.R. 1990. A review of the natural history of the Marshall Islands. *Atoll Research Bulletin*, 330, 1-100.

- Fosberg, F.R. and Carroll, D. 1965. Terrestrial sediments and soils of the northern Marshall Islands. *Atoll Research Bulletin*, 113, 1-156.
- Fosberg, F.R. and Renvoize, S.A. 1980. *The Flora of Aldabra and neighbouring islands*. *Kew Bulletin*, Additional Series, 7, 1-358.
- Fosberg, F.R. and Sachet, M.-H., eds. 1953. Handbook for Atoll Research (second preliminary edition). *Atoll Research Bulletin*, 17, 1-129.
- Fosberg, F.R., Sachet, M.-H. and Oliver, R.L. 1979. A geographical checklist of the Micronesian Dicotyledonae. *Micronesica*, 15, 41-295.
- Fosberg, F.R., Sachet, M.-H. and Oliver, R.L. 1982. Geographical checklist of Micronesian Pteridophyta and Gymnospermae. *Micronesia*, 18, 23-82.
- Fosberg, F.R., Sachet, M.-H. and Oliver, R.L. 1987. A geographical checklist of the Micronesian Monocotyledonae. *Micronesica*, 20, 19-129.
- Fosberg, F.R., Sachet, M.-H. and Stoddart, D.R. 1983. Henderson Island (southeastern Polynesia): summary of current knowledge. *Atoll Research Bulletin*, 272, 1-47.
- Fosberg, F.R. and Stoddart, D.R. 1991. Plants of the reef islands of the northern Great Barrier Reef. *Atoll Research Bulletin*, 348, 1-82.
- Gessler, C. 1937. *Road my body goes*. New York: John Day, Reynal and Hitchcock. xx, 362 pp.
- Gessler, C. 1943. *The leaning wind: the story of a voyage in the South Pacific*. New York: D. Appleton Century. xii, 267 pp.
- MacArthur, R. and Wilson, E.O. 1967. *The theory of island biogeography*. Princeton: Princeton University Press. 203 pp.
- McCutcheon, M. 1991. Contents list and indexes for the *Atoll Research Bulletin*. *Atoll Research Bulletin*, 347, 1-145.
- Newell, N.D. 1954a. Expedition to Raroia, Tuamotus. *Atoll Research Bulletin*, 31, 1-22.
- Newell, N.D. 1954b. Reefs and sedimentary processes of Raroia. *Atoll Research Bulletin*, 36, 1-35.
- Niering, W.A. 1956. Bioecology of Kapingamarangi Atoll, Caroline Islands: terrestrial aspects. *Atoll Research Bulletin*, 49, 1-32.
- Revelle, R. 1954. Foreword. *U.S. Geological Survey Professional Papers*, 260-A, iii-vii.
- Sachet, M.-H and Fosberg, F.R. 1956. *Island Bibliographies: Micronesian botany, Land environment and ecology of coral atolls, Vegetation of tropical Pacific islands*. Washington, D.C.: National Academy of Sciences–National Research Council Publication 335, 577 pp.

- Sachet, M.-H. and Fosberg, F.R. 1971. *Island Bibliographies Supplement: Micronesian botany, Land environment and ecology of coral atolls, Vegetation of tropical Pacific islands*. Washington, D.C.: National Academy of Sciences. 427 pp.
- Wiens, H.J. 1956. The geography of Kapingamarangi Atoll. *Atoll Research Bulletin*, 48, 1-86.



ECOLOGICAL RESEARCH ON CORAL ATOLLS¹

F. RAYMOND FOSBERG²

Coral atolls, scattered over a large part of the tropical seas of the world, provide a natural laboratory for research in tropical ecology that is unique and that has scarcely been utilized. Although a certain amount of marine research has centered around atolls, their biota is so simple that it has not attracted much attention from students of land ecology. However, this very simplicity provides a situation almost ideal for studies of total environment and of human adaptations to and effects upon an environment.

Ecological research may take many forms. Essentially, ecology is a point of view from which almost any subject matter may be considered, that which emphasizes the interrelationships of living things and their environments. One of the most interesting types of such research is the study of a situation to determine what organisms inhabit it, what effects the various characteristics of the situation have upon them, what effects they have on the physical surroundings, and, finally, what effects they have upon each other. This applies not only to individuals of different kinds, but also to members of one population of the same kind. The most severe competition of all is that between members of the same population. Further it must not be overlooked that man is, of all the kinds of organisms in almost any situation, the one that exerts the strongest and most general influence.

Situations are usually selected for study because they are representative of a class of similar ones, so that the results of the research may be applied to the others of the class and may be compared with the results of similar studies of other representatives to arrive at generalities. As in many other fields, the ecologist studying situations is able to adopt either of two very different approaches, that of studying one or a few examples intensively, or that of studying many examples but much less thoroughly. Which of these approaches is best is a philosophical question that is not likely to be solved very soon. It seems unquestionable, however, that where both methods may be applied to one problem, the results will be more sound than those from either one or the other.

The complexities dealt with by ecology are probably greater than those facing any other science. Involved are, necessarily, a complete knowledge of the physical situation and the organisms in it, and their characteristics, requirements, and behavior. This is merely basic information. Then the innumerable processes taking place must be detected and understood. Finally, the effects of these processes on each other and on the various organisms must be determined, and an understanding of the resultant of all of these processes and effects arrived at, which should be an understanding of the situation itself. This ideal final product, this understanding of total environment, is the ultimate objective of ecological research.

Its value is so apparent that it scarcely needs to be pointed out. Such understanding furnishes the only real basis for complete control over a situation, the only basis for predicting the consequences of any use or any alteration of any factor in an

¹This paper was first published in *Atoll Research Bulletin*, 1 (1951), 6-8.

²Department of Botany, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

environment, and the only possible basis for any rational sustained program for permanent habitation of any area by man or his dependent organisms. In other words, it is the only completely sound foundation for conservation and management of any segment of the total resources of the world we live in.

Most ecology gives the impression of being mired down in such a mass of complexity as to be getting nowhere, or of dwelling on single items out of context of the web of which they are a part. This is a logical result of the enormous complexity of almost all situations, and is likely to be extremely discouraging to one who has vision enough to see the whole picture.

The logical way out seems to be to begin with some of the simpler classes of situations. An understanding of some of these may well provide the methods and basis for approaching more complex ones. And, indeed, such an approach seems to have given the best results so far. The ecology of the far north, of deserts, of ponds and lakes, of certain grasslands, and of moorlands has made the most substantial progress.

Coral atolls provide another class of such simple situations, and one of the few possible ones in the tropics.

One of the reasons why a study of total environment is one of the most refractory and difficult of all lines of investigation is that it does not lend itself readily to an experimental approach, as the very process of experimentation will certainly modify the environment being studied. Ordinary experimental technique consists of keeping certain variables constant and manipulating others, in order to ascertain their effects. The nearest thing to a possibility of such an approach in studies of total environment is in a type of natural situation where certain factors are reasonably constant while others differ in various examples.

Coral atolls present nearly an ideal set of such situations. They are flat, eliminating all of the variables commonly associated with altitudinal differences. They are tropical and oceanic, eliminating significant temperature differences. They are calcareous, eliminating most significant substratum differences. They are structurally simple, minimizing hydrologic complexities. Their flora and fauna are small, reducing biological influences and making the biotic communities relatively simple. Thus a fairly understandable basic ecological pattern is discernible. Over this are laid variations in precipitation, size of island, distance from geographic sources of fauna and flora, period of human occupancy, cultural character of human occupancy, etc.

Understanding of the effects of these variable factors and of the functional dependencies between them and other factors may be approached by making comparative studies of several different atolls exemplifying differences in such variables as mentioned above. Comprehensive studies, such as those made on Arno by a team of workers, would be highly significant if available in advance for, say, a small dry atoll in the central Pacific, a small moist atoll in the central Pacific, a moderate sized moist atoll remote from large land areas such as in the Tuamotus, an uninhabited moist atoll, possibly Maria in the Australs, and an atoll near large land areas, such as one in the Melanesian area, i.e. Sikaiana.

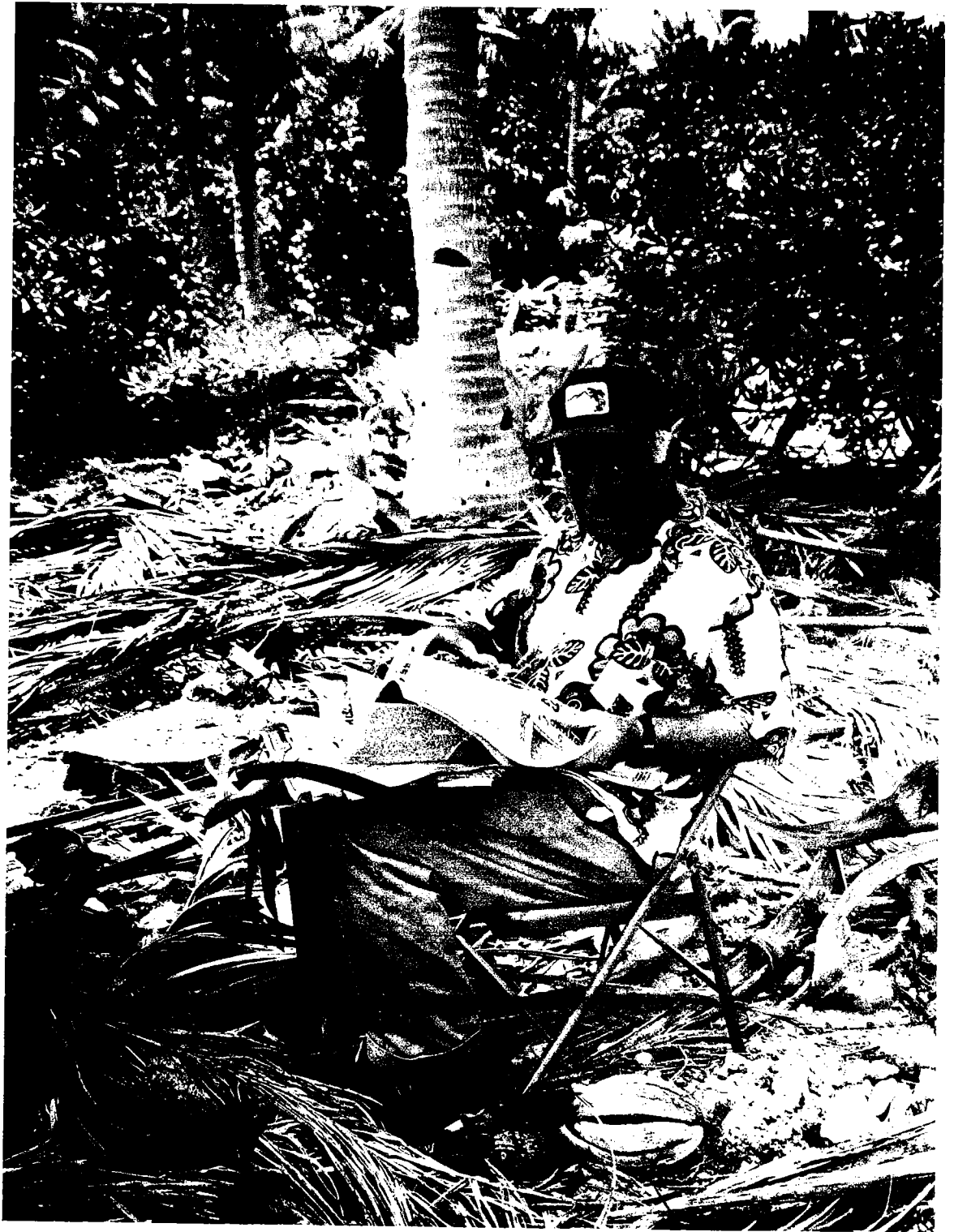
If, over a period of several years, such a series of detailed, integrated investigations might be made, a fairly broad base of modern reliable comparative information would be established. Into this would be integrated the enormous amount of existing information being brought together by the bibliographic phase of the investigation. As a result it might be possible that a coherent and understandable picture

of a limited tropical total environment would emerge, comparable to that developed for English mountains and moorlands by Pearsall (1949).

The significance of this in terms of human values is quite clear. There is no question that, in spite of the limitations of this atoll type of environment, human populations are going to live there, just as they have for many hundreds of years, at least. Atoll peoples had, left to themselves, evolved a mode of life very well fitted to this environment, and in a fair equilibrium with it. Though rigorous and simple, it was, so far as we may know, a happy and satisfactory existence. These people had come to terms with their environment and made the necessary adaptations for life in it.

During the past century and a half, expanding Western European Civilization has burst in upon these self-contained microcosms, inevitably shattering the equilibria established over the previous centuries. Disease, an altered religion, commerce, war, and confusion were the gifts of this alien culture. To some this change may be a matter of regret, to others merely a matter of intellectual interest, to still others it is moral elevation, while some call it "progress". At any evaluation it must be accepted as a fact, and as irreversible. Modern transportation has become so effective that isolation, even for these remote atolls, no longer exists. The influence of western culture must now be reckoned with as a factor in any new equilibrium that is brought into being. Life for these peoples is thereby enormously complicated.

If modern science is to be of any real benefit to these peoples, as well as to others, it is probable that it must be in helping them to come to terms again with their environment, the new environment that has resulted from the shattering of the old. It is here that ecology, particularly the aspect of it dealing with understanding of total environment, is of vast importance. Understanding is certainly the first requisite toward dealing with anything. If this study of atolls contributes, over the years, to the readaptation of atoll peoples to their place in the world, as well as providing a key to the understanding of other, more complex total environments, it will have amply justified itself.



PACIFIC OCEANIC ISLAND BIODIVERSITY IN A GEOHISTORIC PERSPECTIVE¹

BY F. RAYMOND FOSBERG²

Cosmologists, geophysicists, geologists, paleontologists and evolutionists—speculators all beyond their own sciences—have given us a scenario of an earth starting as a featureless accumulation of matter, showing a continuing, possibly at times interrupted, increase of diversity. At first, apparently, contracting and consolidating into a lifeless globe, the earth eventually differentiated into a lithosphere, hydrosphere and atmosphere, intercepting energy from the sun. At some period in its first few billions of years, the right assemblage of carbon and nitrogen compounds, with hydrogen and oxygen, occurred, and what we know as life began. Catalytic influences stimulated the formation of amino-acids, protein chains, and, eventually, photosynthetic pigments that fixed energy from sunlight. Aggregations of these compounds occurred that became autocatalytic, self-reproducing, and the wondrous spectacle of life and organic evolution began.

Meanwhile, physical diversity of the earth's surface developed, providing different environments for the simple bits of akaryotic protoplasm to inhabit. Cell-walls and membranes somehow came into being, enclosing self-reproducing bits of autophytic protoplasm, now called cells. A next step, providing a mechanism for much greater evolution of diversity, was the appearance of karyotic cells with nucleus and chromosomes. As diversity further developed, different habitats harbored the living cells and colonies of cells, and the different habitats selected variants of these organisms with different adaptations to match the habitats. The reproductive potential of some of these variants began to exceed the available habitats. Competition and natural selection began. All of this during hundreds of millions or perhaps several billions of years. The earth cooled, dry land appeared, compounding the opportunity for diversity. Meanwhile, even before the appearance of karyotes, some of the kinds of cells acquired the character of forming hard calcareous or siliceous cell walls, and, dying, leaving their shells to become the earliest fossils.

With natural selection, more than chance diversification came into being. Evolution became a process, more and more multidirectional. More of its products left skeletons, and even chemical impressions, as fossils, and some of the speculations of future evolutionists became founded on the beginnings of factual bases. With mitosis, multicellular organisms, and sexual reproduction, evolutionary diversity or biodiversity proliferated in all directions and in all dimensions. Of course, all along, the majority of forms evolved were incapable of self-sustainment and disappeared. And the diversity of habitats could not possibly keep up with the geometrical increase of forms of organisms. So limits of habitat diversity came to limit organic or biological diversity. The ecosphere or thin layer of habitable space on the earth's surface became populated with millions of species and untold millions of competing individuals.

¹This is the text of a plenary address at the XVII Pacific Science Congress, Honolulu, Hawaii, May 1991. It has been published in the *Proceedings* of the Congress, pp. 71-73, and is reprinted with permission.

²Department of Botany, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Geographical diversification had also been going on for geological aeons, some ages after Pangaea separated into continents, and the earth's crust into infinitely slowly moving tectonic plates. More familiar global geography began to appear. Eventually, after some ages of continental movement and rearrangement, the Pacific Ocean and Pacific basin slowly took shape, the Pacific Ocean came into being, and our Pacific scenario began. By this time there were myriads of organisms, a few of which left fossilized remains. These, when studied, helped fill in the details, but the big picture is reconstructed by what I call *physiographic fossils*.

These take such forms as wrinkles in the earth's crust, mountain chains, island arcs, chains of seamounts and guyots, subduction zones, earthquake foci, extinct volcanoes, coral atolls, elevated coral islands, mid oceanic ridges, and deposits of sediments on the sea floor. Interpreting these, our geophysicists can tell us now far more about the geohistory of the Pacific segments of the earth's crust and surface than anyone could have dreamed of when I first became interested in Pacific phenomena more years ago than I like to realize. If they want to, some of them can even tell us this in terms that an ordinary educated person can understand.

To come to the subject of this paper, we even know now something of how oceanic islands came into being. True oceanic islands are those that have never had any connection with continental land or major islands. They are all, with several controversial exceptions, volcanoes that arose from the ocean floor and reached the sea-surface. In the Pacific area these volcanoes can mostly be sorted into two classes—basaltic shield volcanoes, and andesitic cones. The shield volcanoes occur in the interiors of the Pacific and other tectonic plates. The cones are along the plate margins, where one plate is slipping under the edge of another, a process called subduction. Magma formation and diversification takes place in these contacts. Volcanoes and earthquakes are numerous in such zones.

The shield volcanoes apparently occur where a weak portion of a plate moves over a "hot spot", a place in the earth's mantle that serves as a conduit, where intense energy from the earth's interior comes through, where the heat is sufficient to melt the overlying rock into magma, a liquid rock. This pours out through vents or fissures in the sea-floor and, over the millions of years, builds up piles of solidified magma, or lava, which reach the sea-surface as island volcanoes. All of this geophysical activity is on an incredibly slow time-scale, but continually contributes to geographic diversity. This provides new habitats to accommodate and stimulate new biodiversity.

As the vast Pacific took shape, volcanoes on the sea floor may already have been forming. We have little or no information on what was happening there before perhaps 70,000,000 years ago. We can be reasonably sure though that a diversity of marine life occupied the Pacific Ocean from its beginning. We can speculate, also, that terrestrial plants and animals inhabited the surrounding land-masses, and that currents, storm winds and birds carried propagules into this watery space. How early there were islands there to be populated we can only guess. But volcanic islands did start to form, and evidence of them still exists in the form of seamounts and guyots, as well as coral atolls, the most ancient existing oceanic islands.

We can visualize a time, many millions of years ago, when there were new volcanic islands irregularly scattered in the Pacific, mostly bare lava-dome surfaces, with little environmental diversity, but beginning to erode and subside, terrestrial living organisms were probably there, but very thinly scattered indeed. The few different habitats that existed at first were suitable only for the most extreme pioneer forms. Spores of cryptogamic plants were, in all probability, the earliest propagules to arrive

and the likeliest to find conditions that permitted survival. Those of species with photosynthetic capacity would, of necessity, have been the first successful colonists, but likely would have been simple, probably unicellular plants, but capable of creating minute amounts of organic matter. More complex plants, hermaphroditic or monoecious, capable of reproducing themselves and utilizing the products of rock-weathering and the slight traces of organic matter would have "soon" followed, forming eventually a very simple vegetation and habitats for decomposers and pioneer animals which could consume or decompose raw organic matter. Simple, open ecosystems thus formed would have permitted more diverse colonists to survive. In these open habitats, with little or no competition, organisms with reasonable mutation rates might well have experienced relatively rapid evolution and, as habitats diversified, rapid diversification. Early island faunas and floras may have evolved relatively rapidly, in terms of thousands or millions of years. Every now and then, new and more advanced colonists might have arrived from the surrounding continental areas, to help colonise the increasingly numerous distinct habitats. These new arrivals might also have taken advantage of unoccupied niches, undergoing adaptive radiation and effecting more thorough utilization of available resources.

These early islands, of course, meanwhile underwent erosion and subsidence. Their faunas and floras would, as they developed, be sources for colonists for other islands, young or old. A Pacific terrestrial biota developed through such processes, and diversity increased, though islands eventually may have disappeared and new ones formed.

Because enormous water-barriers existed to slow down migration, this biota, and its sub-biotas, were never large. Nor was it as completely "harmonic" (with a full representation of the plant and animal families and orders) as those of continental regions, nor was change as rapid. Niches tended to remain broader, and some perhaps vacant.

The above, perhaps somewhat fanciful, history brought about the relatively recent major pattern, for which we now have much better evidence than imagined for the earlier stages.

We now had an ocean of its present size and configuration, with a large assortment of islands in all stages of formation, development and decline. Biotas resulting from original colonization from all surrounding regions were, after long isolation, largely endemic ancient relicts, presently flourishing, and newly evolving groups of plants and animals. There was not the great diversity found on continents, but a unique diversity, peculiar to island situation. The formative and declining processes were going on, slowly, as they had for ages. Some species were more dominant, some less, others rare and tenuously hanging on; most were endemic, found nowhere else.

The stage was set for Man, the dominant organism, to arrive on the scene.

Man, of diverse races, had been in the continental and continental island areas around the western Pacific for many thousands of years, in Australia, New Guinea, Malesia, southeast Asia, the Philippines and east Asia. Immigration of a number of very different racial stocks and much differentiation of local races had taken place. For a long time, apparently the wide water barriers between the continental areas and the oceanic islands were effective, and the oceanic islands lacked human inhabitants. But 4000 or more years ago several different cultural groups developed the arts of canoe-building and navigation to the point of making long voyages, and Micronesia and Polynesia were thoroughly explored and the habitable islands populated. Several different cultural complexes developed. The most widespread and one of the most culturally advanced

were the Polynesians who visited and settled islands as far-flung as Hawaii, the Marquesas, Easter Island and New Zealand. Some think, with good reason, that they have even reached South America.

This penetration of the erstwhile isolated and slowly changing oceanic islands brought profound changes. The new culture brought an abrupt increase in a new kind of diversity that associated with human activity. New plants and animals came with the human immigrants. Forests were cleared in the lowlands. Organisms requiring specialized habitats were displaced and disappeared. New plant communities involving exotics were assembled. New ecosystems, including human beings, were established, and as the newcomers multiplied, displaced certain indigenous ones. Birds, which were an important element in the pre-human ecosystems, became scarcer and many species disappeared, as man was also an effective predator. There may have been a net gain in diversity, but diversity was lost as well as gained. In any event, there were great changes, and many organisms, especially large and conspicuous ones, became extinct. Even now, their bones are being excavated and studied. The full extent of this loss may never be known. However, most of the uplands did not change much. For a long time mainly the coastal areas and valley bottoms were inhabited by humans. Of larger vertebrates, other than birds and marine animals, totally lacking up to now, only the dog, pig and chicken came with the people. The rat came too.

Island floras and faunas were conspicuously lacking in defensive mechanisms against herbivorous invaders. Spines, prickles, stinging hairs, acrid or poisonous sap, bad odors, were only found in clearly recent colonists which brought these features with them. Many island birds were flightless or ground nesting. Thus pigs and dogs could have a serious effect on the native biota. The extent of these effects are only recently becoming known, with paleontological studies, especially on deposits of fossil bird bones. The extent and environmental effects of ancient Hawaiian agriculture have recently been demonstrated by Patrick Kirch to have been much more widespread and to have had more influence than previously suspected.

Not much is known of the period between the spread of aboriginal people through Polynesia and Micronesia and the coming in the 15th to 18th centuries of European explorers. It seems certain that natural biodiversity declined some, but some degree of equilibrium may have been reached. All too little was recorded, by the first explorers, of environmental conditions at the time of European contact.

The arrival of Europeans brought vast and drastic changes to the Pacific islands. The cultural impact resulted in changes in life style, new implements, weapons, alcohol, religion, and a cash economy. A different attitude towards the environment resulted in over-exploitation, loss of indigenous natural diversity, substitution of a new diversity comprising European architecture, plantation agriculture, new economic plants and domestic animals, which went feral, and accompanying weeds and diseases. Ultimately came modes of transportation, machinery, and imported food and goods, worst of all a disdain for the old ways of life. Aboriginal populations declined and were replaced by immigrants.

In terms of effects on natural or biological diversity, probably the most serious complex of occurrences was the escape and naturalization of domestic herbivores and introduction and naturalization of exotic plants—edible ones, cultivated ornamentals, and weeds.

Most native vegetation types were closed forests, with the environmental or ecological niches mostly fully occupied. This vegetation was relatively stable, well

adjusted to its habitats. However, the history of complete lack of large herbivores had resulted in no natural defenses or protection against their trampling or browsing. Uninterfered with, the native forests were seldom invaded by exotics. Pigs had come with the aborigines and had initiated some disturbance. The introduction by the Europeans of cattle, goats, sheep, donkeys, horses, and, later, deer had a catastrophic effect. The forests were opened up, trampled, browsed, their structure broken down. This in itself initiated accelerated erosion. But the main effect was to permit the establishment of exotic plants, which, with continued effects of trampling and browsing, tended to out-compete and supplant the native species, and change the character of the vegetation. Goats, especially, over browsed both native and introduced plants, exposing the soil and deeply weathered rock to erosion, preventing revegetation. Floods occurred, streams became intermittent, coral reefs were silted and killed.

The fascinating indigenous floras, with numerous unique endemic species and even genera, were gradually replaced by the widely distributed pantropical flora.

Wherever there were fairly large, relatively flat and fertile lowland areas, their vegetation was completely replaced by coconut, sugar and pineapple plantations. Some areas, even small ones, were occupied by human habitations, industry, roads, towns and cities. Human occupation crept up the lower slopes, already altered to exotic rather than native vegetation.

Introduced bird diseases, rats, mongooses, and aggressive exotic birds eliminated lowland bird faunas and even some from the mountain slopes. Exotic birds were introduced and became established.

Even mountain peaks were utilized for beacons, relay stations and observatories, with roads built to them.

We have not mentioned military establishments and weapons, among the most wasteful and destructive of all human activities. These introduced some types of diversity, but wiped out many forms of indigenous biological diversity.

It is hard to estimate the net loss or gain of total diversity. The concept is hard even to define when applied to cultural effects. "Civilization" has, without doubt, brought about great decline and loss in biodiversity, most of it never to be regained.

Fortunately in very recent years there has grown a rather wide concern about loss of biodiversity, and efforts are being made to slow down or even prevent further loss, where practical. However, money concerns are much stronger than those about environmental matters. Almost always, money wins. Unless this attitude changes soon, most important islands, as well as general diversity, may disappear. A dreary world will be the result, at best. Granted the worst scenario, we may not even be here to experience it.

MAJOR PUBLICATIONS OF F. RAYMOND FOSBERG ON TROPICAL ISLANDS AND CORAL ATOLLS: A SELECTED LIST

[Note: this list does not include any of Dr. Fosberg's shorter taxonomic papers]

The genus *Gouldia*.

Bulletin of the Bernice P. Bishop Museum, 47 (1937), 1-82.

Some Rubiaceae of southeastern Polynesia.

Occasional Papers of the Bernice P. Bishop Museum, 13 (1937), 245-293.

Melanesian vascular plants.

Lloydia, 3 (1940), 109-124.

The Polynesian species of *Hedyotis*.

Bulletin of the Bernice P. Bishop Museum, 174 (1943), 1-102.

Micronesian mangroves.

Journal of the New York Botanic Garden, 48 (1947), 128-138.

Végétation et flora de l'atoll Maria, îles Australes.

Révue scientifique du Bourbonnais et du Centre de la France, 1951 (1952), 1-7.

Vegetation of central Pacific atolls: a brief summary.

Atoll Research Bulletin, 23 (1953), 1-26.

Soils of the northern Marshall atolls, with special reference to the Jemo Series.

Soil Science, 78 (1954), 99-107.

Northern Marshall Islands Expedition, 1951-1952. Narrative.

Atoll Research Bulletin, 38 (1955), 1-36.

Northern Marshall Islands Expedition, 1951-1952. Land biota: vascular plants.

Atoll Research Bulletin, 39 (1955), 1-32.

Island Bibliographies: Micronesian Botany, Land environment and ecology of coral atolls, Vegetation of tropical Pacific islands [with M.-H. Sachet].

National Academy of Sciences—National Research Council Publication 335 (1955), 577 pp.

The palms of Micronesia and the Bonin Islands [with H. E. Moore].

Gentes Herbarum, 8 (1956), 422-478.

Military Geography of the northern Marshall Islands.

Tokyo: Intelligence Division, Office of the Engineer, Headquarters U.S. Air Force (Far East) (1956), 320 pp.

Atoll Research Bulletin 355 (1992), 19-24.

Description and occurrence of atoll phosphate rock in Micronesia.
American Journal of Science, 255 (1957), 584-592.

Vegetation and flora of Wake Island.
Atoll Research Bulletin, 67 (1959), 1-20.

The vegetation of Micronesia.
Engineer Intelligence Study 257 (1959), 160 pp.

Vegetation [of Guam].
Military Geology of Guam, Mariana Islands, ed. J. I. Tracey, Jr. (Intelligence Division, Office of the Engineer, HQ U.S. Army Pacific) (1959), 167-217.

The vegetation of Micronesia. 1. General descriptions, the vegetation of the Marianas Islands, and a detailed consideration of the vegetation of Guam. *Bulletin of the American Museum of Natural History*, 119 (1960), 1-76.

Vegetation [of Ishigaki-Shima].
Military Geology of Ishigaki-Shima, Ryukyu-Retto, ed. H. E. Foster (Intelligence Division, Office of the Engineer, HQ U.S. Army Pacific) (1960), 51-84.

Vegetation [of the Miyako Archipelago].
Military Geology of the Miyaki Archipelago, Ryukyu-Retto, ed. D. B. Doan (Intelligence Division, Office of the Engineer, HQ U.S. Army Pacific) (1960), 165-187.

Qualitative description of the coral atoll ecosystem.
Atoll Research Bulletin, 81 (1961), 1-11.

Description of Heron Island.
Atoll Research Bulletin, 82 (1961), 1-4 .

Vascular plants of Heron Island [with R. F. Thorne].
Atoll Research Bulletin, 82 (1961), 5-13.

Soils, flora and vegetation [in: A report on typhoon effects upon Jaluit Atoll].
Atoll Research Bulletin, 75 (1961), 47-49, 51-55, 57-68, 95-104 .

Vascular plants recorded from Jaluit Atoll [with M.-H. Sachet].
Atoll Research Bulletin, 92 (1962), 1-39.

A brief study of the cays of Arrecife Alacran, a Mexican atoll.
Atoll Research Bulletin, 93 (1962), 1-25.

Man's place in the Island Ecosystem: a Symposium [organized and edited by F. R. Fosberg]. Honolulu: Bishop Museum Press (1963), 264 pp.

The Island Ecosystem.
Man's place in the Island Ecosystem: a Symposium, ed. F. R. Fosberg (Honolulu: Bishop Museum Press) (1963), 1-6.

Terrestrial sediments and soils of the northern Marshall Islands [with D. Carroll].
Atoll Research Bulletin, 113 (1965), 1-156.

Northern Marshall Islands land biota: birds.
Atoll Research Bulletin, 114 (1966), 1-35.

List of Addu vascular plants [with E. C. Groves and D. C. Sigee].
Atoll Research Bulletin, 116 (1966), 75-92.

The oceanic volcanic island ecosystem.
The Galapagos, ed. R. I. Bowman (Berkeley: University of California Press), 55-61.

Vascular plants.
Atlas for bioecology studies in Hawaii Volcanoes National Park, ed. M. S. Doty and D. Mueller-Dombois (Hawaii Botanical Society Papers, 2) (1966), 153-238.

Observations on vegetation patterns and dynamics on Hawaiian and Galapageian volcanoes.
Micronesica, 3 (1967), 129-134.

Wake Island vegetation and flora [with M.-H. Sachet].
Atoll Research Bulletin, 123 (1969), 1-15.

Plants of Satawal Island, Caroline Islands.
Atoll Research Bulletin, 132 (1969), 1-13.

A collection of plants from Fais, Caroline Islands [with M. Evans].
Atoll Research Bulletin, 133 (1969), 1-15.

Preliminary survey of Aldabra vegetation. *Philosophical Transactions of the Royal Society of London*, B 260 (1971), 215-225.

Geomorphology of Aldabra Atoll [with D.R. Stoddart, J.D. Taylor and G.E. Farrow].
Philosophical Transactions of the Royal Society of London, B 260 (1971), 31-65.

List of Diego Garcia vascular plants [with A.A. Bullock].
Atoll Research Bulletin, 149 (1971), 143-160.

The fern vegetation of Aldabra Atoll.
American Fern Journal, 61 (1971), 97-101.

Island Bibliographies Supplement: Micronesian Botany, Land environment and ecology of coral atolls, Vegetation of tropical Pacific islands [with M.-H. Sachet].
 Washington, D.C. National Academy of Sciences (1971), 427 pp.

Geomorphic cycle on Aldabra—hypothesis.
Proceedings of the Symposium on Corals and Coral Reefs (Marine Biological Association of India, Mandapam Camp, 1969) (1972), 469-475.

List of vascular plants [of Rarotonga reef islands].
Atoll Research Bulletin, 160 (1972), 9-13.

South Indian sand cays [with D.R. Stoddart].
Atoll Research Bulletin, 161 (1972), 1-23.

Partial flora of the Society Islands: Ericaceae to Apocynaceae [with M.L. Grant and M.-H. Sachet].

Smithsonian Contributions to Botany, 17 (1974), 1-69.

Flora of Micronesia. 1. Gymnosperms [with M.-H. Sachet].

Smithsonian Contributions to Botany, 20 (1975), 1-15.

Phytogeography of atolls and other coral islands.

Proceedings of the Second International Symposium on Coral Reefs, 1 (1975), 389-396.

Flora of Micronesia. 2. Casuarinaceae, Piperaceae, and Myricaceae [with M.-H. Sachet].

Smithsonian Contributions to Botany, 24 (1975), 1-28.

Identification of vascular plants of Namoluk Atoll, Eastern Caroline Islands.

Atoll Research Bulletin, 189 (1975), 23-48 .

Coral island vegetation.

Biology and Geology of Coral Reefs, ed. O. A. Jones and R. Endean (New York: Academic Press) (1976), 3, 255-277.

Phytogeography of Micronesian mangroves.

Proceedings of the International Symposium on Biological Management of Mangroves (Gainesville, 1975), 1, 23-42.

Flora of the northern Marianas [with M. V. C. Falanruw and M.-H. Sachet].

Smithsonian Contributions to Botany, 22 (1975), 1-45.

Flora of Micronesia. 3. Convolvulaceae.

Smithsonian Contributions to Botany, 36 (1977), 1-34.

List of vascular plants [of Aitutaki reef islands, Cook Islands].

Atoll Research Bulletin, 190 (1975), 73-84.

Distribution of seagrasses in Micronesia [with R. T. Tsuda and M.-H. Sachet].

Micronesica, 13 (1977), 191-198.

A geographical checklist of the Micronesian Dicotyledonae [with M.-H. Sachet and R. L. Oliver].

Micronesica, 15 (1979), 41-295.

The Flora of Aldabra and neighbouring islands [with S. A. Renvoize].

Kew Bulletin, Additional Series, 7 (1980), 1-358.

Flora of Micronesia. 4. Caprifoliaceae-Compositae.

Smithsonian Contributions to Botany, 46 (1980), 1-71.

A Revised Handbook to the Flora of Ceylon [edited by M. D. Dassanayake and F. R. Fosberg].

New Delhi: Amerind Publishing Co. Volume 1 (1980), 508 pp. [subsequent volumes: 2 (1981), 511 pp.; 3 (1981), 499 pp.; 4 (1983), 532 pp.; 5 (1985), 476 pp.; 6 (1987), 424 pp.; 7 (1991), 439 pp.]

Cays of the Belize barrier reef and lagoon [with D. R. Stoddart and D. L. Spellman].

Atoll Research Bulletin, 256 (1982), 1-76 .

Bird and Denis Islands, Seychelles [with D. R. Stoddart].
Atoll Research Bulletin, 253 (1981), 1-76.

Topographic and floristic change, Dry Tortugas, Florida, 1904-1977 [with D. R. Stoddart].
Atoll Research Bulletin, 253 (1981), 1-76.

Cays of the Belize barrier reef and lagoon [with D. R. Stoddart and D. L. Spellman].
Atoll Research Bulletin, 256 (1982), 1-76.

Ten years of change on the Glover's Reef cays [with D. R. Stoddart and M.-H. Sachet].
Atoll Research Bulletin, 257 (1982), 1-38 .

Plants of the Belize cays [with D. R. Stoddart, M.-H. Sachet and D. L. Spellman].
Atoll Research Bulletin, 258 (1982), 1-77.

Species-area relationships on small islands: floristic data from Belizean sand cays [with D. R. Stoddart].
Smithsonian Contributions to Marine Science, 12 (1982), 527-539.

Geographical checklist of Micronesian Pteridophyta and Gymnospermae [with M.-H. Sachet and R. L. Oliver].
Micronesica, 18 (1982), 23-82.

The human factor in the biogeography of oceanic islands.
Comptes rendus sommaire des Seances de la Societe de Biogeographie de Paris, 59 (1983), 147-190.

Henderson Island (southeastern Polynesia): summary of current knowledge [with M.-H. Sachet and D. R. Stoddart].
Atoll Research Bulletin, 272 (1983), 1-47.

An ecological reconnaissance of Tetiaroa Atoll, Society Islands [with M.-H. Sachet].
Atoll Research Bulletin, 275 (1983), 1-67.

Natural history of Cousin Island.
Atoll Research Bulletin, 273 (1983), 7-38.

List of vascular flora of Agalega [with M.-H. Sachet and D. R. Stoddart].
Atoll Research Bulletin, 273 (1983), 109-142.

List of plants collected on Coetivy Island, Seychelles [with S. A. Robertson].
Atoll Research Bulletin, 273 (1983), 143-156.

List of plants collected on Platte Island, Seychelles [with S. A. Robertson].
Atoll Research Bulletin, 273 (1983), 156-164.

List of plants of Poivre Island, Amirantes [with S. A. Robertson].
Atoll Research Bulletin, 273 (1983), 165-176.

List of plants collected on Alphonse Island, Amirantes [with I. A. D. Robertson and S. A. Robertson].
Atoll Research Bulletin, 273 (1983), 177-184.

Vegetation and floristics of western Indian Ocean coral islands [with D. R. Stoddart].
Biogeography and Ecology of the Seychelles Islands, ed. D. R. Stoddart (The Hague: W. Junk) (1984), 221-238.

Phytogeographic comparison of Polynesia and Micronesia.
Bishop Museum Special Publications, 72 (1984), 33-44.

Present state of knowledge of the flora and vegetation of emergent reef surfaces.
Proceedings of the Fifth International Coral Reef Congress, 5 (1986), 107-112.

A geographical checklist of the Micronesian Monocotyledonae [with M.-H. Sachet and R. L. Oliver].
Micronesica, 20 (1987), 19-129.

Marie-Hélène Sachet: islands, atolls and reefs.
Atoll Research Bulletin, 293 (1987), 1-7.

Flora of Maupiti, Society Islands [with M.-H. Sachet].
Atoll Research Bulletin, 294 (1987), 1-70.

Flora of the Gilbert Islands, Kiribati, checklist [with M.-H. Sachet].
Atoll Research Bulletin, 295 (1987), 1-33.

Henderson Island: dedicated to S. Dillon Ripley.
Atoll Research Bulletin, 321 (1989), 1-3.

New collections and notes on the plants of Henderson, Pitcairn, Oeno, and Ducie Islands [with G. Paulay, T. Spencer and R. L. Oliver].
Atoll Research Bulletin, 329, 1-18.

A review of the natural history of the Marshall Islands.
Atoll Research Bulletin, 330 (1990), 1-100.

Plants of the reef islands of the northern Great Barrier Reef [with D. R. Stoddart].
Atoll Research Bulletin, 348 (1991), 1-82.

Phytogeography and vegetation of the reef islands of the northern Great Barrier Reef [with D. R. Stoddart].
Atoll Research Bulletin, 349 (1991), 1-19.

Plants of the Jamaican cays [with D. R. Stoddart].
Atoll Research Bulletin, 352 (1991), 1-24.