LIBRARIES
UNIVERSITY OF WISCONSIN–MADISON

Galapagos science: 1972 status and needs: report of Galapagos Science Conference, October 6-8, 1972, Washington D. C.. 1972

Simkin, Tom; Reeder, William G.; MacFarland, Craig
[Washington, D.C.]: [Smithsonian Instutution], 1972

https://digital.library.wisc.edu/1711.dl/C4LIVN67KQVVJ8X

This material may be protected by copyright law (e.g., Title 17, US Code).

For information on re-use see:
http://digital.library.wisc.edu/1711.dl/Copyright

The libraries provide public access to a wide range of material, including online exhibits, digitized collections, archival finding aids, our catalog, online articles, and a growing range of materials in many media.

When possible, we provide rights information in catalog records, finding aids, and other metadata that accompanies collections or items. However, it is always the user's obligation to evaluate copyright and rights issues in light of their own use.

728 State Street | Madison, Wisconsin 53706 | library.wisc.edu

Galápagos Science

1972 Conference

Edited by Tom Simkin

William G. Reeder

Craig MacFarland

Galapagos Science: 1972 Status and Needs

Report of Galapagos Science Conference
October 6-8, 1972, Washington, D. C.

edited by

Tom Simkin
Mineral Sciences
Smithsonian
Institution
Washington, D. C.

William G. Reeder
Dept. of Zoology
University of
Wisconsin
Madison, Wisconsin

Craig MacFarland
Dept. of Zoology
University of
Wisconsin
Madison, Wisconsin

sponsored by

National Science Foundation
Smithsonian Institution
University of Wisconsin

TABLE OF CONTENTS

ABSTRACT

The Galapagos Islands offer vast opportunities for scientific research. The archipelago includes some of the more volcanically active oceanic islands of the world, whose geological histories are basic to evolutionary studies of their biology. Youthful oceanic islands with their relatively simple ecosystems provide exciting challenges to students of evolutionary and ecological processes and invite comparisons with more complex continental situations. In contrast to most areas of the world, these islands have been minimally disturbed and a few remain in their pristine condition. The extremely fragile environment characteristic of such regions is now threatened by introductions of exotic species and rapidly growing numbers of both resident and transient humans. Conservation efforts in the Galapagos can offer an instructive case study for many other areas of the world.

Scientific interest and activity have increased greatly in the Galapagos in the past 15 years, but most of the research has been uncoordinated. Since field research facilities, scientific manpower, and funding for Galapagos research are all notably limited, it seemed wise in 1972 to: (1) make a critical assessment of the current status of Galapagos science, (2) identify the more important needs, and (3) discuss interdisciplinary cooperation toward meeting those needs. Accordingly, a two-day conference, funded largely by the National Science Foundation, was held at the Smithsonian Institution in Washington, D. C. in October, 1972. All 18 invited specialists, representing the main fields of Galapagos science, conservation, and the Ecuadorian Government, were able to attend.

Brief status summaries by the specialists, printed in this report as transcripts of opening remarks, clearly indicated that sea bird breeding ecology is the sole area of Galapagos science that has been rather thoroughly investigated. We are far from understanding either the past history or present dynamics of the Galapagos ecosystem as a whole or even its principal components.

Extensive discussions by the participants and working groups resulted in a number of priority recommendations for future research. These have been summarized and make up the heart of this report. Many of the recommendations will benefit almost all scientists and will aid conservation efforts as well (e.g., those concerning improved aerial photography, monitoring stations combining meteorological/geophysical instruments with conservation law enforcement, improved facilities and programs at the Charles Darwin Research Station, and summary compilation of specimen records, important field data, and bibliography).

Very basic research in almost all scientific fields is required. Examples of prime needs are: (1) accurate vegetation and geological maps, (2) meteorological data from varied parts of the islands, (3) quantification of the structure, successional relationships, and productivity of plant communities, (4) beginning of marine surveys, including a faunal survey, regular sampling of the littoral zone, and population studies of exploited species, (5) basic "alpha-level" systematic studies of many groups of terrestrial invertebrates, (6) long-term population and bioenergetic studies of many neglected terrestrial species, (7) studies of co-evolution of plants and animals (e.g., pollination systems), and (8) multidisciplinary, interinstitutional, collaborative studies of biological communities.

The conference helped to emphasize the interdependence of many scientific disciplines in the understanding of one simple oceanic setting. Virtually all of the recommended studies will contribute directly to improvement of conservation and management schemes.

INTRODUCTION

Background

The Galapagos Archipelago has been known since the 16th century. The history of the islands from their discovery until the 1950's is largely a tale of human exploitation of the unique fauna, flora, and habitats (see Townsend, 1925; Slevin, 1959).

The Archipelago became widely known to scientists primarily because of the observations of Charles Darwin, made during a one month visit there in 1835. From Darwin's time until the late 1950's, research in the islands consisted almost exclusively of a series of collecting expeditions from the United States and Europe, most of which occurred between 1890 and 1940. There were rare exceptions (e.g., Lack, 1947), but most of the effort was devoted to compilation of an inventory of the islands' flora and fauna and to study of plant and animal systematics based on these collections (see Slevin, 1959 for description of expeditions; Thornton, 1971 for bibliography). The inventory and descriptions were, of course, vital as a basis for further studies. However, until the 1960's advanced studies were almost completely lacking. Meanwhile, destruction of the islands' environment continued apace, by human exploitation and feral populations of domestic mammals.

In 1959, two events brought about the potential for reversal of these trends: (1) Ecuador declared all of the archipelago, excepting four relatively small inhabited areas, as a national park and enacted laws protecting the indigenous wildlife, and (2) the Charles Darwin Foundation for the Galapagos Isles was founded under the auspices of UNESCO and the International Union for the Conservation of Nature and Natural Resources. As an international organization, The Darwin Foundation was entrusted by the government of Ecuador with the establishment of a permanent field station in the islands, the Charles Darwin Research Station, and with the responsibility for preservation of the fauna, flora, and habitats of the archipelago.

By 1963, all of the Station's basic buildings were completed and it has since continued to grow in size and responsibility (see Dorst and Laruelle, 1967, for a summary of the Foundation's activities through 1966). It has three major functions:

(1) to cooperate with the Galapagos National Park Service (established in 1968; now ultimately responsible for all aspects of conservation in the islands) in conducting research on conservation problems,

(2) to serve as a conservation education center for both the local population and visitors,

(3) to serve as a support base for visiting scientific missions that conduct research in the islands.

At the present time, the National Park Service and the Darwin Station are attempting to deal with the following problems:

(1) Colonization. The population of the islands has tripled since 1960 and now numbers almost 5000. Fortunately, the lack of natural resources on most of the arid, smaller islands restricts the spread of the population. However, other more sensitive areas on some of the larger islands are

still threatened.

(2) Tourism. More tourists have visited the islands in the 1970's than in all previous years. The increase has been sudden and recent; for example, in 1969 approximately 100-200 visited the islands, whereas in 1972, 4000-5000 are expected. To date, the tourist companies have cooperated with the Station and the Park Service and demonstrated a responsible approach in conducting their operations. However, tourism will certainly increase and impact studies are urgently required. Ecuador recently established strict guidelines for tourist access and use of the islands, but enforcement remains a problem.

(3) Conservation. The Ecuadorian government is continuing to provide more personnel for the Park Service; however, the Park Service does and will continue to rely on the Station for scientific advice and for financial support for conservation programs and employment of wardens. The primary conservation problems remain the control or eventual elimination of feral mammal populations (pigs, dogs, goats, cats, black rats, cattle, donkeys, and others) and the protection and rehabilitation of native habitats and species.

(4) Research. The number of scientific missions visiting the islands has increased from six in 1965 to seventeen in 1971. The increase calls for additional facilities. There is an urgent need for the Station to employ full-time biologists and other scientists to conduct applied research in the areas of conservation, resource management, tourism impact, and others.

Kramer (1973) has presented a detailed account of the present status of both Charles Darwin Research Station (CDRS) and National Park Service (NPS) in a report to UNESCO.

Since its establishment, the Darwin Station has generally operated on a budget of less than $50,000 per year, the bulk of which has come from individual donations. A recently formulated, detailed, five-year plan (available upon request) has shown that the Station's budget will have to be increased markedly in order to accomplish the three objectives noted previously. This means that, as was true throughout the 1960's, basic research in the islands must be conducted by visiting scientific missions which are funded by other sources. This basic research - its stimulation, organization, and coordination - was the focal point of the conference.

While the large Galapagos International Scientific Project of 1964 (GISP; largely funded by NSF) resulted in a volume summarizing much of the research to that time (Bowman, 1966) as well as providing much new information, it served mainly to point out the paucity of long-term conclusive studies and the vast research needs and opportunities. The GISP stimulated many new research projects, but the situation remains qualitatively the same now. Although the quantity of basic research in the islands has greatly increased over the past decade, it has been largely uncoordinated and the projects undertaken have been as diverse in scale and subject as the individual specialists involved (for a summary of most research until the late 1960's see Bowman, 1966, McBirney and Williams, 1969, Thornton, 1971, and Wiggins and Porter, 1971).

CONFERENCE PROCEDURES

In 1972 we felt that the time was right to take stock of the current status of Galapagos science, to identify the more important needs and to discuss interdisciplinary cooperation toward meeting those needs. We proposed to gather specialists from all main fields of Galapagos science for a 2-3 day conference with the following stated objectives:

"(1) To assist in the budgeting of field research facilities (by Darwin Research Station), scientific effort (by interested specialists), and funding (by granting agencies): all these are now severely limited and we must strive to make the best use of our limited resources.

(2) To encourage the undertaking by specialists of those long-term, comprehensive studies which are most urgently required.

(3) To increase multidisciplinary cooperation among scientists working in the archipelago to the end that greatest use may be made of observational opportunities in the field."

The conference was held October 6 and 7 at the Smithsonian Institution, Washington, D. C. and one measure of its need was that each of the 18 invited participants was able to attend despite very short notice. With the addition of other, largely local, participants, we had 36 scientists present, representing over 20 aggregate years of field work in Galapagos and a wide range of specialities.

The conference was organized as follows:

1. After our initial welcome and introductions, each invited participant was asked to summarize the status of his field in Galapagos, paying particular attention to the gaps in our present knowledge. These short summaries provided a valuable overview or framework for the remainder of the conference. Tape recorded transcripts of these summaries have been edited by each speaker and are included here under the section entitled "Present Status of Galapagos Science."

2. The afternoon of the first day was then devoted to discussion by the full group: following the subject order of the morning summaries, but bringing out additions, corrections, and interdisciplinary aspects.

3. On the second morning we broke into small working groups, organized around the following general fields: plants, birds, invertebrates, vertebrates (other than birds), paleontology, marine science, and conservation. (Less classical groupings, such as "ecology," were found to be unworkable when it was recognized that nearly everyone in the room considered himself to be an ecologist.) There was considerable movement of people from group to group, but the objective was for each group to prepare a report drawing together the important points of previous discussions, including status, needs, interdisciplinary and educational aspects, and recommendations. These reports are included in Appendix II of this report.

4. Finally, in the closing hours of the conference, we came back together as a group to put forward and discuss the main recommendations of each working group.

All meetings of the full conference were transcribed from tape recordings and these, with working group reports, totalled some 260 pages. The authors have attempted to distill the essence of these pages into a short summary of recommendations that makes up the section entitled "Recommendations." We believe that these accurately reflect the feelings of the conference, but we bear full responsibility for any errors in condensation.

ACKNOWLEDGEMENT

All of us who participated in the conference found it a stimulating and valuable experience, and we hope that this report will help meet, in at least some small way, the objectives of the conference. We all owe thanks to the National Science Foundation, General Ecology Section, for the grant that made the conference possible (Grant Number GB 35749); to the Smithsonian Institution for hosting the conference and, with the University of Wisconsin, providing many services; to the latter institution, further, for waiving of overhead charges and providing disbursement; to UNESCO and the Charles Darwin Foundation for Dr. Kramer's expenses; to Lindblad Travel for the travel expenses of Dr. Harris; to Gayle Davis and Marsha Sitnik for translating our incoherent mumblings from tape to page; and to the participants, who gave so freely of their time and ideas.

PARTICIPANTS

Antonius, Arnfried. (Invertebrate Zoology). Smithsonian Institution, Postdoctoral Fellow.

Bertrand, Gerard. Council on Environmental Quality, Washington, D. C.

* Bowman, Robert I. (Biologist). Professor of Biology, California State University at San Francisco. Bowman's 1957 mission to the Galapagos led directly to the founding of the Darwin Foundation and he served as its First Secretary of the Americas as well as, in 1964 Co-director of the Galapagos International Scientific Project. Galapagos visits: '52/'53, '57, '61/'62, '64, '67, '68, and '72. Aggregate time = 2 1/2 years.

Brooks, John. General Ecology Section, National Science Foundation, Wash., D.C.

* Challinor, David. Assistant Secretary for Science, Smithsonian Institution, and Secretary for the Americas (Administration), Charles Darwin Foundation.

Child, C.A. (Crustacea). Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution.

* Colinvaux, Paul. (Historical Ecologist). Professor of Ohio State University. Leader of Ohio State Research Program in Galapagos. Galapagos visits: '66, '68, and '71. Aggregate time = 5 months.

* Coolidge, Harold. (Zoologist). Honorary President of IUCN. Founding Council Member of the Charles Darwin Foundation, and tireless worker for Galapagos conservation and science. Galapagos visit: 1964 dedication ceremony of the Charles Darwin Research Station.

Davis, Gayle. Office of Zoological Museum, University of Wisconsin.

* Dorst, Jean. (Ecologist). Deputy Director of Natural History Museum, Paris, and President of the Charles Darwin Foundation. Three Galapagos visits.

Fitter, Mrs. M.S. Editor of Oryx, London.

Fitter, R.S.R. Honorary Secretary, Fauna Preservation Society, London.

Gooding, Richard. (Invertebrate Zoology). Smithsonian Institution, Postdoctoral Fellow.

Gutermuth, C.R. President, World Wildlife Foundation, Washington, D. C.

* Harris, M.P. (Sea Bird Ecologist). Ecologist with Nature Conservancy, Scotland. Aggregate time = 4 years in Galapagos since 1965.

* Hedgpeth, Joel. (Marine Biologist). Professor and Director of Marine Science Center, Oregon State University. One month in Galapagos, 1968.

Huxley, Michael R. Special Assistant for International Scientific Affairs, Office of the Assistant Secretary for Science, Smithsonian Institution.

* Invited Participant

King, Warren. (Ornithology) . ICBP Affairs, Smithsonian Institution.

* Kramer, Peter. (Behavioral Biologist). UNESCO expert and Director of Charles Darwin Research Station (CDRS). One year in Galapagos in 1962/63 and two more as CDRS Director.

* Laso, Enrique. (Administrator). Director of Forest Service in Ecuador and responsible for Galapagos National Park. Several short visits to Galapagos.

* MacFarland, Craig. (Vertebrate Ecologist). Completing Ph.D. studies (on Galapagos Tortoise) at University of Wisconsin. Two years and 8 months in Galapagos since 1968.

Olsen, Storrs. (Ornithology). Smithsonian Institution, Postdoctoral Fellow

* Ortiz, Fernando. (Vertebrate Zoologist). Completing Ph.D. studies at University of California, Berkeley. Several visits since 1963 totaling 4 months and including work as CDRS Research Assistant.

Porter, Duncan. (Botany). Smithsonian Institution. 1-1/2 months in Galapagos in 1967.

Pritchard, Peter. (Sea Turtles). World Wildlife Foundation and University of Florida. Several visits to Galapagos since 1970.

Ray, Clayton. (Vertebrate Paleontology). Smithsonian Institution.

* Reeder, William. (General Ecologist). Professor of Zoology, University of Wisconsin and leader of Wisconsin's Galapagos Research Program. Seven months in Galapagos on 3 visits since 1968.

* Rick, Charles. (Geneticist, Tomatoes). Professor of Vegetable Crops, University of California, Davis. Three visits to Galapagos since 1956 totaling 8 months.

* Ripley, S. Dillon. (Ornithology). Secretary of the Smithsonian Institution and Founding Council Member of the Charles Darwin Foundation.

Sachet, Marie-Helen. (Botany). Smithsonian Institution.

Schmitt, Waldo L. (Marine Biologist). Zoologist Emeritus, Smithsonian Institution. Six visits to Galapagos, the most recent one in 1943.

Seater, Steven. World Wildlife Foundation, Washington, D.C.

* Silberglied, Robert. (Invertebrate Zoologist, Insect Pollination) . Completing Ph.D. studies at Harvard University. Six months in Galapagos in 1970.

* Simkin, Tom . (Geologist). Curator of Petrology and Volcanology, Smithsonian Institution, and Secretary for the Americas (Science) of the Charles Darwin Foundation. Five months in Galapagos in 1968, '70, and '71.

PARTICIPANTS

Sitnik, Marsha. Office of the Assistant Secretary for Science, Smithsonian Institution.

* Snow, David. (Ornithologist). Head of Bird Division at British Museum, Secretary and Scientific Advisory Committee of the Charles Darwin Foundation, and former Director of CDRS. Two visits including 1-1/2 years in Galapagos during 1963/64.

Whitmore, Frank. (Vertebrate Paleontology). U.S. Geological Survey, Washington, D.C.

* Wiggins, Ira. (Botany Systematics). Emeritus Professor of Biology at Stanford University. Two visits to island in 1964 and '67 totaling 3 months.

Candid photos of the Conference
taken by Robert Silberglied
follow . . .

Tom Simkin Bob Bowman

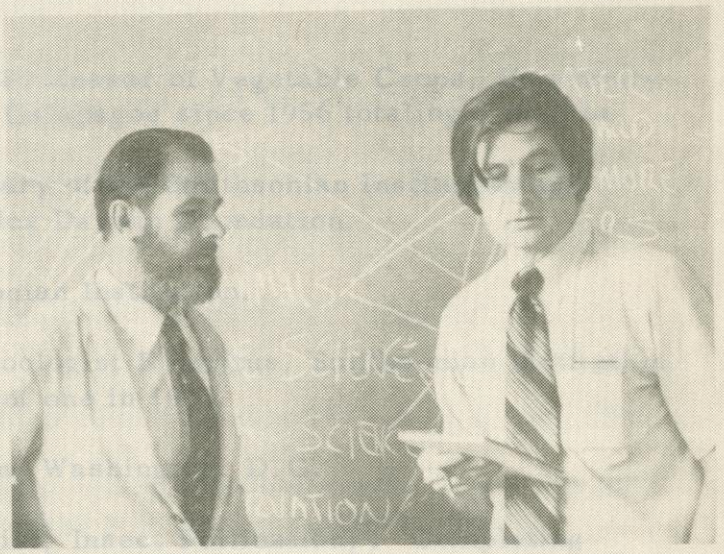
Fernando Ortiz, Enrique Laso, and Peter Kramer

Mike Harris Craig MacFarland Marsha Sitnik

Joel Hedgpeth Waldo Schmitt

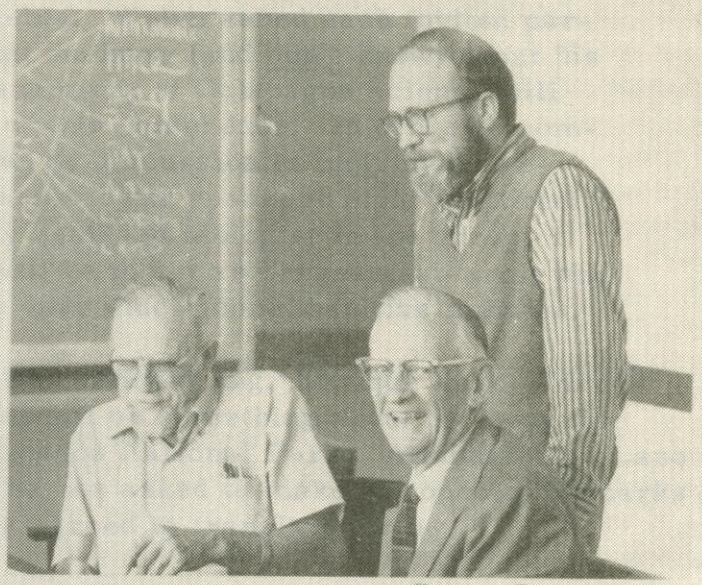
Bob Silberglied Craig MacFarland

"Common Interest"



David Snow Bill Reeder

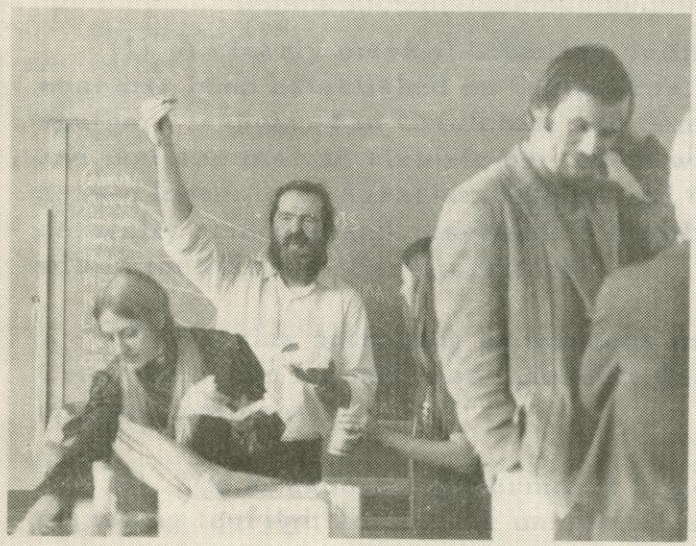
Clayton Ray Frank Whitmore



Charley Rick Duncan Porter
Ira Wiggins

Craig MacFarland Jean Dorst

Peter Kramer Hal Coolidge



(L-R) Gayle Davis, pastrami sandwich, Tom Simkin,
Marsha Sitnik, Peter Pritchard

Paul Colinvaux Bob Bowman

INTRODUCTION AND NATIONAL PARK SERVICE

Simkin: I think we now have most of our introductions behind us and we can proceed to short summaries of individual fields. We've asked each invited participant to give us a short description of what we know (and don't know) about his particular discipline, in the hope that this summary of Galapagos science will give us all a better base for the remainder of this conference. In order to complete this summary before lunch we will have no discussion of individual presentations (The next two days are for discussion.) and speakers must limit their delivery time. As certainly the most poorly qualified biologist in the group, I think my main purpose as moderator here will be to act as Sergeant-at-arms and beat people over the head when they talk for very much more than five minutes.

We're very fortunate in having with us this morning Ing. Enrique Laso, Director of Servicio Forestal in Ecuador, who will tell us something about the very fine work being done by the personnel of the Galapagos National Park. Although Ing. Laso has a very competent command of English, he has asked to make his opening remarks in his native Spanish and Fernando Ortiz has agreed to translate for us.

Laso: Legally, the Galapagos Islands are well protected. The Forest Service has sponsored and won enactment of two important laws in Ecuador: Decree 1306, which establishes very strict rules for access to and conduct within National Parks and National Reserves; and, the complementary Law 818, which prohibits hunting, capturing, or exporting of endangered wildlife and fish. At present we support three conservation officials working in the Galapagos and we supervise the activities of six full-time Galapagos National Park wardens. We hope to send additional personnel as soon as our facilities have been improved. Thanks to Decree 1306, formerly mentioned, we are able to charge each tourist visiting the islands $6.00 per visit and the funds that result are distributed to the Forest Service. This has produced a significant sum last year and we are now in the process of organizing the proper expenditure of this money. We are presently building our park headquarters near the Darwin Station on Santa Cruz; this project costs in the neighborhood of $30,000.

Since its establishment in 1965, the Galapagos National Park Service, with the advice and cooperation of the Darwin Station, has accomplished the following:

(1) A clearly marked boundary delimiting National Park territory from the colonized zone has been established on Santa Cruz. Similar boundaries are being established on southern Isabela, San Cristobal, and Santa Maria. These boundaries are being enforced, and last summer an historic precedent was set in regard to land utilization. The Ecuadorian Institute of Agrarian Reform and Colonization and the National Park Service successfully removed and resettled 15 families from farms which had been illegally settled within the National Park territory.

(2) Regular patrolling by wardens in critical areas of the National Park (Santa Cruz, southern Isabela) has markedly decreased illegal entries and poaching (especially of giant tortoises).

(3) The Ecuadorian government in general has demonstrated a keen interest in managing tourism so that the unique biota and other natural wonders of the Galapagos

will be preserved. Several large, unsuitable tourist schemes have been vetoes, and the major tourist companies which operate in the islands have complied well with National Park regulations.

(4) National Park conservation officials have taught in several of the Darwin Station's educational programs for public schoolteachers in the islands and for guides from some of the tourist companies.

(5) Feral populations of goats have been eliminated on Santa Fe and Rabida and controlled on Pinta, Marchena, Espanola, and southern Isabela. Pigs have been controlled on Santa Cruz, San Salvador, and southern Isabela.

(6) Park Service conservation officials and wardens, Darwin Station personnel, and visiting scientists have worked together to gather basic data on distribution and population biology of several endangered species of birds and reptiles. A successful program of breeding, raising, and restocking of endangered subspecies of the giant tortoises is well underway.

I am very thankful that this meeting has been organized on a subject that is part of the interests of my country. However, the main thrust of the meeting, being a scientific one, is only of tangential interest to an administrator like myself; the main reason I am here is that I want to use the scientific aspects of the Galapagos to emphasize to the Ecuadorian government the necessity of preserving the Galapagos, and thus demonstrate the importance of the National Park Service in the islands. With this purpose, too, we have begun contacts with various Ecuadorian institutions to eventually develop a plan to be presented to the Government. Somehow we must create a connection between the tourist industry and the people living in the Galapagos. Up to now, because of the way in which the tourist revenues are handled, the profit of tourism in the Galapagos goes to the Forest Service and the tourist companies. I see looming on the horizon the day when the Galapaguenos are going to put political pressure on the National Park, the Forest Service and the Darwin Station asking that the benefit of having tourists there be also shared with the people of the Galapagos.

Summing up, there are three kinds of things we might talk about: (1) the scientific aspects of the islands, and these can be handled very well by scientific institutions in the international community and in Ecuador and only indirectly by the Forest Service; (2) the administrative and political functioning of the National Park, which is our main concern; and (3) the implementation of measures toward tourism and conservation, which is a joint responsibility of the Forest Service and the Darwin Station. With this I think I have provided a basis for my presence here, and for the contribution I plan to make during this meeting.

Simkin: Thank you Ing. Laso. Peter, could you give us a quick report on the Charles Darwin Research Station?

Kramer: Despite the rather severe limitations imposed by a small annual budget, the Darwin Station has steadily increased its efforts in all three fields of its activity--research, education, and conservation of natural resources--since operations began in 1959.

CHARLES DARWIN RESEARCH STATION

The Station is now established on a sound basis and is developing to face increased future responsibilities. The physical plant consists of a laboratory (providing basic research facilities and offices), a dining hall, dormitories, shops, tortoise breeding and raising facilities, and a 65 foot long research vessel. An educational exhibit and lecture center and a library-herbarium-museum-office complex are currently under construction. The staff consists of a Director/Scientist, one or two additional scientists, an operations manager, and a maintenance/service staff of 10-12. Additional information on the Station is available in the Appendix.

The basic functions are carried out as follows:

(1) Almost all so-called pure research is being done by scientists visiting the station for the time they need for their specific project. It is one of the functions of the Station to provide technical assistance to these scientific missions. So far the Darwin Foundation itself has had little influence on what kind of research was carried out, but the existence of the Foundation and the Station has greatly stimulated research in general and has facilitated the realization of research projects. Many of these investigations provide information that is directly applicable to conservation problems, and although the projects are generally too expensive for Darwin Foundation financing, the cause of conservation is furthered by the important logistical support that we can provide. Seismographic and meteorological stations are also maintained.

(2) Educational programs at present consist of courses and other training methods for Galapagos schoolteachers, tourist guides, National Park wardens, students from Ecuador and abroad, and the local population. All of these need to be expanded.

(3) Through the Station, human, technical, and financial resources from all over the world are being put to work for conservation on Galapagos. That's where the Foundation and locally the Station have an important clearinghouse position. The execution of conservation measures in Galapagos comes under the Forestry Service and locally the Galapagos National Park Service. The Station provides advice and cooperation in planning and execution of these programs. Ing. Laso had already mentioned most of these specific projects. To this list could be added recent surveys of the effects of feral herbivores on native vegetation and the re-colonization and regrowth of vegetation after such ferals are eliminated.

Thinking of needs and gaps I want to stress only one point that has been mentioned already and that has been motivating me more and more in the past two years. If you go through the contract of 1964 between the Ecuadorian Government and the Darwin Foundation you will realize that it was signed in the spirit to help develop an Ecuadorian fraction of the international scientific community, which in the not too distant future would take the lead in the investigation of those wonderful things we have in Galapagos. No matter what research we consider: if it only results in further training the already well-trained brains and in adding further bits of information to the already well-stocked data banks, then I think, in a sense, the Darwin Station is not serving its purpose. We have taken some steps in the indicated direction, but

on the whole I would think we have done too little. It is not the purpose of this conference to discuss the policies of the Darwin Foundation, but I believe that the necessity to help organize science in Ecuador ought to be an integrated part of science planning for the Galapagos right from the beginning.

Simkin: I wonder if we might reverse the listed order of the next two speakers. I think perhaps what you have to say, Fernando, on involvement of Ecuadorian scientists might follow directly on Peter's comments.

Ortiz: My connection with Galapagos started in 1963 when I had an opportunity to be a research assistant at the Darwin Station; this resulted from life-long interest in Nature and the Galapagos. Eventually I found myself in the paradoxical position of being a pure scientist but one who was born in Ecuador, which is unusual, and this puts me now in the spot of trying to justify pure scientific research on a portion of Ecuador that has obvious practical value and political importance. Now, as you have heard Ing. Laso say, most Ecuadorians are not mainly interested in the scientific value of the Galapagos--they are mainly interested in what the Galapagos can do for Ecuador economically.

In a way this interest results from the lack of scientific education in Ecuador. The reason I am at the University of California may be summarized as the lack, in Ecuador and many other places in South America, of university departments where I could have trained as a serious zoologist. Because of this, after I got my Master's Degree and returned to Ecuador one of my priorities was to see how we could establish joint programs between the university in Quito where I was working (Universidad Catolica) and the Darwin Station, hoping that thus we would be able to improve the quality of the scientific education the Ecuadorian students of that university were getting. We had a long conversation with Peter Kramer about this in 1970, and we agreed that the logical contribution of the Darwin Station to this goal could be to provide facilities--even at a modest level and for short periods--for Ecuadorian university students to work there on small projects of the sort I did in 1963 (i.e., classify beetles, collect plants). The important thing is for young Ecuadorians to get a taste for biological research: something relatively inexpensive to get but something that stays with you for the rest of your life. Therefore I think that this sort of connection--the Charles Darwin Station as the place where young Ecuadorians can go and get a taste for research--would guarantee that future generations of Ecuadorians do not regard the Galapagos simply as an economic resource but also as a laboratory for the study and understanding of Nature. While tourism as a money-making enterprise may help conservation of Galapagos plants and animals for now, the only long-term insurance for the survival of the latter is that the natives of Ecuador come to appreciate the scientific and educational value these organisms have. If the Darwin Station can help in creating this awareness its mission would be very well served.

ECUADORIAN SCIENCE AND CONSERVATION

Simkin: I think, Peter, you might add a little bit to that on the existing student programs at the station.

Kramer: Since last year (1971) we have a limited program which allows Ecuadorian students to come to the Station for three months and carry through small research projects together with one of the scientists that is on Galapagos at that time. This is arranged with Ecuadorian university departments so that it fits into teaching curricula. The results of such a project serves as basis for a thesis, licenciature, BS degree. We can not go beyond having four to six students per year up to now, --which we consider very little. The limiting factors are the scarceness of funds available for travel and accommodation of such students and the number of scientists that are willing and able to supervise such projects.

Dorst: Well, I shall be very brief on this subject for three obvious reasons. The first one is, as everybody knows, that conservation was one of the main aims of the Charles Darwin Foundation in establishing a station in the Galapagos. The second reason is that the word conservation will come back and back again during all the discussions in the next two days. The third reason, of course, is that I would not want to exceed my five minutes and be kicked out of the conference!

As you know, when the station started in the Galapagos we were directly involved in practical problems of conservation and this was really against the rule which was established for the station. We have never forgotten that we were operating in an Ecuadorian country and that the conservation and the practical problems of conservation were purely under the responsibility of the Ecuadorian government. Nevertheless, and with the full support of the Ecuadorian authorities, we were involved in practical measures of conservation there and when the first nature reserve was established in the Galapagos (on Santa Cruz) that particular reserve was put under the responsibility of the Station. Since this time the Ecuadorian government has established the National Park which is now operating in the most brilliant way. And if you will allow me, on behalf of the Charles Darwin Foundation, I would here publicly emphasize the tremendous role which the Ecuadorian government took in establishing the National Park. This park is already one of the most efficient I know in tropical countries, especially in islands, and that is very important to know. Of course now we are working in really close connection with the National Park authorities, but the responsibility can be easily divided: the practical measures of conservation managing of natural parks and reserves are under the authority of the Ecuadorians and we are there only, should I say, for scientific advice. Nevertheless our role is very important, and we have (again in close collaboration with the Ecuadorian authorities) the technical and scientific aspects of conservation more or less in hand.

CONSERVATION

There is, however, a great deal of work which still has to be done, and three tasks seem particularly important to me. The first one is monitoring--monitoring not only a species which is particularly threatened (that's the tortoises, that's iguanas, that's several species of birds like the flightless cormorant), but also monitoring of habitats, because habitats and especially insular habitats are terribly fragile and can be threatened by human inhabitants--and that's the reason we have the difficult task to separate and to study the evolution of habitats and of natural and artificial conditions. The second aspect I will call the analysis of ecosystems. It has been emphasized just a few minutes ago that we don't know very much about ecosystems. The Galapagos ecosystems are particularly important in the perspective of Darwinian ecology and of course this could be very important from the fundamental point of view but also from the conservation point of view. If we don't understand well how these ecosystems are working I think that in the long run our effort to save the Galapagos wildlife and biota would be in vain. The third aspect, of course, is particular conservation applications such as analysis of human interference not only by the colonists but also by the tourists and, as you probably know, we have several projects underway with the assistance of the World Wildlife Fund to study the pattern of both. We need also to study the impact of introduced mammals: we know already a lot about that, but our knowledge is still very rudimentary and we have to go further if we want to find the way to conserve the habitat.

Finally I would emphasize the absolute necessity of integrated research. This has been said already, but I would insist on that point. In modern times the word ecology means a lot of things and under this label you find a lot of very vague programs of research. This shouldn't be the case for the Galapagos study. We need integrated research to understand how all these ecosystems--all these island biota are working. I would also refer to Ing. Laso's comments a moment ago on a master plan of development. This is an idea which has been discussed by the Charles Darwin Foundation and, of course, this should be under the responsibility of the Ecuadorian government. I think that we scientists and particularly all the people involved in the Charles Darwin Foundation should have an important role though, because the scientific, the ecological, aspect should really be the main point in such a master plan. And also I would refer to the "Man and Biosphere" program of UNESCO. This program will come into operation within the very near future. We have good hopes, according to the contract which has been already taken with the Ecuadorian authorities for science and administration, that Ecuador will play a very important role in the program. Among the thirteen program themes, I see at least three which are really important in the Galapagos: that's monitoring, that's functioning of ecosystems, and that's conservation. Our action both as scientists and as conservationists should be integrated in such a broad program of investigation. I think that we shall probably come back to the conservation aspect many times so I apologize for maybe having exceeded my five minutes.

GEOLOGY

Simkin: You can't really separate conservation and science in many places and certainly not in the Galapagos. Let's shift gears now and I'll try to summarize what we know and don't know about the rocks that underly all those glorious beasts and plants in the Galapagos.

The early geological work in the Galapagos was primarily description of a few nice samples picked up by passing scientists. It was not until the International Scientific Project (GISP), 1964, that a single geologic look at the whole archipelago was taken and the resulting memoir by McBirney and Williams provides a basic reconnaissance framework for all of the islands. It also provides, because of the logistic advantages of that expedition, probably the best look that we will have at Culpepper for some time. In 1968 we had a spotlight turned on the islands in the form of the largest caldera collapse that the planet has seen in 70 years, and since then a number of groups have begun much more detailed work in the islands. Keith Howard (U.S. Geological Survey), Bruce Nolf (Central Oregon College), and I have been working on Fernandina, the site of the caldera collapse. Nolf and I have also been working on the truncated volcano that you've all seen passing Cape Berkeley--it's a marvelous opportunity to look at the interior of a modern volcano--and on Marchena with some reconnaissance work on Tower and Pinta. Keith Howard has a map prepared of Alcedo. A group from the University of Arizona led by Bert Nordlie has been mapping on Cerro Azul, Sierra Negra and Volcan Wolf; they have several papers in press and more to come soon. A University of Oregon group broadly under McBirney's direction spent the spring of 1971 working on Santiago or James, Duncan, and Jervis. This means that all volcanoes (except Darwin) in the western part of the archipelago--the area marked by historic volcanism--are now under active study and published geologic maps (the fundamental unit of geology and conspicuously absent in the Galapagos at present) should be forthcoming within the next few years.

This leaves the large islands in the southeast, Santa Cruz, Floreana, Hood, and San Cristobal--the vegetated and apparently older volcanoes with no documented historic volcanism--essentially unmapped. The University of Oregon group is planning a much more detailed attack on those islands for next spring and summer. In summary of the state of mapping: it looks as though we will have the detailed base for more thorough geologic work on all of the major islands in the next few years. From this base we can build more specific studies such as the role of explosive eruptions in the islands, volcanism's effect on the biota, age and development of the islands, and more. This will establish much-needed control on the regional setting of the Galapagos in terms of the new global tectonics and burgeoning interest in this island setting.

We can move now to the classic subfields of geology and look at Galapagos geology from the standpoints of chemistry, physics, and biology. The fundamental

mapping has to be based largely on geochemistry: everyone who has stumbled over those black rocks realizes that they look pretty much alike in the field and one must go back and forth between lab and field to make an accurate identification and reconstruction of the geochemical evolution of any individual volcano. McBirney and Williams' memoir and all previous work in the Galapagos have netted on the order of fifty chemical analyses of volcanic rocks which might be compared with several thousand chemical analyses of rocks from Hawaii. We know very little about the over-all geochemistry of the islands but that knowledge is increasing along with the field mapping that I referred to earlier. We are also recognizing some significant differences between the Galapagos and the better known island settings such as Hawaii, so we're learning something about island volcanoes as well as adding to our knowledge of the Galapagos.

Radiometric dating is of considerable interest to biologists and should be discussed here. The great problem is that there is very little potassium in these rocks and they're very young, so the combination makes dating difficult. Young lavas also have a way of covering old lavas and thereby complicating the search for the oldest rocks in the Galapagos. There are several dates in the literature around 1 million years and one closer to 4 million years. Geophysical data suggest that the sea floor around the Galapagos is not older than about 10 million years. Allan Cox, during the 1964 GISP, began a valuable approach to dating the islands by studying their geomagnetic, or paleomagnetic history. This has been continued by the University of Oregon group and will be carried on throughout the islands by them in this coming year. Again in geophysics, John Filson (MIT) and I have a paper in draft form on the seismology of the 1968 Fernandina caldera collapse, a remarkable earthquake swarm monitored by seismographs around the world. The University of Oregon had a microseismic group on Fernandina in the summer of 1971 and they have plans to continue that approach. The National Ocean Survey continues to maintain a seismograph at the Darwin Station and that's extremely valuable in the world seismic network. Gravity studies have barely been started: Jim Case (U.S. Geological Survey) made a short reconnaissance of the western islands in 1970, returned in 1971 for a few additional measurements, and expects to have a paper ready to submit in a few months. There has been extremely little work on geothermal studies and I think an aerial infrared survey is a major need.

Paleontology (or geobiology)--the surface has, astonishingly, been barely scratched. I hope we will have time before lunch for Clayton Ray to say a few words about paleontology. [See page 30]

Marine geology is a very important gap but one that's being closed with the great surge of interest in the regional setting. There's been some work done by the Naval Oceanographic Office and Princeton University but the only published seafloor sampling that's been done was by Alexander Agassiz in the last century. Coring of marine sediments, deep rock dredging, detailed bathymetry, seismic profiling, and other techniques of modern marine geology should greatly increase our understanding of Galapagos geology.

We need a great deal of monitoring and we'll get into this in the following talk. Monitoring of the active volcanoes from a geophysical standpoint, particularly

seismic and thermal monitoring, offer our best hope for warning of the future eruptions that we know will take place in the Galapagos. We also need work in the several fields of geological knowledge that are virtually untouched in the Galapagos (other than the obvious gap in glaciology!). There's been absolutely nothing done in hydrology--how ground water behaves in the Galapagos setting--and this could be extremely important to the local population. Our former Secretary General, Dr. Laruelle, did the only work that's been done on soils, a most important field from a multidisciplinary sense. Very little has been done on mineral deposits, beyond a few people who have looked at the sulfur deposits and found them not economic, but the islands are not a prospector's paradise.

This has been very brief but is, I think, as quick a summary as I can make of the status of what we know and what we don't know of Galapagos geology. The field is in a surprisingly primitive stage of development, considering the wealth of biological work in the archipelago, yet vigorous steps are being taken to fill the many large gaps in our knowledge. I'll turn it over now to co-chairman Bill Reeder who will talk on environmental measuring plans.

Reeder: Most scientists working on the Galapagos Islands require certain environmental measurements in order to provide context or as basic requirements in their own studies. Some of these, e.g., air temperature at the time and position of censusing an organism; surface humidity at a tree trunk supporting lichen growth, require instantaneous measurement with special requirements suited only to a given project and obviously must be arranged for by each investigator. Other measurements, however, are of continuing interest to a wide variety of scientists and become most useful when combined, year after year, into a continuous record of environmental change. Such record provides historical depth for studies of a changing biota and provides increasing possibility to correlate environmental stability, cycling, or change with observed characteristics of organisms, soils, or geological structure. This is to say that there is a body of information required to be taken continuously from the environment which would provide additional important data for use by a majority of working scientists. We wish here to identify those measurements which appear to be most critical to obtain and could, furthermore, be built into automated monitoring stations without excessive cost or maintenance. It is envisioned that a small group of monitoring stations, disposed in carefully planned array about the islands, would be able to provide accurate descriptions of prevailing broad climatic patterns as well as details of microclimatic significance. Data obtained in this way would be made available for use by any scientific project, thus obviating the present requirement that individual projects must tool up for general environmental measurement as well as their own specialized needs.

Standard meteorological data, including radiosonde records, have been accumulated for past years at the station on San Cristobal. Climatic records of a rather general sort have been made also at the Charles Darwin Station, Santa Cruz, and sporadically elsewhere on the islands. These records are useful as far as they go, but are entirely inadequate for climatic description of the island group, and no microclimatic measurements have been made at all.

ENVIRONMENTAL MEASURING AND PALEOECOLOGY

Thus, during the next two days, I should like to act as a repository for suggestions from all of you regarding those measurements which you feel to be most critical. We intend to recommend, at the end of the conference, a standard monitoring package, funding, construction and disposition of which could be a collective objective of us all. In order to get this started, let me make a few basic suggestions which can be scrapped, changed or supplemented later in the meetings.

Our recording stations should be distributed around the archipelago so that directional patterns of environmental change may be plotted. For example, we want to know details of cloud formation, movement of air masses and water currents, and temperature gradients on the surface and as a function of altitude. In contrast to this example of broadly prevalent pattern, we also want carefully defined microclimatic measurements, such as soil temperatures and those of air layers just above the surface--layers in which insects, spiders and litter organisms are spending their entire lives, but details of whose environments are known in but the most casual way. We would like to measure soil temperature in a column, air temperature also in a column, ocean temperatures where appropriate, relative humidity, rainfall, wind speed and direction at several heights, incident radiation and net radiation. We would find great value in time lapse documentation of sky conditions. Here we would like to collaborate with Tom Simkin's geological group in having a camera set up which would take a very wide angle (perhaps 120°) sky picture including the horizon at perhaps five minute intervals which would permit tracking of volcanic events on the land surface as well as patterning and movement of clouds across the sky.

I have ignored marine measurements not because they are unimportant, but because others must judge those most crucial.

Please, then, let me ask you all to consider the requirements of scientists in your field for continuous environmental monitoring. In this way it may be possible to justify the establishment of such stations for the scientific benefit of all.

Simkin: Dr. Reeder has asked for a minute or two later for comments on feral animals, but we will now move on into paleoecology and limnology. Paul?

Colinvaux: From a paleoecologist's point of view, an historical ecologist's point of view, the first overriding interest in the Galapagos was nothing Darwinian, it was simply that the islands were there, on the Equator, in the eastern Pacific. This was the only site, except for the ocean, where a long historical record of climate of the equatorial Pacific could be obtained. It was with this view point that I first went there. Darwinian interests of course carried one along, but the climatic record was primary. I think I can claim to have cored every major sediment body we are likely to find. I now have a record going back to more than 48,000 radiocarbon years before present for the climatic history for the archipelago based

mainly on the freshwater crater lake on El Junco, San Cristobal. There remain only lesser bogs on islands I did not visit. The gross conclusions are now in press with Nature and they are (adding to Tom Simkin's account) including a glaciological record for the Galapagos. There were no glaciers there but the glacial events of the continental ice sheets, the global events, were felt on the Galapagos archipelago in a dramatic way. On the evidence that a closed lake basin filled and dried, and from some supporting fossil evidence, I conclude in my Nature paper that the Galapagos suffered a much dryer climate in glacial maxima than they do now. This may seem hard to believe, but I think it is true and I think that the spring rains which occur fairly regularly now virtually never occurred then. I have constructed a climatic model which purports to explain this by suggesting that the intertropical convergence remained in its northern position year-round and did not suffer the El Niño advance. These conclusions will shortly be in print and open to attack. It remains to be seen if my climatic model will survive but I feel rather sure of the general conclusion that glacial times were dry times on the Galapagos.

In the process of seeking this record Mrs. Schofield and I have completed pollen analyses from San Cristobal, Santa Cruz, Tower and James. I have no good histories from southern Isabela, which would be nice to have. We have a complete pollen reference collection of all known Galapagos taxa upon which these analyses are based. The pollen work will be published shortly. I don't have much to say about the conclusions now. In the course of the study I looked at every known Galapagos lake so that a crude survey of limnology is available. I think that the possibilities of further work on these lines are not very great.

I have already suggested to this meeting that what I think needs to be done in the Galapagos is ecology, and Darwinian ecology. Our own efforts have moved in this direction. We have just completed a year-round sampling of the marine productivity of a series of sites around the archipelago. We have a great deal of data. This sampling was possible from small fishing boats and I would suggest to the meeting that we need (if we do not have a large oceanographic vessel) a program working from smaller craft on the Galapagos. We'd have a year-round data compilation this way not occasional measurements. The object of this work is to get productivity data to explain distributions of sea birds and land-based fauna. We are now moving to Darwinian ecological studies; quantitative measurements of fitness; the energy supply of plant food for the animals which eat them; the co-evolution of animals and plants. Now I plead again that I think this is the direction in which biological studies need to go. I endorse Professor Dorst's remark that we must understand the working of an ecosystem if we are effectively to conserve it and that our efforts should be directed along these lines.

Simkin: To expand these comments on marine studies, we now move to Joel Hedgpeth.

Hedgpeth: In the last ten years or so, since the Shellback Expedition by Scripps Institution of Oceanography, there have been several oceanographic expeditions to

the Galapagos area, including two by Oregon State University. Some of the data from these expeditions is not yet generally available, but the general picture is as indicated by Wooster and Hedgpeth in The Galapagos, Proceedings of the Galapagos International Scientific Project (1966). More recently Warren Wooster has reviewed the subject in another symposium volume, Scientific Exploration of the South Pacific (National Academy of Sciences, 1970) calling attention again to the considerable scientific interest of this part of the world to oceanographers, and suggesting a desirable monitoring system which would include sea level "and other pertinent and atmospheric parameters." In time the Galapagos might well become a prime monitoring center because of its unique situation in the complex interaction of the current systems of the eastern tropical Pacific and the possibility of obtaining data of predictive value for El Niño years. Intensified activity in the Galapagos by oceanographic research institutions is highly probable since the Peruvian anchovy is suffering a disastrous decline at this time; in any event, it is desirable that some attention be given to a series of standard stations and that others who may be working in related problems consider making observations that can be related to the general oceanographic activity in the region.

It is now believed that in ordinary (non-El Niño) years the water from the Cromwell Current, that subsurface stream moving eastward from the far west Pacific, moves northward of the Galapagos; after that, its ultimate fate is not clearly known. During a very strong El Niño year, such as 1891, the current may possibly surface west of the Galapagos and move south of the Archipelago at the surface. Usually the core of the Equatorial Undercurrent (as oceanographers prefer to call the Cromwell Current) is about 200 meters deep, but near the Galapagos it rises to about 50 meters, then deepens suddenly. There are indications of a persistent thermocline in the Galapagos Islands at about 50 meters. Many puzzles may be resolved when we at last have synoptic data to depths well beyond 200 meters for several periods of the year, and especially at the onset of El Niño conditions, in the region of the Galapagos.

As many of you probably know, I have suggested that some attention should be given to the study of fisheries in the Galapagos, since fisheries are one of the few economic resources of the region. We need information on the sizes of stocks, seasonal movements and present level of exploitation. Our knowledge of marine biology in the Galapagos is almost nonexistent. We have various reports on certain specific taxonomic groups of invertebrates and marine algae. One of the obvious peculiarities is the distribution of the more conspicuous marine algae; intertidal or subtidal brown algae were not observed at Darwin Bay, for example. Furthermore, I could not find some species of invertebrates on one island that occurred on the shores of others. Of course this may be collecting luck, but obviously it suggests that we need a fairly comprehensive study of some of the larger conspicuous invertebrates such as gastropods on all the islands. One might think this could be ascertained from museum collections, but collections even of the larger shelled mollusks at both Stanford University and the California Academy are surprisingly incomplete. This makes it very difficult to determine the presence or absence of a given species, especially the absence.

PLANT ECOLOGY

As already indicated, Wooster has emphasized the need for monitoring sea level changes in the Galapagos; there appear to be differences in mean sea level in the order of six inches in a distance of perhaps 60 miles, a condition not surprising where the value of the Coriolis parameter may be zero (on the Equator). Incidentally, as some of you know, tidal bench marks were established on many of the islands during the U.S. Navy's survey and charting activities in 1942. As far as near shore ecological studies are concerned, we need not only data on temperature changes, but on light intensity as well, as these may be interrelated for many intertidal organisms. Ideally, of course, such monitoring of physical and chemical data should be augmented by regular sampling programs of certain organisms for growth, reproductive state and general abundance.

Simkin: We move then to plants--Charley Rick.

Rick: The present status of plant ecology in the Galapagos, as I understand it, is one of tremendous deficiencies. Our knowledge about the identity of plant species is relatively good, thanks to the monumental work of Wiggins and Porter, but this treats plant distribution only in a qualitative fashion. What is badly needed is a more thorough treatment in quantitative aspects. An enormous number of aspects could be listed that need investigation. Perhaps the most important, already mentioned in the Conference, is the structure of plant communities in representative sites throughout the archipelago, a quantitative determination of the species in these groups at various altitude levels in order to establish the framework of the native habitat. Workers in other fields of biology undoubtedly feel the need for this type of survey. I am quite impressed by the intriguing problems that are posed by the volcanically active regions, as on Fernandina, where the plant material exists in pristine condition. The separation of plant populations into narrow vertical groups by lava flows, the relation of population composition to the age of flows, and effects of ash deposits resulting from the 1968 eruption constitute unique ecological situations.

My interests are slanted more in the direction of evolutionary aspects. Although these might be considered of a less urgent nature, some fascinating problems exist in population studies of a number of groups including the Scalesias. We know the main frame work of species in this genus but have no idea of the nature of genetic variation within the species. According to my limited observations, simple field studies would be highly rewarding.

The physiological aspects of ecology are more sophisticated and accordingly should be deferred until later. Certain phases are nonetheless no less urgent than the ecological surveys; witness the impact of the niño years. Bob Bowman can give first-hand impressions of the present, excessively wet year. The effects are felt not only during the same year but also during subsequent, dry years. Seed dormancy might be mentioned as an example. Seed production increases enormously during niño years and such seed must retain its viability and remain in dormant condition until the right conditions obtain for emergence.

In the few seconds that are remaining I'll pay lip service to agriculture, which has also been placed on my list of responsibilities. The impact of agriculture on the total ecology is an exceedingly thorny problem, which I am sure you all

appreciate, but is also one that nevertheless has to be faced. The conflict is particularly severe with the raising of cattle, which is currently the most important farming industry on the islands. Its worse aspect is the introduction of new, aggressive forage plants, which compete with, and often eliminate, native plant species. In my estimation the problems with crop production are far less severe and could be compatible with conservation goals as they have in many parts of the world. Crops can be produced without violently conflicting with life in the National Park areas. Common points of view exist, however, of which I might mention the introduced black rat. The bane of conservationists, it is also one of the worst pests of the farmer. Thus we really have some points of common interest; research on control of this pest would benefit both groups.

Simkin: Dr. Wiggins, could you expand on the plants from a systematic standpoint?

Wiggins: Well I think I can cover what I have to say rather quickly. I do want to thank those who have mentioned favorably the Flora of the Galapagos that Porter and I got out in May of 1971. I feel that it gives us a basis for continued work in systematic, ecological, and other types of botanical work which involves use of the phanerogamic plants, and other vascular plants of the islands. From this I'd like to go on to what I think we should aim to do in the near future. I think of a number of areas in which priority might be applied. In biosystematics, for example, almost nothing has been done. If a very carefully thought out and continuous program running over a number of years can be started dealing with such things as, for example, the genera Scalesia, Alternanthera, and members of the Cyperaceae, Euphorbiaceae, Convolvulaceae and Gramineae (Poaceae)--plus several others--many valuable results can confidently be expected.

One could go on and name quite a number of other groups that could be approached best by a biosystematic approach in which the material is brought together. Whether the work is done in the Galapagos Islands or the material taken to Guayaquil or Mexico or some other compatible area probably would make little difference. But this type of approach needs to have very close attention paid to the various steps in the developmental processes that are involved among these plants. Such an approach should yield some very important information that then might be transferred to ecology and to other aspects of the biological picture.

Soil cytotaxonomy is almost untouched in the Galapagos, but this phase is mentioned elsewhere. We have some transfer from the work that has been done on species that are reported as common both to the Galapagos and to other areas but we don't know positively whether or not the cytotaxonomy of the Galapagos representative of a particular species is the same as that of one growing native in Mexico, Central America or, for example, in Peru. The only way to find out is to work on them in the Galapagos, --or with material collected in the three.

Anatomical and morphological investigations of the native vegetation is still completely untouched. That would require a program of a number of years coverage and by people who pass on from one year to another or one phase to another some of their findings for others to carry further.

PLANT SYSTEMATICS AND TERRESTRIAL INVERTEBRATES

I'm coming back to my own field, which I have a difficult time ignoring, that's of systematics. There are numerous refinements in the systematics of the vascular plants of the Galapagos that could be profitably investigated. For example we don't know the details of the micro-distribution of a species from one island to another or from one end of Isabela to another or from one end of Fernandina back and forth to Isabela. There's just an infinite number of things that can be done on these individual projects, any one of which could be handled very nicely in one to three years by a graduate student under proper supervision. But such projects take time, thought, and money. I would like to emphasize again the importance of ecology that has been mentioned by several already, Dr. Colinvaux, Dr. Kramer, and Dr. Rick have all mentioned it and I'd like to emphasize that stress should particularly be placed on the ecology of such different communities as the littoral zone, (and we know little about the littoral zone), the transition zone (about which we know almost nothing), and the shrubby zone above the rain forest. I think we know a bit more about the rain forest than we do about the shrubby zone above it and the grass-sedge-fern zone up above that. All these areas could be investigated intensively and extensively with great profit.

As to phenological work, we know very little about the through-the-year program and processes of growth for flowering and seed production of the plants;--particularly when we take into consideration the El Niño years and their contrast with characteristic reactions during dry years.

And finally the Mycology--there are epiphytic and parasitic fungi in the Galapagos about which we know nothing. Orr has done some good work on the larger, fleshy fungi, but nothing (or almost nothing) has been done on the epiphytic and parasitic fungi which occur on both the native plants and those which represent the escaped, introduced plants such as the citrus on Floreana and the microscopic soil fungi.

These are some of the things that should be mentioned, even though they are merely representative of the ones that readily come to mind.

Simkin: We now turn to terrestrial invertebrates--Bob Silberglied.

Silbergleid: As far as terrestrial invertebrates are concerned the most serious problem is that the fauna is very incompletely known from a taxonomic standpoint. It will probably be decades before we can even produce an invertebrate Fauna comparable to the Flora of Alban Stewart, not to mention the level of Wiggins' and Porter's new volume. One of the major gaps in systematics is that neotropical entomology, and neotropical invertebrate zoology as a whole, is in a very rudimentary state; in fact the Galapagos fauna is better known than that of South America. Therefore, until our knowledge of neotropical invertebrate zoology is more advanced, the biogeography and distribution of most Galapagos forms will have to remain virtually untouched. Little is known about the invertebrates that are neither arthropods nor molluscs, particularly nematodes and annelids. Within the arthropods, the mites are almost completely unknown.

TERRESTRIAL INVERTEBRATES

"Earthworms" have been noted by Kastdalen on Santa Cruz, and they were mentioned by Eibl-Eibesfeldt; I took some but they turned out not to be lumbricids--we do not know what they are as yet.

Given this state of systematic knowledge, it is not surprising that there are virtually no ecological, physiological or population studies on Galapagos invertebrates. There are very few life history studies. It is much easier to state what is known about Galapagos invertebrates than what is not. A few Lepidoptera life histories have been worked out. A small amount of pollination biology has been done. The biology of land molluscs has been studied to a limited extent, and there are a few other fragmentary studies--largely behavioral in approach. In a few groups there have been recent advances in systematics. The Hemiptera have been heavily covered in the literature in the last few years. The Psocoptera or Corrodentia (book- and bark-lice) is a group that has never been reported in the literature on the Galapagos Islands, yet I would estimate that perhaps a tenth of the entire insect fauna belongs to this order--between 50 and 150 species. This group is Ian Thornton's specialty and he has students working on the Galapagos fauna.

What are the gaps in our knowledge and how can they be filled? Systematics research cannot be accelerated, but it can be helped by careful collecting. One way of assisting and encouraging systematics research would be to coordinate researchers with lists of who is working on, and what is known about, various groups. Lists of the insects (Linsley and Usinger, 1966, now being updated) and spiders (Roth and Craig, 1970) have recently been published.

Work on the population dynamics of Galapagos invertebrates is sorely needed. For example, where are the immature insects? I have not, and I don't know anyone who has, seen the immature of the very common and colorful giant grasshopper, Schistocerca melanocera. Perhaps they develop during El Niño years. There is evidence for remarkable longevity among some Galapagos insects. For ordinary annual cycles, biological clocks dependent upon day length measurement, so common among temperate insects, would probably be useless at the equator. How are their cycles regulated and synchronized with the seasons?

I would like to bring up one serious conservation problem concerning terrestrial invertebrates. It has to do with the little fire ant, known in Puerto Rico as the "abayalde," and to science as Wasmannia auropunctata. This is not the well-known imported fire ant of the southern United States, but rather a different widespread neotropical "tramp" species--a follower of man. It frequently turns up at quarantine stations, has on occasion been intercepted as far north as New York City, and has in the past infested the botanical greenhouses at Kew. The species spreads by extension as a single inter-connected colony, rather than by means of nuptual flights and the establishment of independent colonies, as do most other ants. (Its means of spread is very similar in this respect to the "Argentine ant.") Although winged forms have turned up in some places they have not yet been found in the Galapagos. We can expect perhaps one or a few colonies per island. They form massive inter-connected series of tunnels with multiple queens, in chambers six

to eight inches apart under optimal conditions, so it is not the sort of thing you can stop by knocking out small, single colony units. There are several reasons why this ant is important: (1) It replaces much of the indigenous ant fauna. This has already happened on Puerto Rico, where it is a very serious pest. (2) It can live in all zones, provided a small amount of moisture is present. (3) They attack insects and other terrestrial invertebrates, and (although not documented) may attack immature birds and other small vertebrates. (4) A potential problem is that this ant is a specialist attendant of honeydew secreting Homoptera, such as aphids, leafhoppers and scales, which in turn are known to transmit plant diseases. So the presence of this ant in the Galapagos provides an avenue for the introduction and spread of various plant diseases (such as Yellows diseases, which are spread by leafhoppers and psyllids) which are not yet present in the Galapagos. And of course (5) the sting is a minor annoyance to Galapagos workers.

The ant is now found on the southern half of Santa Cruz, from the arid zone to the upper edge of the Miconia belt. (Its spread has been documented in the notes at the Darwin Research Station.) It is also present on San Cristobal in the highlands near El Chino. It has been collected on Santiago, and on Isabela. Its distribution well demonstrates the fact that it is associated with man. There is absolutely no ecologically safe means of control for this ant, or for virtually any other ant with the present state of technology.

Finally, this brings up something that Craig MacFarland has mentioned to me: the total lack of adequate quarantine coverage. We have no quarantine control over transportation facilities, such as the Cristobal Carrier, tour boats, planes, visiting yachts, and so forth. Nor are all scientists informed about the dangers of transferring material from one island to another. During my stay, there was one scientist who made it a habit to bring plastic bags full of leaf litter from the various islands and sort or run them through open Berlese funnels at the Station on Santa Cruz. This thoughtless employment of otherwise standard sampling techniques is dynamite in a place like the Galapagos, because one can seriously affect the uniqueness of each island's invertebrate fauna, and without any record of introductions inadvertently made. So we really need quarantine coverage--both from the mainland and inter-island. The Galapagos is virtually pest-free. There is no malaria, and there are few agricultural pests. In the absence of a quarantine program pests will be introduced and become established. The next point of control would be pesticides, and I don't have to say where that would lead us.

Simkin: Craig, how about the larger terrestrial beasts?

MacFarland: My comments will cover the terrestrial vertebrates excluding birds, in other words the reptiles and the few land mammals. For lack of a better place, my comments will also cover the sea turtles, sea lions, and fur seals. With few exceptions, we basically know only the following about these species: (1) their systematics are generally well worked out; (2) the general distributions of the species within the archipelago are well known or at least have been roughly determined. There are few exceptions to this general state of our knowledge: some detailed and elegant work has been done on physiological and behavioral thermoregulation in the

marine iguana and on the physiology of diving and of the salt glands of the marine iguana; at present the social structure and the function of territoriality in the lava lizards are under investigation. In terms of priorities, I think that we urgently need detailed studies of the population ecology of most of these species. We need to know the following about each: (1) detailed distributions, (2) population sizes, sex ratios, and age and size class structures, (3) reproductive potential, (4) natural mortality, and (5) the effects of exotic species on these native species populations. In effect, we need life tables for each species in order to determine if the populations are increasing, decreasing, or stable. Once such studies have been completed, continual monitoring of selected populations of marked individuals should be done. At present, we are close to having such knowledge only for the giant tortoises. And evidence is accumulating that most of the other species are more or less endangered. For example, where introduced black rats are present, the native rice rats are either extinct or present in only very small numbers, yet we do not have the slightest idea as to the nature of this competitive interaction. Also, wherever cats or pigs are present, the endemic snakes are extremely scarce in comparison to habitats free of these introduced species. There is similar evidence concerning the interaction of cats with lava lizard and gecko populations. And where pigs are present, the land iguana populations have either been eliminated or sharply reduced in numbers. Beyond these important autecological studies, there exist dozens of possibilities for less applied, more purely biological studies. To name a few: (1) the bioenergetics of one of the largest terrestrial ectothermal herbivores (giant tortoises); (2) the co-evolution of the tortoise and land iguanas with the prickly pear cacti (Opuntia); (3) the social structure and function of territoriality in land iguana populations in a variety of quite different habitats; (4) the co-evolution of and amount of learning involved in the various symbiotic relationships in which several species of Darwin's finches remove ticks from tortoises, land iguanas, and marine iguanas.

Simkin: While still on terrestrial vertebrates, Bill Reeder wanted to add some comments on ferals.

Reeder: My comments on feral land mammals will be very brief, since Craig has mentioned most of them.

There is no question but that the introduced mammals such as black rats, goats, burros, pigs, dogs and cats have badly disturbed breeding populations of endemic animals or, indeed, have brought certain of them to extinction. There is presently great concern with the elimination or at least the very strong suppression of ferals on the Galapagos. While attempts at elimination are being made, for most species of concern there is no known method which is quickly effective and also safe to endemics. My principal point is to urge immediate ecological and behavioral study of the ferals. With sufficient knowledge of a life history, it may be possible to apply a biological control.

Within the last few months we have organized an expedition which, for a period of about three years, will be looking at the black rat--its ecology, behavior, nutritive demands and, it is hoped, competitive interactions with orizomyzine endemics. We are also trying to organize a biological examination of parts of the goat life cycle, with the hope of devising a control that is more efficient than shooting.

I would therefore urge that we discuss these problems and consider priority recommendations for studies to be undertaken on the immediately critical questions. We should plan for a sequence of feral studies leading to biological control methods.

Simkin: We move now to the birds. David Snow has been traveling and has had absolutely no warning that he is to cover land birds for us.

Snow: I first learned that I was to present this summary only an hour or two ago. I shall try to do justice to it but I am slightly out of touch with some of the recent work that has gone on. The position of the land birds is, I think, different from that of most of the other organisms that have been talked about because there are fairly few species and their distribution and taxonomy at the gross level is pretty well known. So we are not really concerned with the same sort of problems as those that most of the other contributors have been talking about. Also I think that it is true to say that there are not such great conservation problems involved either. As long as the vegetation of the islands and associated invertebrate life are more or less undisturbed, the land birds can largely look after themselves, so we are not concerned in quite the same sort of things that affect tortoises, land iguanas, and so on. Also the birds have been pretty well studied, and it was this that made me feel that if one is going to get any further with the land birds one needs to get down to much more long-term studies. It was this that partly prompted my thinking on the ornithological part of the scientific program which I drafted for the Darwin Foundation and which led to some very sharp reactions from other people interested in other fields. I entirely understand those feelings. I possibly overstated the case, but at least had some small part in stimulating this meeting.

So much by way of preface. I feel myself now very strongly that, as I said before, one very much wants long-term continuous studies of the birds if we are going to do very much more with them, and this I think is because their general habits, their food and distribution and so on, are fairly well known. A little is known about their behavior and a little is known about their annual cycles and so on, but not very much is known about some of the more important evolutionary aspects of the land birds--and after all, as we all know, Darwin's finches are one reason why the Galapagos Islands are of such importance in the history of science. The undisturbed islands seem to me to offer an almost unique chance for long-term ecological and evolutionary studies on such things as the factors controlling bird populations over the years. Particularly the whole ecosystem is so simple compared with continental situations. A start has been made to a limited extent by deVries on the Galapagos Hawk on Barrington Island. This is not published yet but from what little I have heard from him he has some extremely valuable results and I am glad to say that he, deVries, is now going back and will be continuing the basis of that work for another couple of years at least. The importance, I think, of these long-term studies is that there is some evidence accumulating that major population fluctuations may have been far more important in the past than we realize. Mike Harris has some information on this and may say something about it. Extinction of species or sub-species on islands may have been a far more frequent occurrence in the past than we now realize, and this could be part of the explanation for the puzzling distributional records which some of the early expeditions obtained of species of

Darwin's finches on islands where they no longer exist. I am sure that if one is going to do this sort of long-term work on birds it ought to be integrated with long-term work on other parts of the terrestrial ecosystem, and if one is going to do this one ought ideally to find one good island to concentrate some of this work on. I do not mean to say that work should not go on more extensively, as of course it should, over the whole archipelago, but there are tremendous advantages in having people working on similar interrelated problems of the terrestrial ecosystem over a period of years on a single island. I put forth the suggestion that Barrington might be the most suitable island for this. There is an additional reason of importance. I believe it is true that the goats have been finally eradicated from Barrington and so there is obviously an extremely interesting study of regeneration of vegetation to be undertaken there, which I believe is now starting.

I am not going to say much about particular birds but Darwin's finches could certainly do with a more detailed study in some of their aspects. Bob Bowman of course has done a lot of this. In certain ways they are now very well known but there are still some important microevolutionary studies that could go on with Darwin's finches. For instance I think it has generally been assumed, but not really been investigated since David Lack's original work, that inter-specific recognition is simply based on bill size. This has never I think been properly tested and could well be tested in the neighborhood of the Darwin Station on Santa Cruz. The detailed relationships between the three very similar species (fuliginosus, fortis, and the big one, magnostris) have never really been gone into in detail. These three species, as is well known, represent three very marked stages in size. On some islands they are discrete in size and do not overlap, while on other islands such as Santa Cruz there is overlap and it seems that in certain places these three are not fully discrete species. They are extremely similar in their behavior, voice, nesting, and so on. A detailed investigation in what exactly is happening in this group would be well worthwhile.

Since the meeting began I have begun to think a little bit about the education aspect of this work. This has already been raised by others and is of general importance. As regards ornithological research, there are obviously tremendous problems in keeping a long-term population program going. At the moment it depends entirely on one or two people such as deVries who are in a position to go there and to be there over a number of years and keep such things ticking over at least on a minimum basis. I do not think that we can hope that this will necessarily go on without some more deliberate effort being put into it, and in this connection I think that the presence of Ecuadorian field assistants--using that term at a fairly high level--could be extremely important in keeping going over a period of years these kind of long-term population programs on birds, and perhaps on other terrestrial animals. This, I think, would simply mean supervision by one of the permanent high-level scientific staff of the Darwin Station and is a promising field for cooperation with Ecuadorian universities.

Simkin: Now to sea birds, Mike.

Harris: Well I think the sea birds are relatively well known. In fact they are very well known and it is probably fair to say that we know more about the sea birds

of Galapagos, even such a small island as Plaza, than of almost any other tropical area. The islands have 17 species of sea birds and the main gap in our knowledge of distribution is the one species of storm petrel which has not been found nesting. For the other species I reckon that about twenty man-years have been expended on them since 1960. As well as the distributions, we know the absolute numbers of over half the species, and these range from something like 12,000 pairs in the albatross to 800 pairs of cormorants to 400 pairs of lava gulls. Breeding cycles have been studied in detail and we know fairly exactly the cycles of sixteen species--including the species which has not been found nesting. The only species which we do not know is the sooty tern way up on Culpepper, and this is only a fringe Galapagos species anyway. Behavior has also been studied. We have got good monographic behavior studies on nine of the seventeen species. Ecology is well known--both the overall patterns and detailed patterns for quite a few species. Conservation has been studied in some detail, but there are three species which are in need of more conservation research. However, it should not be forgotten that all species should be monitored in some way. The first species is not truly a sea bird but can be considered here--it is the flamingo. It has a small population in Galapagos, 500 to 1,000 individuals, but as far as I can see there never have been any more. It is a species which has not been studied and should be studied. The second species is the flightless cormorant on which there is at present a study in progress. If fisheries expand in Galapagos, and nets are used either for fish or lobsters, then the cormorant must be in great danger of extinction. I reckon that if you started using nets over around Fernandina you could possibly eliminate the cormorant in six months or less, so great care must be taken in this area. People might start using nets and you could lose half the population before the Station even knew about it. The third species is the Hawaiian or dark-rumped petrel, which is restricted to Galapagos and the Hawaiian Islands, where it is now very rare. It was once very common in Galapagos but its numbers have declined very markedly for the old settlers talk of vast numbers which are certainly no longer there. Land clearance has reduced the habitat, rats bring their nesting success on Santa Cruz down to zero, or as near zero as makes no difference, and on James the pigs just gobble up the birds and their eggs. Even though the species is still not rare, it is now an endangered species, probably the most so of any bird in Galapagos. Apart from those mentioned above, the main gaps in our knowledge are mainly oceanographical, that is to say what the birds do at sea, but this is the problem for sea birds throughout the world.

To look to the future there are several problems which could be tackled in sea birds. No one has looked at the pelican, and this could be important because we know that in many other parts of the world pesticides have had a great impact on this species. The tropicbird has been done in some detail but these studies have thrown up some interesting problems, for the species has entirely different breeding regimes on nearby islands. For instance, on Plaza there is a very rigid annual breeding cycle, whereas on nearby Daphne, which you could see from Plaza if Santa Cruz wasn't in the way, there is a non-annual cycle. How have these evolved? What are the advantages of each? Is one giving rise to the other? At an even more detailed level you could go into the taxonomy of the storm petrels on Plaza where we have two populations breeding, one in the hot season, another in the cold season,

with no interchange. You could look at this at the protein level. However, personally, I would be against stressing this sort of research for its own ends, and think that we should put our effort into long-term population studies. If you do this, then the scientists coming here for long term studies will also work on these less important aspects, just because they are interested in them. I would prefer studies to be channeled into these long term studies and concentrated on the three species mentioned before, the Hawaiian petrel, the cormorant and the flamingo.

Sea birds are one of Galapagos's main economic resources as most tourists come mainly to see the animals, and birds form a large proportion of these. These resources must be managed. I would like long term studies continued, and new ones set up, by the Station. As David said, these give opportunities to train Ecuadorians by using students both for the sake of the research and to give these people a feeling for research. In summary, I would not discourage people from coming to do more detailed research on sea birds, but, as it seems that our resources for accommodating scientists will be strained in the next few years, I would like to see people coming to continue long term work and to do more fundamental research on the side.

Simkin: It's delightful to find an area of Galapagos science in which we really know something. It's also nice to know this from the author of a guide book in the Peterson series (Mike has the page proofs with him for this bird guide and we should give him a little plug).

We have another author in our midst who has edited the major scientific volume on the Galapagos and has since embarked on a book length description of the natural history of the Galapagos. Bob Bowman's extensive background in Galapagos science makes him the obvious person to summarize its general status. We have given him the large subject of "General Biology" and as much time as he needs for his summary. Bob?

Bowman: Much has already been said about scientific needs in the Galapagos, some of which relates to the area of general biology. I am not at all sure what "General Biology" is all about, and even less certain of what a general biologist does. I have come to think that a good generalist is a very specialized kind of person, one with a professional single-mindedness, who, after years of intensive practice, relates his findings to those from other specialties, and in so doing, sooner or later, becomes a general biologist. A well seasoned ecologist comes closest to my notion of what a good general biologist ought to be. Such a person should be able to place any small piece of scientific information into a broad interdisciplinary matrix.

I should first like to say that had nothing more resulted from the 1964 National Science Foundation funded "Galapagos International Scientific Project" than the publication of the Proceedings (University of California Press, 1966; R.I. Bowman, Editor), the Geology and Petrology of the Galapagos Islands (Geological Society of America Memoir 118, 1969; A.R. McBirney and H. Williams), and the Flora of the Galapagos Islands (Stanford University Press, 1971; I.L. Wiggins and D.M.

Porter), this truly modern, interdisciplinary, and multinational effort would have been fully justified. Of course, much more was, in fact, accomplished, including the publication of many journal articles, the establishment of long-range conservation goals for the Galapagos by the Ecuadorian Government, and the formal opening of the Charles Darwin Research Station at Academy Bay.

The nature of the research initiated by that contingent of scientists has for several years set the pace and direction of Galapagos science. But now there are changes in the winds that point up the need for a review of research potential in the Galapagos and an ordering of specific proposals in the light of overall scientific urgency and economic feasibility. Topsy-like growth of research that reflects the uncoordinated whims of independent workers from around the world, is no longer the modus operandi of science in general. A more formal structure and planning of Galapagos science is desirable in view of several significant developments. Principal among these is the greater involvement of the Government of Ecuador in natural resources protection and development, including the establishment and governance of the Galapagos National Park and the encouragement of a thriving tourist industry. Additionally, the Charles Darwin Foundation for the Galapagos Isles, through its field station at Academy Bay, has expanded its facilities for research and its educational role by serving as a local resource center for residents and visitors, and as an advisory agent to the Government of Ecuador.

It is most encouraging to note that once again the National Science Foundation is taking an active part in helping to formulate international scientific policy for one of the world's most precious treasures, the earth and life forms of Ecuador's Galapagos Islands.

* * *

What I propose to do here is to point out a few of the research topics, which in my view, might most profitably be investigated in the Galapagos, where the findings could have broad ecological significance.

a. Feral Animals--Throughout the world, and particularly on remote oceanic islands, domesticated animals have accidentally or deliberately been liberated by buccaneers, whalers, and fishermen, in order to assure a ready source of fresh meat on voyages far away from ports. Among the various domesticates, including cattle, horses, donkeys, pigs, dogs, cats, rabbits, and chickens, the prolific goat has been one of the most devastating in the feral state. In the Galapagos their reputation as the great spoilers of native vegetation is strikingly evident on Barrington and Hood islands, where the populations of the endemic land iguana and giant tortoises, respectively, have been adversely affected. I am pleased that Dr. Reeder alluded to the "problem" of feral animals. For reasons I do not fully understand, "pure" biologists have shown little inclination to study the behavioral ecology of feral stock in exotic environments. I recall a Galapagos talk that I gave in 1953 at the University of California, in which I casually dismissed the problem of overbrowsing by goats. At the time I was unaware of the presence of Professor Carl O. Sauer, the distinguished geographer and student of plant and animal domestication.

Rightly and forthrightly I was taken to task for virtually ignoring these feral animals, and it was suggested that biologists ought not to "turn up their noses" at a perfectly legitimate and dominant animal in the Galapagos environment, where its presence for several centuries may have had an evolutionary impact on endemic species. For example, he questioned whether the goats could, in part, be responsible for the tree-like growth-form of the Opuntia cactus on those islands where this plant is fed upon by the introduced goats. More recently, the late Dr. Yale Dawson suggested that the presence or absence of tortoises on a given island was the key factor in shaping the growth-form of the cactus. This particular plant-animal interaction needs much closer investigation. I agree with Professor Sauer that goats are pretty important animals and useful for basic biological studies, especially when they occur in the feral state, as in the Galapagos. The scientist's first reaction to feral goats is to take steps for their eradiation. With this ultimate goal I would have no quarrel, but only if it were agreed that a thorough assessment of their environmental impact be made in advance of their extermination, followed by careful studies of the ecological recovery process. Regrettably, this is not happening in the Galapagos where we have a near-classic example of environmental degredation brought about by feral ungulates in general. Hunters have moved in to areas such as Barrington and Hood islands and have killed untold thousands of goats. The reason for such haste in implementing the eradication program is not entirely convincing. Those reptiles presumably threatened through over-browsing by goats, have survived in coexistence with their exotic colonists for perhaps hundreds of years. Surely the populations of tortoise and land iguana on Hood and Barrington islands, respectively, would have held on for a few more years while pre-eradication studies were in progress. Not only that, but we should have formulated a plan whereby good scientific use could be made of the thousands of goat carcasses! We might wonder, for example, whether the feral animals have, over the generations, evolved significant inter-island differences in their morphology that are akin to those we see in the classical Darwin's finches and Scalesia composites. As biologists, perhaps our approach to feral animals has been motivated more by emotion than by science. In any case, there are other islands or portions of islands where impact studies of feral goats can be made, and hopefully, the necessary plots will be established so that we might have good quantitative data on pre- and post-eradication conditions that will form a base of reference for future ecosystem studies.

b. Biological monitoring of climatic fluctuations--The climate of the Galapagos region is characterized by peculiarities that are intermediate between those of the equatorial west coast of South America and those of the dry zone of the Central Pacific. Systematic climatic and hydrologic record-keeping in the Galapagos is in its infancy, and the data available are inadequate for assessing even very short-term variations. In addition, comparatively little is known about climatic anomolies over the equatorial Pacific to the west. Thus the Galapagos Archipelago is strategically situated for the collecting of climatic data that would surely have important biological implications locally, and meteorlogical significance globally.

For the moment I am particularly concerned with the reconstruction of the picture of past climates in the Galapagos as a whole, and changes in the local environments of particular islands. A start in this direction has already been made

by Dr. Colinvaux who has studied pluvial deposits from several areas in the Galapagos. But much more needs to be done and some of this could be accomplished through the techniques of dendrochronology--the science of dating annual growth layers in woody plants. In my opinion much could be done to reconstruct the fairly recent climatic and volcanic history of Galapagos through tree-ring studies, if we could get our increment-borers into the large trunks of such common Galapagos trees as Bursera graveolens ("Palo Santo") that stand out so conspicuously on the kipukas on Bindloe, Narborough, and other islands undergoing rapid volcanic transformations. Studies made in Mexico have shown that woody trees situated near active volcanoes have several kinds of abnormalities in their xylem tissues, and that even twelve years after volcanic activity had ceased, normal annual growth-rings were not being formed.

We must never lose sight of the fact that oceanic islands such as the Galapagos are extremely unstable volcanic ecosystems. Before man arrived on the scene, this instability was caused almost exclusively by volcanic eruptions and by seasonal and long-term fluctuations in rainfall, apparently due to the latitudinal oscillations of the Equatorial Counter Current ("El Niño" Phenomenon). These dynamic selective forces are continuously at work in slightly different ways on the various islands. For example, when we ask what the impact of aridity and volcanic fire has been on the growth-form of the plants or on the physiology of seed germination, then we realize how important it is to have all the historical information we can muster, if we are to correctly formulate our ecological perspectives of Galapagos.

A dramatic example of the consequences of a highly fluctuating climatic environment in the Galapagos was well documented during the "El Niño" year of 1965. A filming group from the Canadian Broadcasting Corporation travelled to Hood Island to photograph the breeding behavior of the Waved Albatross, a species nesting only on this island. The few remaining birds encountered were so tormented by the hordes of mosquitoes that they soon joined other members at sea, deserting their eggs. Vernal pools were so abundant during this year of heavy rainfall that successive generations of mosquitoes were spawned, and made their way to these large warm-blooded avian hosts.

Albatross eggs thus deserted may endure for years. Their presence in large numbers prompted some scientific observers to suggest that a high degree of infertility exists, probably due to massive inbreeding! We now know this conclusion is incorrect. The cause is not genetic failure but rather an intolerable abundance of mosquitoes caused by atypical (?) weather! But that is not all. The abandoned albatross eggs provide an important food resource for the local population of long-billed mockingbirds. Thus the evolutionary fates of the mockingbird and the albatross are intimately tied in with the "El Niño" phenomenon.

c. Paleontology--I am amazed at the meager amount of paleontological research that has been done in the Galapagos, especially in view of the fact that locations of rich fossiliferous strata are known. For example, marine invertebrates are abundantly evident in sea-level sandstones at Cerro Colorado on the east side of Indefatigable Island, opposite Islas Plaza. Professor Wyatt Durham of the University

of California has examined these marine fossils in situ and is of the opinion that they date from Pliocene times, and possibly earlier.

Mention should also be made here of a recent paper by the late Dr. Leo G. Hertlein (in the Proceedings of the California Academy of Sciences, 39:25-46: 1972) which deals with Pliocene invertebrates, chiefly molluscan, from tuffaceous deposits on South Seymour Island. Of the 99 species of snails described, including seven or eight that are extinct, there occurs one land snail, Gastrocopta munita, which is extant on South Seymour and other islands of the Galapagos! This single fact is sufficient basis for the assumption that vegetated dry land existed as far back as Pliocene times, and that evolutionary rates, insofar as this species is concerned, have been minute, if not nil. New potassium-argon datings of older lavas will probably establish a much greater age for the Galapagos than is assumed today. I for one have long been of the opinion that scientists have under-estimated the geological age of the archipelago. Biologists, largely unsophisticated in field geology and generally unfamiliar with volcanic landscapes, have been misled by the superficial appearance of lava flows formed under very arid conditions, and have felt free to make broad geological implications on the basis of morphological variations in recent organisms! A classical example concerns Darwin's finches, in which, by comparison with the famous drepaniid honeycreepers of Hawaii, we have far less adaptive radiation in the shape of the beaks. From this condition it has been erroneously concluded that in the Galapagos there was less time available during which adaptive radiation in the finches could produce as broad a spectrum of bill forms as in the Hawaiian honeycreepers, and therefore, Galapagos is much younger geologically than Hawaii! Such conclusions are entirely unjustified, in my opinion. We should never forget that in the Galapagos, the evolutionary process has probably gone as far as it can go in evolving bill types in the finches, considering the limitations of the environment. We don't find nectar-dependent finches with bills like sickles, because there is no year-round nectar source or flowering season to support such a specialized feeder. Time has probably not been the limiting factor.

I am enough of an optimist to think that there was at least one unfortunate finch that got stuck in the volcanic mud or ash some millions of years ago, whose skeletal remains are awaiting detection by an experienced paleontologist. There is no reason to think that vertebrate fossils cannot be found, and I would suggest that the search begin in the lava tubes that abound in the Galapagos. These natural animal traps provide very stable environments in which skeletal remains are well preserved. I have personally collected vertebrate remains of recent forms of birds, reptiles, and rodents in a large tube about fifteen minutes by foot from the Charles Darwin Research Station (see Noticias de Galapagos, No. 5/6, December, 1965 (1967), pp. 17-20). Unfortunately, this tube was blasted closed early in 1972 in the course of road building, but there are many more tubes available for exploration. The cave and tube environment has been a rewarding collecting ground for unique organisms, including blind cave fishes (see N. Leleup, Noticias de Galapagos, No. 5/6, December 1965 (1967), pp. 12-13) and fossil rodents (see Niethammer, J., Mammalia, 28:593-606, 1964). So let us encourage paleontological field studies in the Galapagos.

d. Pollution monitoring--Recent studies on the distribution of pesticides in the marine environment remind us that we live in a tight little world. Atmospheric and oceanic circulations have carried our industrial pollutants to the far corners of the world, and Galapagos has not remained untainted. Dr. Robert Risebrough has shown that Yellowfin Tuna captured in Galapagos waters in recent years, show a significant level of DDT in their tissues. This suggests the possibility that the recalcitrant chlorinated hydrocarbons may be making their way into the Galapagos ecosystem, pointing to the need for monitoring tissues of such land-based but marine-dependent organisms as the sea-birds and marine iguanas, etc. We might go even further and keep our eyes on those egg-eating mockingbirds on Hood Island. These ubiquitous birds are prone to peck open the eggs of sea-birds and feed on the contents. If sea-birds are concentrating pesticides in their tissues, we ought to see this reflected in their uterine physiology as indicated by thinning of the eggshell. Such a condition would make the eggs far more vulnerable to predatory attacks by mockingbirds. Therefore, we should view with alarm any unexpected increase in mockingbird attacks on sea-bird eggs, until it is definitely established that pollutants are not involved or that nesting birds are not being subjected to excessive disturbances by humans associated with burgeoning tourism in the islands.

Because of its peculiar geographic location, i. e. an area of confluence of oceanic winds and currents, I should think that a good case could be made to establish an eastern Pacific Galapagos station as part of a world-wide environmental monitoring network.

e. Adaptive radiation and speciation studies--Oceanic islands and archipelagoes are the locale for some of our most instructive examples of adaptive radiation and speciation. Indeed, the Galapagos has provided several well known classical examples: among the birds we have Darwin's finches and mockingbirds; among the reptiles we have the tortoises and the marine iguanas; and among the plants we have the Scalesia and Opuntia complexes. Of course there are many more examples, but they are less well studied.

I would like to strongly urge speciation studies on the land snails. The Galapagos supports more species of Bulimulus snails than any area of comparable size in the world. Over fifty species have been described to date. There is an inordinately large amount of character variation in these snails. Some species are ground dwellers, others are tree dwellers; some have globose shells, others have long and slender shells, and so on. As Allyn G. Smith of the California Academy of Sciences has aptly remarked, "The great variability of the land snail fauna, especially the dominant element represented by the genus Bulimulus, provides the basis for an evolutionary study fully as interesting and scientifically as important as similar, more advanced studies of the flora and of the bird and reptile faunas." Such a study will be very time consuming because of the multiplicity of intermediate forms, and the fact that virtually nothing is known about their ecology and distributional patterns.

Among the plants and animals of the Galapagos there are numerous examples of groups showing adaptive radiation and insular speciation. As in most cases, we

don't know why there are so many different sizes and shapes (e.g. shells of snails); we have little notion about the ecological requirements and habits (e.g. insects); we know very little about the climatic, elevational, and edaphic requirements of plant species (e.g. ecotypic variation along the southern slope of Indefatigable Island). This situation is not unique to the Galapagos but is indicative, in general, of our lack of knowledge of organisms on oceanic islands of the world (cf. Sherwin Carlquist, 1972, Bioscience, 22:221-225). Even in the finches of Galapagos our knowledge of the variations in bill size and shape is so limited that in many respects we have not moved much beyond the understanding that Darwin had of the situation back in 1845 when he remarked that the bills are "modified for different ends." The nature of the "ends" is unknown in almost every group of Galapagos organisms. But in the Galapagos finches the situation is especially disturbing since these birds are used over and over again in beginning textbooks, to explain the role of interspecific competition for food in shaping the bill structure. The only supportive evidence comes from Dr. David Lack's measurements of museum study skins, not from anatomical or field-based ecological studies. All the purported examples of competitive interaction in island populations of Darwin's finches are open to question and certainly in need of re-study.

We ought to broaden the basis for our knowledge of Darwin's finches by looking into their genetics (chromosomal configurations), biochemistry (protein diversity), and behavioral ecology (geographical variation in feeding habits). I suspect that we shall discover more variability than hitherto suspected. We very much need to "put to rest" some notions, probably ill-founded, that keep re-appearing in the ornithological literature. For example, on the basis of very limited examples of karyotypes, I am convinced that most of the sibling species of Darwin's finches are incapable of successful hybridization. Supportive evidence comes from experimental crosses made with birds in our San Francisco aviaries. The large number of presumed "hybrid" specimens in museum collections, is likely to be better explained after completion of an analysis of relative growth rates in bill dimensions. There is no reason to think, as one notable biologist has done, that in the Galapagos we have "hybrid swarms" of finches!

We have only begun to "mine" the finches of their instructive value. Some of the results of my ten-year vocalization study (now nearing completion) indicate how useful these birds can be in tracing evolutionary pathways of behavior. The research, of necessity, will be incomplete because of limitations in our knowledge of vegetative differences of the various islands (which affect the acoustical environments to which the songs are adapted) and of territory sizes (which affect amplitude levels of the songs).

Finally, let me make a plea for someone to study the species of Drosophila. To judge from my own collecting experience for Professor Th. Dobzhansky, there are many undescribed species of fruit fly in the Galapagos. This fact alone should cause new excitement among evolutionary biologists in view of the tremendous contribution that this group of organisms has made to modern genetics, population dynamics, and behavioral biology. In a recent article in Science (177:664-669), Prof. Dobzhansky

has comprehensively reviewed the several kinds of species and processes of speciation that can occur in Drosophila. He reviews the important contributions that investigations of the Hawaiian drosophilids have made to our understanding of the evolutionary potential within one group of animals. "With the aid of cytogenetic, morphological, and distributional studies, it has been possible to establish with a high degree of probability which species on one island, particularly a geologically younger one, have descended from ancestors similar or identical with species on other islands." For example, the youngest and largest island, Hawaii, has a particularly interesting array of eleven groups of twenty-three species, the nearest relatives of which are found mostly on the next younger island, Maui, and only one each on Oahu and Kauai, Dr. H. L. Carson has proposed that in the Hawaiian drosophilids, reproductive isolation and speciation preceed differential adaptedness, and that reproductively isolated species remain, at least for a time, adaptively equivalent in similar environments.

Such an untraditional view of speciation commands attention, and what better place could we choose than another oceanic archipelago such as the Galapagos! Here as in Hawaii we have islands of differing geological age and (presumably) of differing species composition. I predict that there will be rich rewards in speciation studies of Galapagos Drosophila.

f. History and philosophy of science--Because the study of the history of science provides a rich source of insights to philosophers and scientists, I should like to propose that some attention be given to the role of insular phenomena in the formulation of Charles Darwin's views in the "Origin of Species." We know that insular phenomena played a crucial role in the "Origin." Examples of geographic variation in island populations of Galapagos birds and reptiles were the basis for much of Darwin's views on species formation. From the beginnings of Darwin's speculations on this subject he used islands (especially archipelagoes) as a model in which evolution was assumed to have occurred, although he was ignorant of its mechanisms. He applied this model to the data of biogeography to see whether they could be explained without invoking special creation or catastrophic events. The model, simply, is this: species change on islands. Oceanic islands are isolated, being separated from the continents by barriers, yet the species found on islands are related by descent to those on the mainland. Accidentally or otherwise, mainland species must have in the past arrived on the island.

Darwin's method is clear in the "First Evolutionary Notebook," the 1842 "Sketch" and the 1844 "Essay," but by 1859 the argument was buttressed by so much detail, so many experiments on seed and land snail dispersal, pigeon breeding, etc., that island phenomena became another--but major--example that evolution occurs. Moreover, Darwin's emphasis in the "Origin" shifted to the role of natural selection in species divergence.

Thus, to read the "Origin" one would never suspect that islands were so important in Darwin's thinking. As early as 1842 Darwin had written this note on the back of a piece of manuscript paper: "islands are the nursery of new species." By re-

reading all of Darwin's notations, it becomes clear that he used the Galapagos as the "elastic template," which was stretched to fit examples from all over the world, including those from continents. In view of the renewed interest in insular phenomena by professional biologists, it is timely that a well-documented historical review be made of the role of the (Galapagos) "island model" in Darwin's "Origin of Species."

Simkin: Thanks Bob. We do have a little time left, so I'd like to call on Clayton Ray, of the National Museum staff here, to expand on paleontology. I'm sorry to say that this subject needs very little time for summary.

Ray: Dr. Bowman has already said very well what needs to be said about paleontology. Perhaps I could add a few comments to underline some of those points. It's always been ironic to me that the holy land for Darwinian evolutionists has a fossil record that's essentially nil, particularly as regards the terrestrial vertebrates. As Dr. Bowman said, there's no reason why this has to be. Through the cooperation of the past and present personnel at the Darwin Research Station we have gotten just a tantalizing sample of what there may be in the caves on the islands. We have remains from Santa Cruz and Isabela and I think that it's perhaps significant that they've all come from places easy to get to; who knows what else there is? We don't even know where the caves are as yet, much less what's in them. I have in hand the study of the extinct giant rice rat from the islands, which makes up the bulk of the bones recovered thus far. This animal was described by Niethammer a few years ago, and we now have really quite adequate material of it. These remains prove that the deposits are there. What we now need is a lot more field work: for example, a cave survey or perhaps a mapping project.

I think that this material has a practical significance also. Reference has been made to undisturbed islands. I would challenge that we know what the undisturbed fauna on any of the islands was in prehistoric times. I think however, that the cave remains offer the principal opportunity of finding out what it was. Here, as in other islands, we call these "fossil deposits" by courtesy only, because many of these species have become extinct very recently. The giant rice rat remains, for example, have been picked up off the surface. They look as if the animal could have died yesterday. So we're really sampling what the modern fauna is, or was, in most instances. Of course if we're lucky and hit a stratified deposit we may get well back in time as well.

With regard to the open air sedimentary rocks, Dr. Bowman has covered the subject very well. There are good prospects there, but again we don't really know where those deposits are. In that connection I think one would have to put in a plug (a non-volcanic plug) for mapping those non-volcanic rocks.

Simkin: There are additional fields that we've neglected and we should at least put these on the record. While we have no meteorologist present, the need for climatic studies has been well argued, but we've had no proponents of archeology and we haven't said much of anything about fish. Are there other fields that people think should be added? Paul--

DISCUSSION

Colinvaux: One investigation which I omitted earlier becomes particularly important in the light of the ensuing remarks. The Arcturus crater lake on Tower has nice banded sediments which I have cored and which we have examined rather thoroughly. We believe we have been able to interpret the deposits in terms of the productivity of the lake, particularly of the phosphorus inputs to the lake. These can be explained in terms of the guano input, and this in turn in terms of the size of the breeding sea bird population. This investigation has been completed and a doctoral dissertation describing the conclusions was presented to me last week. It will be published shortly. The central part of our conclusion is that indeed we can interpret the phosphorus inputs into the lake sediments over a long span of time as reflecting the approximate size of the pink footed booby population on Tower island. The population has remained stable over six thousand years or thereabouts. The dating is very difficult because we have radiocarbon anomalies. This means that we cannot plot El Niño. But the supposed instability of Galapagos bird populations was mentioned earlier. This population I believe, on the basis of this work, has been stable. It is the bird which is the top predator in a simple ecosystem and the conclusions can be used as an empirical test of the hypothesis that complex ecosystems are more stable. The hypothesis fails, as I expected it would. Three, very brief comments. We have done some tree ring work. A colleague is working on finch bill size problems from the point of view of the thermodynamic advantages of feeding on foods of different sizes (papers will be out shortly). I have just sent an acarologist to the islands--at least he's going in about two weeks--Roger Mitchell.

Sachet: I'd like to make a few comments on human ecology. Number one--Do you have any problems with the impact of scientists on the islands (Besides the case mentioned earlier of the entomologist who carried soil samples around from one island to another for his Berlese funnel)? They do have such a problem at the Royal Society Station on Aldabra. They are constantly worried about it. Aldabra, of course, is very very small, and there are occasionally many scientists there at one time.

Number two--You stressed your intention to cooperate with the Ecuadorians and to have students participate in Galapagos research programs, which obviously are important considerations. My question is: how much thought have you given to the future of these students? Once you get them interested in research, will there be jobs for them in Ecuador? Is there a possibility that they might become over-educated for the available positions in their country, and therefore frustrated or forced to look elsewhere? This is a fairly general problem in tropical countries.

Silberglied: As long as Dr. Bowman has brought up what is in vogue, I'd like to mention the use of electrophoresis. Very few electrophoretic studies have been done on material from the islands. Although these techniques are not applicable in the same ways to all groups of organisms, and although it is almost impossible to relate the results of electrophoretic studies directly to morphological, physiological and behavioral findings, nevertheless this technique is of great value because it allows us to get a direct measure of genetic variance within and between populations. Clearly anyone who will be doing biological work in the islands, involving differences between island populations or closely related species, would

profit from looking into the potential use of electrophoretic techniques to solve problems in their group of organisms.

Ortiz: You heard that Dr. Patten was in the Galapagos this year. He got a great amount of serum samples from different islands and lost them all when the ship sunk before reaching California. They lost everything--the only things they saved, essentially, were themselves.

Simkin: One last comment from Duncan Porter.

Porter: I'd like to mention three fields--three types of studies that have not as yet been mentioned and that impinge both on botany and ecology and are thus interdisciplinary in nature: (1) a detailed study of pollination and pollinators, (2) a study of plant dispersal mechanisms, and (3) a study of phytogeographical relationships, both within the archipelago and between it and mainland South America. Now that the Flora has been completed, much of the basic information is available to pursue such studies. They should be given priority on any list of botanical projects for the Galapagos.

Simkin: We must adjourn now for lunch at the Smithsonian Commons across the Mall. Let's all be back here in one hour for the afternoon session chaired by Dr. Reeder. The last few hours have given us, I think, a valuable overview of where we are in Galapagos science, and this should serve as a base for further free-for-all discussions of interdisciplinary needs, suggestions, and priorities.

RECOMMENDATIONS

The editors culled the following suggestions from the working group reports and the full transcript of all meetings of the conference. Order of presentation in no way implies greater or lesser importance of the various recommendations; these are all considered priority needs.

Interdisciplinary Needs

Aerial Photography

One of the strongest needs discussed by the Conference was increased aerial photography of the Galapagos. Aerial photography and the topographic maps obtained from it are vital, not only to the mapping requirements of all scientists, but also to officials concerned with land use. Existing air photographic coverage misses the populated highland regions of San Cristobal, Santa Cruz, and southern Isabela, as well as several important uninhabited regions. But we need more than a filling of existing gaps in air photo coverage: tripling of the human population of the Galapagos and five major volcanic eruptions since the last air photo mission (1959-60) emphasize the importance of periodic photography of changing islands. In addition, improved technology now permits real and false color photography and infrared sensing from the aircraft doing the usual photography, and these techniques offer vegetation and thermal mapping of great importance to many disciplines. Records of water temperature variation are of value to fishery and marine biologists and provide, through indications of productivity, important data for bird investigators. Geothermal areas are known in at least ten different parts of the Galapagos and aerial infrared work would both refine this mapping and, by periodic repeated surveys, indicate the migration or intensification that warns of impending volcanic activity. Aerial coverage during and after an eruption is critical to mapping its products with time (and thus understanding its dynamics). Vegetation mapping has been singled out as vitally important to all Galapagos biologists and modern aerial surveys are essential to good vegetation maps. Close coordination will be necessary between the aerial surveys and ground observations; close radio communication with the islands will be required to avoid the cloud cover that is responsible for existing gaps in aerial coverage. After an initial thorough study, follow-up flights would be valuable as frequently as every two months (used in N.E. Pacific fisheries studies), but flights at any frequency would improve on the present situation. Ing. Laso offered to explore the possibility of obtaining this urgently needed aerial coverage through the Ecuadorian Government.

Environmental Monitoring and Conservation

Discussion of the considerable conservation damage by small unguided yachts led to the conclusion that wardens, stationed on boats at critical locations, offer the best hope of effective control. At the same time there was full agreement on the importance of remote meteorological/geophysical monitoring stations with observers to complement, maintain, and protect the instruments. Both science and conservation can be well served by stationing warden-observers at critical locations. Two prime locations, from both considerations, are Isla Genovesa and Punta Espinoza (Fernandina). Additional sites considered for future monitoring stations are Punta Albemarle, Villamil, and Iguana Cove (all Isabela), Hood, and North Seymour. Brief descriptions of the monitoring needs, with proposed equipment, follows.

RECOMMENDATIONS - INTERDISCIPLINARY

Meteorological Monitoring: Published accounts of Galapagos meteorology are restricted largely to Baltra airbase records during World War II, and thus give information on but one part of the widely variable climate of the islands. An accurate description of this climatic variation is perhaps the most important single requirement of most biological work in Galapagos and is critical for informed guidance of the local population addressing hydrologic and agricultural problems. The Conference commended the Meteorological Service of Ecuador for maintaining a well-equipped station on San Cristobal; CDRS gathers some meteorological data from selected highland sites on Santa Cruz and southern Isabela as well as at Academy Bay. Summary and publication of existing data, which include daily radiosonde records, are of top priority, but it is also clear that further data from additional sites are required to provide an adequate meteorological record of the islands.

Automatically and systematically recorded data should be taken regularly under standard conditions by semi-portable instrument packages which will permit climate description, heat budget and thermal flux calculations, and minimal microclimatic detail. Desirable measures, with equipment, are: (1) radiation, incident and net (by radiometers and flux plates), (2) temperatures at standard height in air, soil surface, and deep constant soil (thermocouples and flux plates), (3) relative humidity (wet-bulb depression and thermocouple), (4) rainfall and garua (large area tipping bucket and accumulator), (5) wind speed and direction (integrated measure per short time period), (6) tidal gauging and ocean temperatures (surface to depth) are desirable at some sites, (7) clouds (see below).

It is urged that redundancy be built into the data accumulator. Where possible, data should be recorded both as paper chart printout (Brown recording potentiometer) and as telemetered to the CDRS for storage on magnetic tape. The magnetic tape can be read directly by computer, decreasing errors of data transcription and providing immediate compilation and processing.

As the peripheral instrument packages are placed in the archipelago, regular servicing by a trained technician, capable of moderate trouble shooting, must be provided approximately monthly. Regular monitoring of the telemetered data at CDRS advises of a malfunctioning instrument, which can then be sought out and repaired.

Time-lapse photography at these same sites would yield valuable data for several fields. Single frame cinematography in the 5-30 min interval range, using wide-angle lens and automatic exposure devices, would require maintenance on only a monthly basis and a well-chosen format would provide inexpensive records of (1) cloud incidence and movement, (2) volcanic eruption dynamics with timed development from the earliest visible phase of activity, and (3; occasionally) faunal behavior from photo foreground.

Geophysical Monitoring: Monitoring of earthquakes and other physical changes in the Galapagos is essential to understanding the past growth and development of these volcanoes. The ability to predict future volcanic activity depends on this understanding, but it further requires geophysical monitoring to provide direct warning of changes.

The CDRS presently operates a unit of the Worldwide Seismic Station Network

(NOAA) and provides valuable records of local and regional seismicity. However, accurate location (with depths) of the frequent Galapagos earthquakes requires two additional seismographs well-placed for triangulation within the archipelago. Portable seismographs should be included in two of the environmental monitoring packages described above. The recommended sites of Espinoza and Genovesa are well-placed, with CDRS, to locate local events; additional units on any of the suggested Isabela sites would significantly strengthen the monitoring.

Microbarographs should be a part of these monitoring packages; these instruments might read directly on the same time recorder as the seismographs. Documentation of airwaves generated by future Galapagos volcanism would be valuable and the instrumentation is inexpensive.

Monitoring of the inflation (and deflation) undergone by active volcanoes has proven to be an effective guide to subsurface migration of magma, with the possibility of providing warning of some eruptions. Sensitive tiltmeters should be installed on active volcanoes, particularly those such as Sierra Negra, that are a real hazard to human populations. A simple and inexpensive alternative to tiltmeters is the periodic releveling of three permanently established benchmarks arranged in a 60 m triangle. Six of these tilt stations were established on Fernandina in 1970, but this program should be extended to other volcanoes and the frequency of releveling increased.

Thermal monitoring of an area as logistically difficult as the Galapagos is best done by aerial surveys and is recommended under that heading.

Standard Photo Stations

Photographs of the same scene through seasons and years provides efficient and valuable documentation of changes. Some photo stations have been reoccupied by individual specialists, but their location (and existence!) is known to few. A photo station map, annotated with descriptions, should be compiled by CDRS, starting with obvious existing stations such as Daniel Weber's caldera panoramas and expanding to include other positions where change can be expected (e.g., settled regions, areas visited heavily by tourists, recent ash deposits or uplift areas, active fumaroles), as well as selected stations where stability seems apparent (e.g., forest floor, rocky shore, tidepools). Some stations should be permanently marked. Panoramas by field workers passing near these stations, and possibly systematic reoccupation by CDRS/NPS personnel, would be an easy way of capturing data for a variety of studies. A basic slide set from these stations should be deposited and curated at CDRS.

Charles Darwin Research Station

The clear consensus of the participants was that the basic Station facilities (see Appendix III for details of present facilities) are in large part adequate for the support of visiting scientific missions. Specifically: (1) the Station should not increase greatly in size; the present capability of supporting 12-15 scientists at a time is both adequate and desirable; (2) it should continue to supply only basic laboratory facilities such as refrigeration, scales, basic glassware, a few microscopes, a drying oven, distilled water, etc.; each mission should bring all its own expendable supplies and specialized items of capital equipment.

The entire area of marine studies has been almost untouched in the Galapagos. It is strongly urged that a small, relatively inexpensive marine laboratory be constructed at the Station as soon as possible. This should be approximately the size of a one- to two-car garage, situated just above sea level, supplied with constantly running sea water (plastic hose and plastic-lined pump), and with basic equipment such as a water table, aquaria, work tables, microscopes, and a 50-100 gallon overhead tank with feeder lines to the water table.

The following improvements in Station facilities are strongly suggested: (1) additional storage facilities for scientific missions, in the form of individual compartments within a larger building; (2) a simple wooden cabinet, heated by light bulbs, for drying botanical specimens (an inexpensive, tried-and-true method which avoids the danger of fire); (3) although the library contains many of the monographs and papers on Galapagos, basic reference texts to most fields of Galapagos science are almost completely lacking in the collection. The participants and other interested scientists will draw up a list of such references, to be used by the Darwin Foundation for improving the library collection. Many of the major monographs on Galapagos are no longer readily available; these should be microfilmed and a microfilm reader purchased by the Station; (4) because of the increasing number of scientific missions, and the inherent dangers of travel in the islands, communication between the Station and field parties and among individuals of the latter are vitally important for safety reasons. The Station should have 3-5 two-way radios (compatible with those owned by the Park Service) and approximately a half dozen walkie-talkies. These could be used by Station personnel on field trips and rented to scientific missions for short periods. Missions requiring radios and/or walkie-talkies for extended periods should provide their own (compatible with CDRS equipment); (5) since adequate storage space will soon be available, basic reference collections of specimens should be improved and carefully curated. It is the responsibility of individual investigators making collections to provide duplicates for the reference collections, and to assist with authoritative identifications. For invertebrates, difficult to preserve at CDRS, a group of authoritatively identified color photographs should be accumulated as an aid to field identification.

Scientist Movement Map

Most Galapagos workers appreciate the value of notes, photographs, and collections made by other workers at other times. The Conference discussed several suggestions such as maintaining a photo log at CDRS and requesting copies of field notes for filing at CDRS. While encouraging these approaches, the Conference strongly recommended the simple measure of requiring rough maps with descriptions, showing the routes followed by each scientific party in the Galapagos. If sketched on common base maps provided by CDRS, these could be periodically combined on a transparent overlay, which would provide a valuable record of who was where at what time. Photographs and noted could then be solicited directly by any investigator needing information on a particular locality.

Interdisciplinary Instruction Sheets

Galapagos field workers are often in a position to make observations and collections of great value to workers in other disciplines. Good communication is required,

however, and the group strongly endorsed the suggestion that scientists prepare and duplicate succinct descriptions of their needs that can be distributed at CDRS to scientists starting field work in the islands. Extensive and overly detailed requests are likely to be ignored by busy field workers and too little instruction may result in useless data, but well-worded instructions (possibly including sketches or photos) have a strong potential for increasing the effectiveness of all of our work. Most scientists doing field work in the Galapagos understand the value of cooperation and a supply of request sheets at CDRS is an excellent way of fostering that cooperation. For example, a standard phenology recording card, guiding the uninitiated in taking proper note of blossoming, fruiting, bird fledging, insect emergence and other seasonal events, should be prepared and made available for distribution at CDRS.

Short-Lived Event Communication

The Galapagos are dynamic islands and rapid investigation of events such as volcanic eruptions, shoreline uplifts, or animal epidemics is essential to understanding how such events have affected the islands in the past. The Smithsonian Center for Short-lived Phenomena (60 Garden St., Cambridge, Mass., U.S.A., 02138) has proved to be an effective communication center in these situations, but it is important: (1) that they be alerted of the addresses and interests of Galapagos scientists and, (2) that they be notified immediately of any short-lived event in Galapagos.

Scientific Bibliography

The scientific literature of the Galapagos is scattered through many years, many languages, and frequently obscure journals. To benefit from the important observations of earlier workers, an extensive Galapagos Bibliography is needed. This has been under preparation by Tom Simkin and Lana Everett and should soon be ready for publication. It consists now of over 2500 references, with cross-indexed keywords stored in computer format. Publication will be by photo-reduction of computer printout. The Conference urged cooperation of all interested scientists in supplying the additions and corrections that will make this a more valuable document for all Galapagos researchers.

Survey of Existing Galapagos Collections

With the present and valid restrictions on collecting in the Galapagos, it is particularly important to know the whereabouts of valuable material collected in the past. Ultimately, a detailed survey of existing collections, possibly in computer format similar to that used for the bibliography, should be prepared, but a simple listing of present location of material from major expeditions could be easily prepared by a small number of veteran Galapagos workers and published in The Darwin Foundation's journal, Noticias de Galapagos. A listing of existing collections would also be valuable in assessing future research proposals that involve collecting. Other suggestions concerning collections are given in Appendix II (Conservation working group report).

Satellite Observations

Weather satellite photographs of the Galapagos area proved very helpful to investigators of the 1968 Fernandina eruption, and today's improved satellite technology

offers considerable potential for Galapagos workers. Studies of cloud development, volcanic eruptions, fires, sea temperatures, seasonal defoliation, telemetered movement of large animals (e.g., whales), and other investigations can all profit from existing and future satellites, but NASA must be made aware of both collective and individual interests in Galapagos.

Science

Ecuadorian Science

The Conference strongly approved the present CDRS programs involving Ecuadorian students, recommending that their number be increased by actively matching visiting scientists with students to further the well known symbiosis between field assistant and experienced researcher. Duplicate collections for Ecuadorian universities are another of the many ways in which foreign scientists can "put something back" into a country that has been kind enough to permit scientific access to the Galapagos.

Money for basic research is rarely available in Ecuador. Research funds for Ecuadorian scientists to study in the Galapagos (and for comparative studies on the mainland) should be sought from international sources; this would include encouraging Ecuadorian students who are pursuing advanced degrees in other countries to do their research in Galapagos.

Geology

The Galapagos are among the more active oceanic volcano groups, their setting is important in the global tectonic framework, and their geologic history is critical to evolutionary and other studies of island flora and fauna. Geologic studies in the Galapagos are few, however, and the most urgent need is for basic geologic mapping of each island. Work now in progress is filling this need but can be facilitated by cooperation of other Galapagos workers in supplying documentation of eruptive activity, locations of burned organic matter that might date lava flows by C^{14}, etc. Chronological studies, of course, are a major need, as are structural studies attempting to place island growth in a regional tectonic framework, but such investigations develop from basic geologic mapping. The extreme regional climate variations, coupled with lack of strong seasonal changes, make the area well suited to rock weathering studies, and the spectacular pyroclastic deposits of the islands are worth special study. Interdisciplinary studies of soils, groundwater, ash revegetation, and the like have both practical and scientific value in Galapagos. See also recommendations under Geophysical Monitoring, Paleontology, Marine Science, and Aerial Photography.

Marine Science

Shallow water littoral studies have been badly neglected in the Galapagos. Biogeographical and ecological studies are needed in order to assess micro-evolution and endemicity, particularly for littoral invertebrates and algae. Museum collections should be searched and inventoried for specimens reflecting change of environmental conditions. Likewise, older data from oceanographic transects and sampling should

be located and studied. Measure of littoral productivity, with free-diving study of feeding in marine iguanas and shore-feeding birds, is needed to provide a baseline against future changes affecting the populations. Permanently marked transects, quadrats, and reoccupiable photography stations must be established and visited regularly.

Productivity of a small number of potentially valuable marine resources (e.g., spiny lobster, sea turtles, and edible fish) should be studied immediately in order to provide data to aid in decisions on catch, fishing limits, etc.

Fresh collections of selected mollusc species are required for chromosome preparations.

Marine geology and geophysics within the archipelago have been virtually ignored. Marine sediment cores NW and W (downwind) of the major volcanoes should record explosive ash chapters in volcanic growth and may be datable by interlayered fossils. Dredging and bottom photography on the remarkably steep scarps W and S of the Galapagos platform offer clues to the development of these volcanoes. Detailed bathymetry and seismic reflection profiling are needed to relate submarine to subaerial features and to provide the baseline documentation necessary to recognize the new submarine faults and lava flows certain to occur in the future. Colonization studies on their submarine extensions might assist in at least relative dating of young, featureless lava flows while providing useful data for marine biology. None of these, or similar, studies appear now to be under way in the Galapagos. They should be.

Vegetation Mapping, Sampling, and Productivity

Accurate vegetation maps are needed by most Galapagos workers and their preparation should have high priority. Such maps require (1) collation of data from previous transects and qualitative descriptions; (2) continuation of walking transects and subjective basic delineation of gross community boundaries or gradients, but most critically, (3) aerial photographic coverage (standard, false color, infrared; see aerial photo recommendations), and (4) careful quantitative study of presence, densities, and pattern of plant distribution along most critical transects of important islands such as Santa Cruz, Fernandina, and Tower. The need for detailed, quantitatively-controlled vegetation maps is urgent not only for many current investigations, but also to provide baseline data permitting later evaluation of vegetation changes through succession, manipulation, or natural physical events.

Primary productivity should be measured at selected sites along sampling transects; this must be done seasonally and annually and repeated as required. When combined with detailed vegetation maps and quantitative descriptions of the structure of plant communities, primary productivity studies will provide a basis for evaluating (1) cropping and foraging by invertebrates and vertebrates (native and introduced), (2) carrying capacity for the variety of animals inhabiting the plant communities, and (3) the overall dynamics and economy of the various biotic communities.

See Appendix II for amplification.

Terrestrial Invertebrates

In recognition of the large and still poorly known invertebrate fauna, it is strongly recommended that "alpha-level" systematic studies be continued, with systematic collection, study, and description of invertebrate species and their variants. Such studies, basic to understanding of evolution within each group, should be made where possible by specialists also working on equivalent groups from mainland South and Central America. Evolutionary studies, using modern tools of analytical genetics (e.g., electrophoretic analysis of enzyme polymorphism), should be undertaken immediately, using, in particular, the more systematically diverse insects (e.g., the tenebrionid beetles) and molluscs.

Basic autecological studies of invertebrates, including developmental and population biology, food requirements, and microenvironmental relationships, should be encouraged. Community studies, dependent on the above, but comparing faunae of different vegetation types and climatic regimes through time, are urgently required for basic understanding of the Galapagos ecosystem.

Study of pollination biology at the level of the plant community, with support of genetic studies of endemic plants, would permit testing of general theories of plant-insect coevolution. Such studies in the Galapagos have the advantage of relative simplicity, compared with those of the tropical mainland.

It has been strongly recommended that a systematically arranged file (perhaps in computer format) be established to include literature references, as well as currently obtained data summaries (e.g., phenology, trophic and pollination ecology, symbiotic observations) for each species. Included also should be information on specimen deposit and identification authorities. In view of the complexity, this task should not initially be recommended for the CDRS, but rather a cooperating institution.

Terrestrial Vertebrates (Excluding Birds)

The native mammals and reptiles, almost all of which are endemic, are an important natural resource, all the more so since tourism is clearly becoming the major economic activity in the Galapagos. The exotic mammals are at present the greatest threat to native Galapagos environments. Their great variety and broad distribution in fragile Galapagos ecosystems present an ideal opportunity to study their population ecology and methods of control and elimination.

Top priority should be given to detailed autecologies, the bioenergetics, and long-term population studies of the land iguanas and snakes and the most destructive exotics: goats, pigs, cats, dogs, and black rats. Recent and current investigations of the tortoises and rice and black rats should be continued.

Community level studies, including these vertebrates, are needed to obtain a holistic understanding of the Galapagos ecosystem. These will be valuable both for conservation purposes and for testing theoretical models by comparison with continental areas.

These studies will require extensive integration with the following investigations

and data-gathering services: (1) environmental monitoring, (2) vegetation and geological mapping, (3) quantification of the structure, successional relationships, and productivity of plant communities.

See Appendix II for detailed discussion.

Birds

Birds are easily the most thoroughly studied group on Galapagos. Because of their importance to tourists, the Galapagos birds are a major natural resource and should be treated as such. Basic ecological field studies are needed only for a few species of water and sea birds, such as the brown pelican (the pelican is particularly important because of its known sensitivity to pesticides and other pollutants). Monitoring of populations, including banding, mapping, and censusing studies already in progress, should be continued and expanded, with priority given to the flightless cormorant, penguin, frigate birds, Hawaiian petrel, and waved albatross. Long-term population studies and general monitoring of the avifaunas of different islands are badly needed for the land birds; it is highly desirable to continue, at least at intervals, population and ecological studies such as those recently undertaken on the Galapagos Hawk and owls by T. de Vries. Attention should be paid to the local extinctions and inter-island colonization which seem to be a feature of the various species of finches. A variety of interdisciplinary services and studies in other areas would contribute greatly to future bird studies; e. g., meteorlogical monitoring, physical and biotic oceanographic data, mapping and phenology of vegetation, and distribution, abundance, and phenology of invertebrates.

See Appendix II for further discussion.

Paleontology

The evolutionary importance of the Galapagos stands in marked embarassing contrast to the paucity of paleontological work in the islands. The work that has been done shows great promise, but the top paleontological priority at the moment is simply getting a paleontologist to the Galapagos. Other field workers and local residents should be encouraged to report the locations of lava tube caves, fissures, other possible former habitats, limestone deposits, peat bogs, or any other situation in which evidence of former life might be preserved. However, excavation of deposits must be done by a trained paleontologist lest invaluable specimens be accidently destroyed or otherwise lost to science. See additional discussion in Appendix II.

Conservation

The primary threats to the Galapagos environment are introduced plants and animals and human exploitation. The following recommendations are made with full recognition that most problems involve complex political issues. They clearly must be solved by the combined efforts of the Ecuadorian Park authorities, other Ecuadorian governmental agencies, Ecuadorian scientists, and the Darwin Research Station. See Appendix II for a more detailed discussion of these recommendations and the contributions that visiting scientists can make to conservation efforts.

RECOMMENDATIONS - CONSERVATION

Research

A variety of socio-economic studies are urgently needed. Carefully controlled and limited tourism and a limited human population size need not undermine preservation efforts; in fact, proper management of settlements and tourism offer the only hope for preserving the Galapagos. Critical studies are: (1) human population dynamics and the feasibility of introducing population control methods; (2) the present status of agriculture and land utilization and methods for improving yields without increasing the land area utilized and unfavorably affecting preserved areas; and (3) compilation of catch statistics and long-term population studies of important fisheries species (spiny lobster, green sea turtle, edible fishes) so that cropping levels and fishing methods can be controlled.

The current studies of the effects of tourism on the most frequently visited sites should be continued and expanded whenever necessary.

Detailed autecologies, long-term population dynamics, and the environmental effects of introduced plants and animals need to be studied in selected sites where control programs are not in operation. The most destructive species urgently require attention: goats, pigs, cats, dogs, black rats, the little fire ant, and a number of plant species. A variety of control methods need to be tested for these species.

Many species of native birds, reptiles, mammals, invertebrates, and plants are endangered. Knowledge of basic population dynamics is required for some. For others, a minimal requirement is continual monitoring through counts in standardized quadrats or along standardized transects.

Pollution studies, particularly of pesticides, should begin immediately to establish baselines, followed by frequent checks. The following species are suggested: brown pelican, sea lion, a predatory fish, snake or lava lizard, hawk or owl, a predatory invertebrate.

It is important to extend the National Park boundaries beyond the shoreline. As a first step we need: (1) a marine faunal survey; (2) regularly sampled permanent quadrats in the littoral zone; and (3) population studies of some cross section of marine species.

Education

The local Galapagos population must be made more aware of the unique natural history of the islands, the common interests of settlers and conservationists, and the idyllic situation in which they live as compared to polluted, industrialized countries. Appendix II contains a variety of specific suggestions. A major point is that current educational programs should be continued and all means should be used to carry information directly to local inhabitants in their villages.

Educational efforts are needed in order to channel a large proportion of the local economic activity into areas that will help preserve, or do the least harm to the biota and the natural landscape.

RECOMMENDATIONS - CONSERVATION

Present educational effort on mainland Ecuador should be extended. Additional features include Galapagos Information Centers and vacation courses for students and schoolteachers.

Also, see the recommendation entitled Ecuadorian Science.

Enforcement of Laws

Quarantine procedures should be established in the near future and proper education programs should prepare the way for their acceptance. See the recommendation entitled Environmental Monitoring and Conservation for explanation of the proposal to station wardens permanently on boats in certain critical areas.

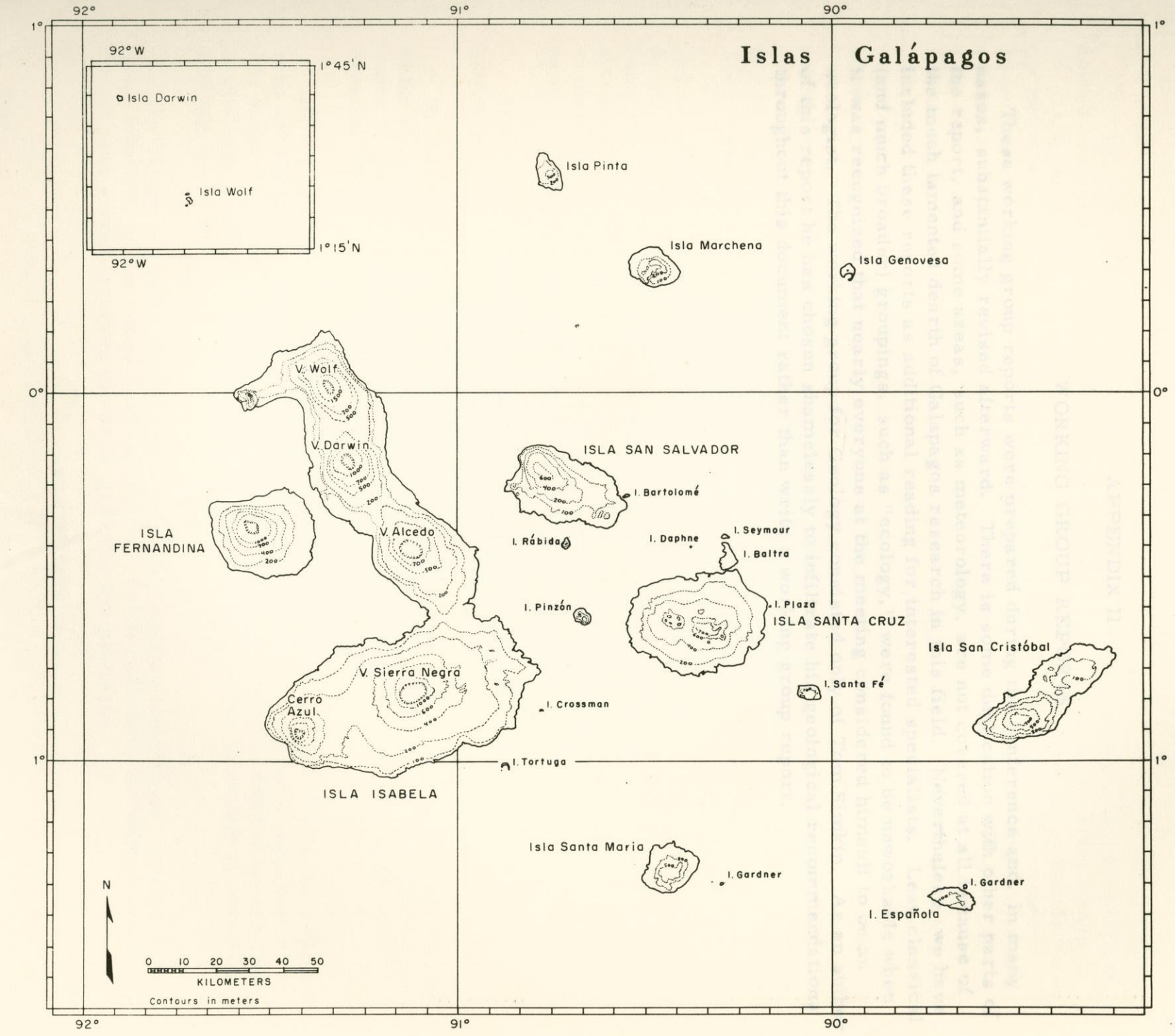
APPENDIX I

SYNONOMY OF ISLAND NAMES OF THE GALÁPAGOS

Official Ecuadorian Names[1]	English Names[2]
Baltra	South Seymour
Bartholomé	Bartholomew
Darwin, Guerra	Culpepper
Española	Hood
Fernandina, Plata	Narborough
Genovesa	Tower, Ewres
Isabela, Santa Gertrudis	Albemarle
Marchena, Torres	Bindloe
Pinta, Geraldino	Abingdon
Pinzón	Duncan, Dean
Plaza	---
Rábida	Jervis
San Cristóbal, Grande	Chatham, Dassigney
San Salvador, Santiago, Gil, Olmedo	James, York
Santa Cruz, Bolivia, Chavez, San Clemente, Valdez	Indefatigable, Norfolk, Porter
Santa Fé	Barrington
Santa María, Floreana	Charles
Seymour	North Seymour
Wolf, Gasna, Nuñez	Wenman
---	Daphne Major
---	Gardner-near-Charles
---	Gardner-near-Hood

[1] Official names given first; locally preferred names, when different from official names, are underlined.

[2] Preferred English names given first.


Islas Galápagos
92° W
1°45' N
1°15' N
92° W
Isla Darwin
Isla Wolf
Isla Pinta
Isla Marchena
Isla Genovesa
V. Wolf
V. Darwin
V. Alcedo
ISLA FERNANDINA
ISLA SAN SALVADOR
I. Bartolomé
I. Rábida
I. Daphne
I. Seymour
I. Baltra
I. Pinzón
I. Plaza
ISLA SANTA CRUZ
Isla San Cristóbal
I. Santa Fé
V. Sierra Negra
Cerro Azul
I. Crossman
I. Tortuga
ISLA ISABELA
Isla Santa Maria
I. Gardner
I. Gardner
I. Española
92°
91°
90°
1°
0°
1°
N
0 10 20 30 40 50
KILOMETERS
Contours in meters

APPENDIX II

WORKING GROUP REPORTS

These working group reports were prepared during the conference and, in many cases, substantially revised afterward. There is some duplication with other parts of the report, and some areas, such as meteorology, are not covered at all because of the much lamented dearth of Galapagos research in this field. Nevertheless, we have included these reports as additional reading for interested specialists. Less classical (and much broader) groupings, such as "ecology," were found to be unworkable when it was recognized that nearly everyone at the meeting considered himself to be an ecologist. The working group for Geology consisted only of Tom Simkin. As an author of this report he has chosen shamelessly to infiltrate his geological recommendations throughout this document rather than write a working group report.

MARINE SCIENCE

Subcommittee: J. Hedgpeth

MARINE SCIENCE RESEARCH

I. The most urgent research need at this time in the Galapagos is a biogeographic survey of the marine invertebrates, macroscopic algae, and shallow water fishes of the archipelago. We know very little of the comparative distribution and abundance of the shore fauna from island to island. The impending development of a souvenir business in sea shells and other sea-shore mementos could seriously alter the coastal ecosystem by removing such key species as intertidal carnivorous gastropods and set in motion ecological changes that will make it difficult to evaluate the present patterns of distribution and the evolutionary significance of this element of the Galapagos biota.

There are many questions concerning the marine fauna that require intensive field work, as well as analysis of existing museum collections where appropriate. These include the possible existence of endemic subspecies and races, especially among predatory gastropods (in this context material must be gathered and appropriately preserved for chromosome studies); the herbivorous gastropods, especially Nerita (which may be absent from Floreana); and common crabs and echinoderms. The barnacles, a classic field of Darwinian studies, would also be included in this survey. In addition to the systematic-biogeographic aspect, estimates of numbers and densities of the more abundant species should be attempted. It must not be forgotten in this context that the intertidal system is intimately related to the well being and maintenance of stocks of marine iguanas and shore feeding birds, and therefore the knowledge of the interactions of the shallow water system and the evolutionary status of the species of invertebrates and algae is of vital significance to understanding vertebrate stocks in the Galapagos.

Studies would include establishment of longterm observation stations, i.e., transects, quadrats, etc., for assessing changes in time.

II. Of perhaps less immediate urgency, but nevertheless significant, are studies of the shallow sublittoral fauna and flora by free diving. The distribution and abundance of corals, oddly neglected in the context of the Darwinian canon, deserves especial notice.

III. There has been considerable oceanographic research activity in the Galapagos area and the eastern tropical Pacific in general. There is need for a summary of this activity in order to elucidate problems and indicate the directions of needed study. A catalogue of this effort will be prepared as soon as possible to include geophysics, geology, bathymetry, etc.

IV. There is need for studies of species of economic importance, especially the spiny lobsters, edible fishes, and sea turtles. Catch statistics, including number, weight, and sexual condition should be gathered and published.

FACILITIES

I. Ship

The present status of the Beagle is not reassuring. Recognizing the somewhat

incompatible requirements for a ferry-supply-logistics-support vessel and a small research vessel, we would recommend serious consideration of exchanging the Beagle for a more practical, easily maintained and less expensive vessel, or perhaps two smaller vessels, one for logistics support and the other for shallow water research. In any event, it is essential to reduce operating and maintenance costs and this may best be done by obtaining a different vessel.

There should be more skiffs, boston whalers, and similar small craft.

II. Laboratory

Marine studies will require a minimal additional facility at the Darwin Station. A small building near sea level in a location remote from any outfall or seepage is needed. This would include work tables, stout enough for microscopes, and a water table and several aquaria. The sea water system would consist of plastic lines (hose or pipes), small, possibly transportable pump (plastic lined or cast iron - never bronze!), a 50-100 gallon overhead tank and feeder lines to the water-table. The essential is simplicity, a minimal flow-thru system for holding specimens for short-term observation and photography. A battery- or gasoline-powered pump could be placed on a small boat or removed to another island when necessary.

PLANTS

Subcommittee: D. Porter
W. Reeder
C. Rick (Chairman)
I. Wiggins

Preamble

Studies of the Galapagos flora are urgently needed to provide the basic understanding necessary for progress in other biological disciplines as well as to probe the origins of the endemic species and biogeographic relationships of the flora as a whole.

The contemplated research is admirably abetted by the Wiggins-Porter flora, which provides required basic systematic information. According to our crude estimates, this work covers perhaps 90% of existing species; pursuit, capture, and study of the remainder are contemplated as part of our recommendations.

Ecological botany in the Galapagos is as yet in a primordial stage. Piecemeal surveys of varying degrees of completeness have been made, the most significant being the recent project of Hamman, consisting of transect studies and mapping of plant communities on several of the larger islands. When made available, the results of these studies of plant community distribution should provide biologists with preliminary ecological information basic to the development of further important ecological, systematic, and evolutionary projects.

The most immediate and urgent need is for detailed vegetation mapping of certain islands; such an enterprise is indispensable for understanding of broad biological interactions.

Quantitative sampling of plants along selected transects of the islands is required to provide basic data for studies of natural pattern and its modification with slope, exposure, edaphic variation, and disturbance. Data from such sampling provide the basis for study of succession within the various communities, aid in evaluating the age and stability of boundary situations observed in the field, and provide a basis for calculating carrying capacity for the variety of animals inhabiting the communities. Other contemplated ecological studies are essential for an interpretation of the dynamics and total economy of the biota.

Critical research is proposed approaching key problems in phylogenetic relationships and evolution of the Galapagos flora. Throughout all of these considerations we have also become aware of the need for equivalent studies in areas of similar climatic conditions on the adjacent continent, for which less information is often available than for the Galapagos.

It must be emphasized that the plans hereafter outlined envisage much interdisciplinary interaction. For the sake of efficiency, certain phases should be undertaken simultaneously by scientists in several fields. Cooperation of workers in the following fields will be essential to the execution of these investigations:

Geology - in understanding processes of land formation and the age and composition of igneous deposits;

Meteorology - in understanding the impact of climatic variables on plant growth and reproduction, thus, secondarily, on animal populations and their distribution;

Pedology - in ascertaining mechanisms of soil formation, learning the structure and composition of soils, and their potential for continued plant production in the natural and agricultural communities;

Vertebrate and invertebrate zoology - in tackling problems of cropping, dispersal, and the role of plants in providing the habitat framework for animals;

Entomology - in studies of predation and population ecology.

We anticipate that most phases of the recommended research would not require excessive participation of professional scientists. They would be responsible for the planning, coordination, data analysis, and communication of results, but most of the field work could be done by Ecuadorian students and local field assistants under the direction of one or two professionals.

Proposed Research

I. Vegetation mapping and quantitative sampling (top priority)

A. Qualitative transect surveys - continue qualitative survey and mapping of plant communities, e.g., work of Hamman; collate, index, and record results of previous (mostly unpublished) observations; maintain and extend master vegetation map with careful measurement of linear and altitudinal distributions; continue collection of plant specimens, especially less well known species, weedy invaders, known food plants, others.

B. Quantitative sampling - establish more permanently marked quadrats, initially along altitudinal gradients; establish uniform sampling such as the following.

1. Establish strip of 10 X 10 M. quadrats at selected altitudinal intervals.

2. Identify, count, and measure all trees and shrubs in quadrat.

3. Measure leaf canopy using midline intercept.

4. Sample forbs and grasses - line intercept counts, several short transects per quadrat.

5. Evaluate substrate (litter, sand, bedrock, etc.).

6. Sample litter (depth, composition, moisture content; collect samples for invertebrate extraction).

7. Provide standard photographs - oblique (of quadrat); litter photographs (several per quadrat; verify substrate composition); canopy photographs (vertical shot at each litter station; verify cover measurement).

8. Excavate and face soil profiles along transects; photograph and prepare plastic embedded "peel" of profile; collect sample of eroding bedrock of size to permit chemical and physical description of weathering rind as well as deeper fresh bedrock (should be carried out at each station by competent pedologist).

Note: Canopy and herb measures should be repeated at different seasons, and, if possible, 2-3 year intervals thereafter. Permanently marked quadrats are required.
(Above methods, 1-7, used by Reeder, et al., on initial Santa Cruz transect, 1971).

C. Islands (in order of priority): Santa Cruz, Duncan, Fernandina (especially western transect through 1968 ash deposits), Tower. Hood, Floreana, and San Cristobal also recommended, but of second order.

D. Pre-test infrared and false color photography of principal canopy trees and shrubs; provide recommendations for useful emulsions for aerial photography.

E. Integrate above data (transect community mapping and quantitative results) with aerial photography, with ultimate goal of detailed quantitatively-controlled vegetation maps.

F. Measure primary productivity, selected sites along primary transects.

1. Using methods of IBP, clip and weigh herbaceous growth; estimate timber production; clip, weigh, and measure shrub samples; repeat seasonally and annually as required.

G. Study community relationships, aggregation, exclusion, etc., using computer analysis of above data; apply techniques of ordination, factor and cannonical analysis, others.

II. Plant-animal interrelationships (this and following recommendations are second order priority)

A. Cropping and foraging by invertebrates and vertebrates, native and introduced. (To be based largely on observations of animal behavior patterns; measures of differential productivity in exclosure. Requires collaboration with production ecologist (Pt. I-B)).

B. Pollination ecology.

Requires cooperation of entomologist. (1) Flowering patterns; (2) systematic observations of pollinator behavior; (3) attractivity - visible and ultra-

violet spectra; (4) behavior of flowers when untreated and artificially pollinated in isolation.

C. Dispersal of propagules; properties of pollen rain.

D. Epidemiology of plant pathogens, endemic and introduced.

III. Phytogeography: Standard techniques - generally qualitative

A. Relationships with floras of other areas (mainland South America, Central America, Cocos Island, etc.). Relationships between islands; within islands. This topic directly related to population structure (V).

B. Dispersal - mainly based on qualitative observations.

Agents: wind, ground water, rafting, bird feet, bird digestion, mammal fur, mammal and reptile digestion.
Test such aspects as (1) flotation and survival of propagules in fresh and sea water, (2) effects of animal digestion on germination, (3) drift of seeds in normal wind situations, (4) spore and pollen collections.

C. Human factors.

1. Introduction of exotics and weeds.

2. Interisland transport.

IV. Reproductive ecology (see also parts II-B, -C, III-B).

A. Flowering; phenology, environmental Zeitgeber.

B. Seed germination ecology; viability and special requirements for germination per species. Relations of germination and viability with seasonal climatic conditions and annual variation (e.g., Nino vs. "normal" years).

C. Interisland reproductive success.

V. Population structure (intraspecific).

A. Sample selected populations of certain species for such characters as (1) morphological variation, (2) chromosome constants, (3) chemical composition (particularly electrophoretic determination of isozymes).

B. Compare results within and between islands; detection of clines (as in the well known example in Alternanthera).

C. Comparisons with mainland equivalents.

D. Genetic studies and population ecology of (1) Scalesia, (2) Alternanthera, (3) Euphorbia, (4) Opuntia, and (5) Lycopersicon.

TERRESTRIAL INVERTEBRATES

Subcommittee: C. MacFarland
R. Silberglied

Work Done on Terrestrial Invertebrates to Present

I. Systematics

The work done on Galapagos terrestrial invertebrates to date is, almost without exception, "alpha" systematic in nature - that is, descriptions and catalogues. Less than 1,500 species of terrestrial invertebrates are now known from the archipelago, a minute figure relative to a region of similar area on the equator, but on the mainland of South America. Many groups have been little studied (nematodes, mites) or not at all (earthworms). It is expected that the number of species eventually found in the islands will be more than double the present figure. The most recent catalogues of the larger groups of Galapagos invertebrates are those of Linsley and Usinger (1966) for the insects, Roth and Craig (1970) for the arachnids (excluding mites), and Dall and Ochsner (1928) for the terrestrial molluscs.

Part of the systematics problem lies with our incomplete knowledge of Neotropical invertebrates, which is in even more rudimentary shape than is the Galapagos fauna. Numerous species first described from Galapagos material (often under the names galapagensis, darwini, and the like) are later found to be synonymous with mainland forms. Comparative systematic work is needed in most groups.

Modern systematic studies of Galapagos invertebrates are entirely lacking, in spite of their great potential for contributing to our understanding of evolutionary and ecological problems. No comprehensive studies have yet been done on any of the numerous groups of arthropods that have radiated within the islands. Genetic studies of Galapagos invertebrates are entirely lacking. Immature stages, life histories, and associations with host plants and animals are, for most species, completely unknown. The few exceptions are based on fragmentary evidence, collecting notes, and techniques.

II. Ecology

The ecology of Galapagos terrestrial invertebrates is a virtually untouched field. Little is known of species abundances and detailed distributions, not to mention attempts at causal analysis. Population cycling with Galapagos seasons and the effects of El Nino years have not been studied. Although pollination biology in the Galapagos has attracted some attention (due to the presence of but one bee species there), knowledge presently consists of lists of plants visited and anecdotal descriptions of flower visitation and bee behavior. A similar situation exists as regards the (description and) ecology of invertebrate parasites - their distributions, densities, population dynamics, modes of transmission, etc.

Ongoing Studies

I. Systematics

Systematic studies of Galapagos invertebrates continue to appear at a slow, steady rate. The limiting factor is the number of systematists; systematic studies

cannot be rushed. In many cases such studies cannot proceed without simultaneous studies of mainland forms.

Recent emphasis has been on certain groups of Diptera and Hemiptera. Work in progress at the present time includes research on ticks (Ixodea), ants (Formicidae), Neuroptera, barklice (Psocoptera), and several families of Lepidoptera, as well as terrestrial molluscs. A supplemental list of Galapagos insects is also in progress, and a revision of the arachnid list will soon be available.

II. Ecology

A few ecological studies of terrestrial invertebrates in the Galapagos are now in progress. Examples are: analyses of arthropod distributions within transects of the lower vegetation zones on Santa Cruz, and sensory and behavioral aspects of the pollination of Galapagos flowers.

Areas Needing Investigation

I. Systematics

A. The hard work of classical "alpha-level" systematic studies - descriptions, etc. - still needs to be done for most groups of Galapagos invertebrates.

B. Modern systematic studies of particular groups, augmented by the use of analytical genetic methods, should be undertaken. Electrophoretic analysis of enzyme polymorphisms are particularly apt for studying within- and between-population variation in groups of closely related organisms, such as the products of insular radiation. Among the terrestrial invertebrates, special attention should be given to the molluscs and tenebrionid beetles.

II. Ecology

A. Classical descriptive autecology of most Galapagos invertebrates remains to be touched by scientists. Such studies are needed if we are to make use of invertebrates in broader ecological studies (below). We know nothing about the developmental biology, life table data, and detailed interspecific interrelationships of Galapagos species.

B. Community level studies, stressing population dynamics under different environmental regimes and in different vegetation zones, over time, would contribute greatly to a holistic understanding of the Galapagos ecosystem. Environmental monitoring is a first-level priority for such studies. Monitoring of microclimates should also be considered.

C. Symbiotic organisms provide models for theories of coevolution and community evolution. A broad approach to pollination biology at the community level (with interdisciplinary studies of the genetics of Galapagos plants) is strongly recommended, for it would provide data on a simple system that could be used to understand better the more complex systems now under intensive study (e.g., I. B. P. 's pollination studies).

INVERTEBRATES

III. Conservation

Most conservation activity in the Galapagos Islands has centered on the unique vertebrate fauna and introduced feral mammals. A more subtle, but very important effect is produced by introduced invertebrates. Their distributions and dynamics deserve study now, as they are continually being introduced and spread throughout the archipelago. Special attention should be given to Wasmannia auropunctata (fire ant), which has a direct and detrimental effect on the indigenous terrestrial invertebrates, particularly other ant species. Its spread should be carefully monitored.

IV. General suggestions

A. Invertebrate collections are difficult to keep under tropical conditions. However, a good set of photographs would suffice for many groups, and such a set kept at the Charles Darwin Research Station would enable workers rapidly to identify most collected species in the islands. This would be a great help to ecologists, who may not be immediately familiar with all organisms of interest to them, as are many systematists who come prepared with a knowledge of "their" group.

B. It is both hard to get Galapagos invertebrates identified, and for systematists interested in identifying Galapagos material to locate the extant collections. A clearinghouse for information concerning invertebrate collections and systematists would be a wise arrangement.

TERRESTRIAL VERTEBRATES (EXCLUDING BIRDS)

Subcommittee: C. MacFarland
R. Silberglied

Excepting birds, the extant terrestrial vertebrate fauna consists of the following:

1. Native Mammals - two species of bats (Lasiurus); two species of rice rats (Oryzomys); the sea lion (Zalophus californianus wollebaeki); and the fur seal (Arctocephalus australis galapagoensis); all but one of the bats are endemic species or subspecies.

2. Reptiles - the marine iguana (Amblyrhynchus cristatus); two species of land iguanas (Conolophus); a number of species of lava lizards (Tropidurus), snakes (Dromicus), and geckoes (Phyllodactylus); and the giant tortoise (Geochelone elephantopus); all are endemic species.

3. Introduced Mammals - most of the islands are inhabited by feral populations of one or more of the following: pigs, dogs, cats, black rats, house mice, goats, donkeys, cattle, and horses.

WORK COMPLETED OR IN PROGRESS

I. Systematics and Distributions

The basic work in systematics is more or less complete for these groups of terrestrial vertebrates. Adaptive radiations have occurred in most of the native genera, but the function of most differences found in the various species or subspecies within a given genus are unknown or at best poorly understood. The general distributions of the genera throughout the archipelago are reasonably well known.

II. Population Ecology and Behavior

Detailed distributions on individual islands, rough population sizes, breeding ecology and annual cycles, behavior patterns, food species, the effects of introduced species, and some details of population dynamics are known only for the giant tortoises, and to a lesser extent, the marine iguana. Such studies are currently being carried out (comparatively) on the rice rats and introduced black rats; an investigation of the social behavior and some aspects of the population ecology of the lava lizards was recently completed.

III. Physiological Ecology

Behavioral and physiological thermoregulation, diving adaptations, and the functioning of nasal salt glands have been studied in the marine iguana.

PRIORITY RESEARCH NEEDS

The native mammals and reptiles, almost all of which are endemic, must be considered as important natural resources for Galapagos, especially since tourism is clearly becoming the most important economic activity in the islands. Top

priority should be given to the following:

I. Detailed autecologies (as under II above) and long-term population studies of these species, including the exotics, are vital in order to provide information for broader community and ecosystem approaches. Most urgent are the following studies:

A. Land iguanas and snakes. Virtually nothing is known and species of both are threatened with extinction.

B. Tortoises and rice rats. Recent and current investigations of these threatened species should be continued.

C. Exotic mammals. Virtually no information is available on their population ecology or comparative exclusion of endemics. Casual observations have demonstrated that they have produced tremendous effects in the fragile island environments of the Galapagos, but quantitative studies of their direct and indirect effects through predation on plants and predation or competition with native vertebrates are urgent. The Galapagos present an ideal laboratory in that there are habitats where the various exotic species are present singly, present in various combinations, and absent. Priority should be given to the most destructive species: goats, pigs, cats, dogs, and black rats.

D. Bioenergetics. Such investigations are needed for all the species mentioned in A. through C. above. For example, the Galapagos present a unique opportunity to study the bioenergetics of large ectothermal herbivores (tortoises, land iguanas) in two extreme situations: 1) with virtually no competitors or predators (the natural situation) and 2) where predation and competition are severe (introduced mammals).

II. Community and ecosystem level studies in the Galapagos would be valuable for testing theoretical models and ultimately for conservation practices.

A. Model testing. Island communities and ecosystems are widely claimed to be less complex and less stable than similar ones on continents, perhaps in large part because island habitats are less saturated with species than continental ones. The relatively undisturbed communities of the Galapagos Islands provide an ideal area for testing these theoretical arguments and their corollaries by comparing them to continental communities. Such hypotheses as the following could be tested: (1) that the range of different habitats occupied and the "sizes" of species niches are inversely related to the number of species present; (2) that competition is of far greater significance on continents than on islands; (3) that intensity of competition and the amount of allowable niche overlap among species are inversely related; and (4) that species diversity and stability of communities are positively correlated. The effects of exotic mammals in various Galapagos and continental communities should aid in testing these hypotheses. These studies should emphasize the population dynamics of whole communities of energetically related species (e.g., primary producers and herbivores) in different vegetation zones and under varying environmental conditions (e.g., dry vs. "El Nino" years), over long time periods.

B. Conservation. Somewhat of a holistic understanding of Galapagos communities

will be necessary in order effectively to preserve and manage them. For example, tortoises are currently being raised in captivity and depleted populations are being restocked. It will soon be vital to understand the carrying capacity of various islands (i.e., phytosociological structure, primary productivity, and tortoise bioenergetics) and the amount of predation and competition which the tortoises can withstand, in order to determine control efforts for exotic mammal populations. Similar questions will continue to arise as conservation programs are expanded and integrated studies of whole communities will be vital.

GENERAL COMMENTS

I. All of the above studies will depend upon extensive integration with other investigations and certain general data-gathering services. Most important will be the following: (a) environmental monitoring; (b) vegetation and geological mapping; and (c) quantification of the structure, successional relationships, and productivity of plant communities.

II. As implied above, the suggested studies will contribute directly to solving conservation problems. Continual monitoring of these vertebrates is required in order to detect changes in population sizes. When possible, i.e., after autecological studies have been completed on a species, this should involve regular marking of populations and quantification of reproductive and mortality rates. For the less threatened species, regular counts along permanent transects or in permanent quadrats should be a minimal requirement.

BIRDS

Subcommittee: R. Bowman
J. Dorst
M. Harris
D. Snow

The avifauna is well known and only the major gaps in knowledge, especially those associated with avifaunal change are detailed below. For convenience, sea- and water-birds are separated from land-birds.

Present Knowledge

I. Sea- and water-birds

Over the years, data have accumulated on distribution and breeding cycles, but in the last decade or so almost continuous observation has resulted in the sea-birds being as well, if not better, known than those of any other tropical area. The rough population level, breeding ecology and cycles, food, behaviour, moult, and some detailed population dynamics are now known for many species. This contrasts with water-birds, which have been neglected. The basic need is for the study of a few neglected species and the continuation of long-term population studies.

II. Land-birds

The composition of the land avifauna and its distribution is rather well known; its zoogeographical affinities are also adequately understood. Something is known of the breeding habits and food of all the land-birds, and some behaviour studies have been made of the endemic forms. The major gaps in knowledge concern: the extent and time-scale of changes (extinctions, introductions, etc.) in island populations; the factors controlling population levels; details of micro-evolutionary events, relationships, and competition between closely related species of finches, etc.; movements of individuals, especially between islands; differences in annual cycles at different altitudinal levels.

The Future

I. Sea- and water-birds

These must be considered as one of the major natural resources of Galapagos tourism and future research should be concentrated toward conservation.

A. Important species not yet studied

1. Flamingo. Despite some regular observation on southern Isabela, relatively little is known. Data on breeding and inter-island movements are urgently needed and, hopefully, will be collected in the next couple of years.

2. Brown Pelican. Virtually no information and an ideal subject for study. As fish-eating birds are extremely sensitive to pesticide contamination and act as indicators of pollution, a detailed study of this species, associated with a smaller project on the herons, is urgently needed.

B. Monitoring populations, including banding, mapping, and censusing studies already in progress should be continued and expanded, but priority given to the following species:

1. Flightless Cormorant (and possibly the more difficult Galapagos Penguin), as these could be easily removed if net-fishing were allowed around Fernandina and western Isabela. (Studies already in progress by Harris and Boersma.)

2. Frigatebirds, as these apparently are already suffering from tourist disturbance.

3. Hawaiian Petrel, as this species is now seriously declining due to clearing of its nesting areas for agriculture, killing of adults by dogs and pigs, and low nesting success due to pigs and black rats. Now extremely rare in Hawaii and the most endangered species in Galapagos. The present study should be continued.

4. Waved Albatross, as it could suffer from disturbance. General observations and banding since 1960, detailed study by Harris 1970-72 (? 75).

C. As with all sea-bird studies, little is known of the availability of food; sampling of the larger plankton, fish, and squid might be a profitable cross-disciplinary study.

II. Land birds

Long-term population studies:

A. Monitoring of bird populations of interior areas

Work begun by de Vries should be continued. Continued study of the Galapagos Hawk is of conservation importance, but finches, mockingbirds, and other species should be included. Basic data will be obtained from standard transects. Localities: Barrington (island undergoing regeneration of vegetation), one other island (Hood?), and neighborhood of Darwin Station.

A standard recording card would be very valuable as an adjunct to this work. This should include phenology of plants, insects, etc., as well as birds. We suggest that de Vries should be asked to design such a card, since he has been collecting these data for several years.

B. General monitoring of avifauna of different islands

Purpose: to improve the inadequate present knowledge of the distribution of the Geospizinae and other land-birds, and to monitor major avifaunal changes (extinctions, introductions, major changes in numbers).

Special attention should be paid to the smaller islands, the finch popula-

tions of which are very inadequately known.

Methods: will depend entirely on the competence of the observer. At the lowest level, the use of standard recording cards will be of some value. More specialized work would include the trapping and measurement of samples of birds.

III. General

Obviously there are gaps in knowledge of all species and promising projects would be:

A. Basic biological field studies

Breeding and territorial behaviour, local movements (based on banding), and comparison between different altitudinal populations of land-birds. Comparison between Tropicbirds nesting on different islands which show different breeding cycles (annual vs. nonannual), Masked Boobies in northern and southern colonies.

B. Micro-evolutionary studies

Adaptive radiation of finches; competition; isolating mechanisms and protein analysis in land-birds and, to a lesser extent, sea-birds. Such studies will depend on the interests of individual research workers.

General services needed:

Meteorology
Oceanographic data, physical and biotic
Phenology of vegetation
Phenology of invertebrates
Infra-red monitoring

Local participation

There is at present good liaison between ornithologists and the National Park Service, and this is being extended by a World Wildlife Fund grant to Harris to train and supervise an Ecuadorian to monitor the effects of tourism on animal and bird populations.

Birds make ideal subjects for training biologists and some of the more important gaps in knowledge could be filled by students from universities in Ecuador doing short (e.g., three months) research projects under the supervision of the CDRS.

PALEONTOLOGY

Subcommittee: C. E. Ray
F. Whitmore

Status

Pioneering and very substantial work has been done on marine invertebrates of ?Miocene, Pliocene, and Pleistocene age in the Galapagos, summarized with bibliography by Hertle (in Proceedings of the California Academy of Sciences, 1972, 4th series, volume 39, number 3, pages 25-46). The Pliocene fauna from Baltra includes a land snail, offering the intriguing prospect of evidence of the terrestrial fauna of the islands in Tertiary time. Dr. Bowman reports that there is a large bone, imbedded in volcanic rock, in the California Academy collections (specimen misplaced at the moment), probably representing a pinniped.

Published knowledge of vertebrate remains from cave deposits is limited to Niethammer (1964, Mammalia, volume 28, number 4, pages 593-606), the principal contribution of which is the description of the giant rat, Megalomys curioi. Much more material is now under study by C. E. Ray, demonstrating that the animal must be placed in a new genus.

At this time, we have just enough information to demonstrate that deposits are present in the Galapagos which will produce a fossil record if prospected. We know very little of the distribution, extent, and nature of either "outdoor" sedimentary strata or caves and their sedimentary deposits. Lake and bog deposits have not been prospected at all for vertebrate fossils, although Craig MacFarland tells us that there is evidence of a local man digging up a tortoise from a peat deposit.

Needs

It is ironic that the Galapagos should be virtually unknown paleontologically in view of its justifiable status as holy land for evolutionists. This need not remain so. Prospecting for fossiliferous deposits by trained paleontologists will surely produce results; a very little field work by good men has produced a spectacular beginning for marine invertebrates, but the surface has barely been scratched. We don't even know where the strata are yet. These beds may also produce marine vertebrates (just one specimen of a Pliocene marine iguana would be a bonanza), and possibly also terrestrial vertebrates and invertebrates.

Topographic and geologic mapping and aerial photographic coverage are prime needs, with special attention to locating sedimentary or parasedimentary rocks (as tuffs), peat bogs, fissures, and caves, especially those with earth fillings. Caves used at present by owls or bats probably were similarly used in the past; such caves, with a deep earth floor, are ideal possibilities for a rich and varied fossil and/or subfossil fauna, of both vertebrates and invertebrates (as land snails and sometimes insects). Deep, stratified cave fills should be excavated only by trained personnel, with proper attention to stratigraphy and such matters as sediment samples for pollen analysis and C-14 dating.

Recommendations

Good mapping should be top priority for most disciplines in Natural History

study of the Galapagos, certainly for paleontology, so that deposits can be located. Any biologist or geologist should be encouraged to note the location and nature of potentially productive fossiliferous deposits. The location of a cave or fissure, even with no knowledge of its character, is useful information at this stage. Collecting by non-paleontologists should be limited to salvage of whatever is possible in situations where specimens are in danger from the elements (say a bone in a sedimentary rock on the intertidal zone) or from the hand of man (bones exposed on the surface in a cave). In no case should a non-paleontologist excavate a cave barth or a bog deposit. Such deposits will be few in number in the islands, and there will be none to spare. A rich and extensive cave fill should in no event be completely excavated. A part should be preserved intact for voucher purposes and against the development of new techniques or posing of new questions.

Discussions are underway now between Dr. Kramer and the Smithsonian (Tom Simkin, Clayton Ray, Storrs Olsen) to institute a program of paleontological exploration with concomitant training of Ecuadorian students.

Interdisciplinary Considerations

The interrelationship of vertebrate and invertebrate paleontology and of palynology is implicit in the preceding discussion.

Students of every aspect of natural history working in the Galapagos would like to know how long there have been islands in the area capable of supporting life - one Pliocene land snail offers a beginning in that direction.

Study of the evolutionary biology and phylogeny and adaptive radiation of any group would profit by the discovery of ancestral forms of that group.

Since extinction is the rule and survival the exception for species through geologic time, a knowledge of what organisms have been present and have perhaps become extinct even prior to the advent of man should help to place conservation efforts in perspective.

Most important of all however, for baseline studies of the development of the biota, its conservation and ecosystem analysis, is the unique character of cave faunas as a source of evidence of what the fauna was prior to human interference. Throughout the world, shallow or superficial cave deposits or even middens on oceanic islands have yielded faunas commonly called "Pleistocene" either by courtesy or imprecision, because they include so many extinct taxa. Many of these are important primarily as the only known source of evidence as to the modern fauna prior to human devastation of the fragile island biotas.

The prospect of having this evidence available for a given island should be a factor in selection of an island for intensive study, such as has been proposed for Barrington. Without this evidence, there is no means to establish a baseline for the vertebrate fauna of an "undisturbed" island.

CONSERVATION

Subcommittee: J. Dorst
P. Kramer
E. Laso
C. MacFarland
F. Ortiz

Preamble

Galapagos conservation problems extend far beyond those that are usually thought of as being part of the functioning of a national park. Most human activities in the islands directly affect the environment, and the effects of many events on mainland Ecuador eventually are felt in the Galapagos, at least in part as a result of immigration. Added to the threat of human exploitation are the severe effects produced by introduced plants and animals.

The suggestions presented below are made with full recognition of the following: (1) The Ecuadorian Government has passed strict laws protecting the Galapagos environment; the major problems now are enforcement, education, more research, and development of additional conservation management procedures; (2) the Galapagos National Park Service and its parent organization, the Ecuadorian Forest Service, are responsible for formulating and effecting conservation programs for the Galapagos; (3) the Darwin Foundation (and Darwin Research Station), in accord with its agreement with the Ecuadorian Government, acts primarily to advise and cooperate with the National Park Service in carrying out these programs; (4) visiting scientists offer aid by cooperating with the National Park Service and the Darwin Research Station.

No specifics as to which organizations or individuals should carry out these suggestions are given below. Since most of the problems involve complex political issues, they clearly must be solved by the combined efforts of the National Park Service and Forest Service, other Ecuadorian governmental agencies, Ecuadorian scientists and researchers, and the Darwin Research Station. Visiting scientists can aid these efforts by such activities as: (1) providing basic information from their studies; (2) helping to plan conservation research programs and design management schemes; (3) providing field research experience for Ecuadorian students; (4) teaching in courses given by the Park Service and Darwin Station; (5) giving guest lectures, slide shows, etc., in the islands.

Threats to the Galapagos Environment

I. Human exploitation

A. Local population. The population of the islands has tripled since 1960, and now numbers approximately 5,500. Immigration was heavy from the late 1950's until recently and, as pressure for land ownership increases in continental Ecuador, this factor could become important again. At present a strong population growth results from a very high birth rate coupled with a decreasing death rate due to improved medical care. The lack of natural resources would eventually restrict the spread of population, but several uninhabited islands and areas on the inhabited ones are arable and have been threatened recently. This situation will rapidly worsen if the

population is not controlled. The local lobster fishery is overexploited already and others (some edible fishes, green sea turtle) could rapidly become so.

B. Tourists. More tourists have visited the Galapagos in the 1970's than ever before. Most come via one of the major companies operating ships in the islands. So far, these companies have cooperated with the Park Service and Darwin Station and tours have been responsibly managed. Most damage done by tourists has been caused by those coming on private yachts or chartering local yachts and fishing boats. As tourism increases, the disturbance of natural habitats and the biota must be carefully monitored.

C. Scientists. The number of scientific missions has been rapidly increasing, i.e., from six in 1965 to seventeen in 1971. It is vitally important that scientists demonstrate sound conservation principles in the islands. Though the total damage has been minimal, some scientists have disturbed animal populations, allowed campfires to get beyond control, denuded some areas of wood (for campfires), and left extensive amounts of litter. Appendix III contains a list of requirements for scientists set by the National Park and Darwin Station.

D. General. Pollution is increasing in the Galapagos, especially in the marine environment. In addition to the more obvious forms (petroleum residues, litter), there is evidence that chlorinated hydrocarbons may be entering the ecosystem through atmospheric and oceanic circulations. Farmers are beginning to use "hard," long-lived pesticides. There is a continual danger of the introduction of exotics from the mainland and inter-island transfers of biota; this includes both purposeful and accidental (ticks, seeds on clothing or in soil) transport of organisms.

II. Introduced species

A. Feral mammals continue to be the greatest threat to plant and animal species and to the Galapagos ecosystem as a whole.

B. At least one introduced invertebrate, the fire ant, is a major threat to many native invertebrates, e.g., other ants, centipedes. Also, at least several crop pests and several diseases of domestic animals are known from the islands. Without strict quarantine procedures, these will certainly increase in number, to the detriment of the native biota and the human inhabitants.

C. A large number of introduced plants are already in the islands. Several of these have become major weeds and are replacing whole native plant communities in some areas, especially in the more elevated, wetter zones of the larger islands.

Conservation Needs

I. Research

A. Socio-economic studies

1. Population dynamics - gather basic data on birth rates, death rates,

immigration, and emigration for the recent past and continue such studies from now onward; it is especially vital to determine the root causes of immigration from the mainland and to follow-up the movement patterns of the immigrants and their offspring; the feasibility of introducing birth control methods and population planning centers should be investigated (many local inhabitants frequently ask how to obtain such aid, but virtually none is now available).

2. Agriculture and land utilization - determine total arable areas now occupied and unoccupied, population densities, agricultural methods employed and land use patterns, crop and livestock yields, crop and livestock pests and diseases present and the amount of damage they cause, and types and amount of pesticides and herbicides being used; it will then be possible to investigate methods of improving yields without increasing the total land area utilized and to determine the carrying capacity of presently settled areas. This will require compilation of existing meteorological records and the establishment of careful environmental monitoring.

3. Fisheries - begin compilation and evaluation of catch statistics and start long-term studies of the population dynamics of important species such as the spiny lobster, green sea turtle, and edible fishes; it would then be possible to set and control cropping levels and fishing methods.

B. Effects of tourism

Studies of the effect of tourism have been started by M. Harris at the most frequently visited sites. An Ecuadorian assistant is being trained to continue them. These should be expanded whenever necessary, continued as long as is necessary, and followed up by practical measures immediately.

C. Introduced plants and animals

1. Baseline information - detailed autecologies, long-term population dynamics, and the effects of these species on the native biota should be studied in selected sites where control programs are not in operation; besides the rats that are presently being investigated, other destructive species urgently require attention, i.e., goats, pigs, cats, dogs, and a variety of introduced invertebrates and plants.

2. Control methods - the only method now widely used is systematic hunting (for some feral mammals) and it needs to be more carefully evaluated; other methods should be tested for specific cases.

D. Endangered species

1. Studies on the basic population dynamics of the following species are needed soon: Hawaiian petrel, flamingo, land iguana, Galapagos snakes, Galapagos geckoes, the centipede, certain ant species, and certain other invertebrates and plant species.

2. Continual monitoring

a. Animals - in some cases detailed studies of population ecology are

being continued; for others, a minimal requirement is that frequent counts be made in standardized quadrats or along established transects; the following species are most critical: flamingo, Hawaiian petrel, cormorant, penguin, albatross, plus some cross section of the land birds, rice rats and fur seal, all reptiles. Furthermore, the status of the invertebrate fauna urgently needs investigation.

b. Plants - regularly sampled, permanent quadrats should be established on a number of islands at various altitudes and where introduced mammals are both present and absent.

E. Pollution monitoring

1. Pesticides - studies should begin immediately to establish baselines, followed by frequent checks; the following species are suggested:
marine: brown pelican, sea lion, a predatory fish;
terrestrial: lava lizard, hawk or owl, a predatory invertebrate.

2. Petroleum wastes, plastics, other pollutants - routine surveys should be made, at least in some of the most affected areas such as main ports and anchorages.

F. Marine studies - the paucity of marine studies in the Galapagos is obvious, and it is important to extend the National Park boundaries beyond the shoreline; as a first step we need: (1) a faunal survey; (2) regularly sampled permanent quadrats in the littoral zone; (3) basic population studies of some cross section of at least the more prevalent species.

II. Education

A. Local population

1. Adults - at present, discussions, lectures or slide shows are occasionally presented in the port village on Santa Cruz; these should be expanded to include all the inhabited islands and the meetings ideally should take place in local villages, both in the highland agricultural zones and in the ports; important discussion topics include the unique natural history of the Galapagos, comparison of the islands to polluted industrialized countries, and the common interests of settlers and conservationists (e.g., maximizing agricultural production in already settled areas, elimination or control of crop pests and ferals such as the black rat, the value of establishing quarantine procedures). Conservation and natural history courses and radio programs for local authorities, teachers, park wardens, and other community leaders should be continued and expanded.

2. Children - the present teaching by station and Park Service personnel should be continued; additionally, special lectures, slide shows, and movies could be given occasionally, and course teaching packets, demonstration materials (photos, slides and simple projectors, charts), etc., could be provided to schoolteachers.

3. General - exhibits will be prepared soon at the Darwin Station and National Park Service headquarters; similar smaller exhibits could be installed on

the other three inhabited islands; an additional tortoise breeding/raising center is planned for San Cristobal - such a "conservation in action" demonstration could be placed on southern Isabela also.

B. Tourists

1. Guided tours - the current courses for guides should be expanded and improved.

2. Other tourists - two simple pamphlets explaining National Park laws and the importance of the Galapagos are being prepared for private yachts and tourists travelling on chartered yachts and fishing boats.

C. Mainland Ecuador - educational methods such as Galapagos Information Centers, courses for schoolteachers, films, and lectures need to be extended to the continent; a secondary school level textbook is currently being written, and a primary level one has been completed.

D. Ecuadorian scientists and students

1. Students - present programs should be expanded; this will depend upon additional funds and the willingness of visiting scientists to become involved in such training; the Darwin Station can act as a clearinghouse for matching up scientists and students, and scientists could request money for field assistance when applying to granting agencies.

2. Scientists - money for basic research is rarely available in Ecuador; research grants and fellowships for Ecuadorian scientists to study in the Galapagos should be sought from international sources; this would include encouraging Ecuadorian students who are pursuing doctoral studies in other countries to do their research in Galapagos.

E. Foreign scientists and students - every researcher working at the Darwin Station must be made aware of his responsibility strictly to follow the National Park and conservation laws of the country and must understand the need of his contribution to Ecuadorian science as a teacher and technical advisor.

III. Enforcement of laws

A. Monitoring - it is proposed that permanent wardens be stationed on boats in certain critical areas; initially Isla Genovesa and the Punta Espinosa (Fernandina)-Banks Bay (Isabela) area are considered the prime sites for both conservation and scientific needs; additional sites for future stations are suggested to be Isla Espanola, North Seymour, and Punta Albemarle and Iguana Cove (both Isabela).

B. Quarantine procedures should be established in the near future at all ports; proper educational programs should prepare the way for their acceptance.

IV. Resolutions

The participants unanimously agreed to support the numerous resolutions concerning conservation of island ecosystems which resulted from the Second World Conference on National Parks (Yellowstone, September, 1972) and the Caribbean Conservation Association Conference (St. Kitts, August, 1972).

Following is a list of suggestions concerning Galapagos collections.

GALAPAGOS COLLECTIONS

At present the National Park Service (Forest Service) has full control of granting collecting permits in Galapagos, and the Darwin Station Director acts as an advisor in making such decisions. Collecting in general is being very strictly controlled and collecting of endangered species and rare materials must be severely limited. The following suggestions were made at the conference:

1. A detailed survey of existing collections needs to be prepared and computerized. This will require the cooperation of a large number of experts on Galapagos material. It will help solve three problems: (a) the whereabouts of much valuable material collected in the past is unknown; (b) at present, new collections are being made but not systematically recorded as to final location, contents, etc.; (c) it is sometimes difficult to assess the validity of new research proposals which involve collecting.

2. When possible, techniques should be used which do not require sacrifice of specimens, e.g., biopsy, standardized photography and measurement in the field.

3. When specimens must be sacrificed, but a large sample or insular diversity is not required (e.g., physiological studies), so-called "junk" specimens are often available; for example, there are both land iguanas and tortoises at the Station which cannot be identified as to population of origin.

4. Multiple use of specimens should become the rule rather than the exception, e.g., animals sacrificed for physiological studies can be used by systematists, for collection of endo- and ecto-parasites, etc.

5. Material should be deposited in institutions where they can best be used, i.e., the collections should either be strong in Galapagos material or strong in a particular taxonomic group.

6. Publications should clearly indicate the specimens examined, the location of the collections, and identification numbers. Amazingly, this is still not done by some workers.

7. A record should be compiled at the Station of what is collected, what leaves the islands and where it goes, and requests for material. This will aid in maintaining an up-to-date list of experts in the various areas for identification purposes.

8. Scientists should take the responsibility to help develop and maintain the reference collection at the Station and teaching collections for Ecuadorian universities. Much of this material can be compiled from dead specimens found in the islands, e.g., a set of Darwin's finches.

APPENDIX III

Charles Darwin Foundation for the Galapagos Islands
1 rue Ducale, Brussels, Belgium

Information for Scientists Staying at the Charles Darwin Research Station

The Charles Darwin Research Station (CDRS), established and administered by the Charles Darwin Foundation with the support of the Government of Ecuador, has as its aims the conservation and the study of the Galapagos Archipelago and its unique flora and fauna. The Station is available to visitors of all nationalities who wish to undertake research work, provided they have complied with the requirements of the Government of Ecuador and the Charles Darwin Foundation.

Conservation of the Islands' ecosystems and conservational education of the inhabitants of the Archipelago are integral parts of all activities of the Darwin Station. Scientists visiting the Station are therefore obliged to observe the following general rules*:

1. Don't bring any live material from the continent to the Archipelago or back and don't carry any live material from island to island.

2. Keep your influence on the environment to an absolute minimum:
   Don't make camp fires (Bring a kerosene stove; you can buy one in Guayaquil.),
   Don't leave litter,
   Collect only what has been permitted to you by the National Park Authority (Tell your colleague who wanted you to bring a crab, a rock or a plant sample that this will have to be justified to the Park Authority separately.),
   Avoid upsetting animals or damaging the vegetation in any way.

3. When at sea don't throw plastic or waxed paper overboard and when close to shore don't dump anything (If the crew of the boat you are chartering does it tell them that the plastic kills marine turtles and the litter affects wildlife on shore.).

4. In your contacts with inhabitants and visitors show your conservational attitude. Explain basic ecological facts and the dangers stemming from human mismanagement, particularly on islands. Also, explain your Galapagos project and show that it is in harmony with conservation principles. You can be an important factor in the promotion of these principles.

*Much of this is included in Ecuadorian legislation and some is repeated elsewhere in this statement of information in more detail.

Authorization to Work

Requests to work at the CDRS or for CDRS support of field work should be submitted to the Foundation (see addresses below) and permission to work and camp within the limits of the National Park (which includes the entire Archipelago with the exception of the settled areas) must be requested from the governmental National Park administration. These two agencies should receive an outline of the proposed research. The format of this proposal is not fixed; it may be a copy of the proposal submitted to the agency funding the research, but it must cover the following points:

1. Description of research program: Include discussion of objectives, explaining why this work must be done in the Galapagos and how it relates to previous investigations. While the Darwin Foundation is not a fund granting organization, limited facilities and support at CDRS often force a choice between alternative proposals. To ensure that this support goes to the projects of greatest scientific merit, detailed descriptions of the proposed research are requested. Besides serving as basis for the decisions of the National Park administration and the Darwin Foundation, this description will enable the Foundation and Station to act as a clearinghouse by putting the investigator in contact with colleagues of similar or complementary interests and by advising beforehand on research methods and logistics.

2. Support needs: Accomodation, ship time, equipment, and facilities. Give as much information as possible on your expected needs and the Station will be able to tell you how much support can be supplied (see later sections) and suggest alternatives.

3. Effect on the biota: Scientists visiting the Darwin Station are expected to support the conservation aims of the Foundation. All uninhabited areas of the Archipelago are included in the National Park and strict conservation laws are in force. Indicate exactly to what extent your activity within the National Park might affect wildlife. While most field research leaves some small temporary mark on the environment, the Park administration and the Darwin Foundation will not permit projects that will do serious harm to any element of the indigenous fauna or flora. Most scientists are keenly aware of the importance of an unspoiled Galapagos environment and visiting scientists should set an example of sound conservation principles.

All species indigenous to the islands are protected by law. Limited collecting and exporting of soil, rock, animals or plant specimens may be permitted by the National Park administration in cases where it is clearly indispensable for the realization of the study. Therefore the investigator should state the specimens required, their amount, their proposed final destination, and any other relevant details. Collecting of specimens not related to the project in question will not be permitted. The Park administration may ask the investigator to submit a representative collection to an Ecuadorian Institute or Museum.

4. A brief resume should be included for each prospective researcher (along with names and addresses of sponsoring institutions) and research director (if other than expedition leader).

5. Expected itineraries and camp-sites must be specified for approval by

the National Park authorities.

Copies of the proposal must be sent to the following offices:

Director
Servicio Forestal y Piscicultura
Casilla 2983
Quito, Ecuador

Director
Charles Darwin Research Station
Casilla 58-39
Guayaquil, Ecuador

Dr. David Snow, Secretary General
CDF Scientific Advisory Commission
c/o Zoological Museum
Tring, Herts
Great Britain.

In addition, copies to the following offices would be appreciated:

Prof. Jean Dorst, President
Charles Darwin Foundation
c/o Museum National d'Histoire Naturelle
55, rue de Buffon
75005 Paris 5e, France

Dr. Tom Simkin, Secretary for the Americas
Charles Darwin Foundation
c/o Smithsonian Institution
Washington, D. C. 20560
U. S. A.

Permission from Ecuadorian authorities will come directly from Quito. It is based generally on the recommendation by the Station Director. Authorization for Darwin Station support is given by the Darwin Foundation Executive Council on the basis of recommendations of the Station Director and the CDF Scientific Advisory Commission. The Council meets only twice a year, so proposals must be submitted at least six months before the planned start of the research program.

Once permission has been granted to a scientist to stay at the Station a request should be made to the nearest Ecuadorian consular office for the appropriate visa. A normal tourist visa is valid for three months and may be extended once for another three months. For longer stays courtesy visas are necessary. Reference should be made to the agreement between the Ecuadorian Government and the Charles Darwin Foundation, signed in February, 1964, published in the Registro Oficial No. 181, page 37.

A valid certificate of vaccination against smallpox is required for entry into

Ecuador.

Publications and Reports

When the Charles Darwin Research Station has been of significant assistance in field or lab work, this is generally acknowledged by including the resulting publication in our contribution series. This means nothing more than adding the phrase "Contribution number ___ of the Charles Darwin Foundation" in the "Acknowledgement" section (or at base of title page). Upon receipt of title and intended journal, the Secretary for the Americas will issue a contribution number to you. Upon publication, we would appreciate roughly 25 reprints for distribution at the Darwin Station and elsewhere within the Foundation; these should be sent to the Secretary for the Americas.

At the end of the scientific mission on the Islands, a brief research report is strongly requested. It should be about 100 to 300 words long and should cover the problems the investigations were dealing with; it does not have to include any results. It may be written in English, Spanish, French, or German. These reports are then published in Spanish in one of the Ecuadorian periodicals and this has been an excellent way both of demonstrating world scientific interest in the islands and of thanking the Ecuadorian hosts that permit work in their country.

Language

The language of the Islands is Spanish, and some knowledge of it is strongly recommended.

Travel to the Galapagos Islands

Normally there are one or two boats monthly and two flights a week.

1. Civilian ships travel from Guayaquil to Galapagos irregularly. Generally there are one or two sailing dates a month. Also Ecuadorian naval vessels provide an unscheduled service from Guayaquil to the Islands. Enquiries should be directed through the appropriate consul or directly to a travel agency in Guayaquil or to the naval authorities (The office of the port captain of Guayaquil is situated in the city administration building on the Malecon Simon Bolivar.). It is generally not possible to predict the sailing dates of the ships.

2. Every Tuesday and Friday there are flights leaving Quito and Guayaquil in the early morning, arriving around noon on Baltra (South Seymour Island), to the north of Santa Cruz. The planes go back to Guayaquil in the afternoon of the same day. Enquiries and requests for reservations should be directed to Metropolitan Touring, Casilla 2542, Quito, or to Galapagos Cruises, Casilla 7132, Guayaquil. Return air fare Guayaquil-Baltra is U.S. $120. These are charter flights for tourists who travel through the Islands on one

of the cruise ships. Space on the planes is always very restricted. Reservations should be made well in advance. Flight baggage is restricted to 30 pounds per person. If larger amounts of equipment are to be shipped to Galapagos, surface transport should be anticipated.

The routine flight schedule is usually interrupted from the end of August to the beginning of October, because the tourist cruise ships do not operate during this time. There are, however, generally one or two unscheduled flights in September.

Large groups may consider chartering their own plane for transport to Baltra. Enquiries should be directed to Metropolitan Touring. Charter of a flight Guayaquil-Baltra costs approximately $3,000 to $5,000 depending on aircraft used.

No boats are based at Baltra and no accomodation is available there. Visitors should write or cable the Station beforehand to arrange onward transportation to Santa Cruz. The journey by sea from Baltra to Academy Bay takes some six hours.

Scientists travelling directly to the Archipelago by boat should be aware that all visiting vessels must call initially to clear papers at San Cristobal.

Customs

Duty free import of scientific equipment will be granted to scientists coming to the Darwin Station according to the agreement between the Ecuadorian Government and the Darwin Foundation (Acuerdo entre el Gobierno de la Republica del Ecuador y la Fundacion Charles Darwin, publicado en el Registro Oficial No. 181 del 15 de Febrero de 1964: re. articulo decimo tercero).

Lists of contents of all baggage in Spanish should be on hand upon arrival. Embassies and consulates in Quito and Guayaquil are generally able to help in cases where difficulties arise and they should be alerted well in advance of large shipments.

Scientists accompanying their equipment into the country are in a better position to clear customs quickly than those who send material ahead. If larger shipment is made by surface in advance, it is advisable to be in Guayaquil when it arrives and stay there for three to seven days to see it through customs and arrange forwarding to the Islands.

Duty free import implies that all non-expendable items have to be taken out of the country again when the scientific mission is terminated.

It can be told from experience that import and transport of equipment regularly involves difficulties and frustrations. Sufficient thought should be given in advance to this operation and enough time should be allowed.

Guayaquil Agent

Mr. Erwin Maenz, Casilla 53-33, Guayaquil, Telephone 38-30-56, is executing

commissions for the Station in Guayaquil. He is also prepared to help visitors concerning customs, transport to Galapagos, and other commissions. Mr. Maenz speaks Spanish, English, and German. He charges U.S. $3. per hour for his services.

Facilities of Research Station

The CDRS, situated on the shores of Academy Bay on the south of Santa Cruz (Indefatigable) Island, provides living accomodations, simple laboratory facilities, and basic equipment for research.

Accomodation is twin-bedded rooms and there are toilet and shower facilities with running brakish water (fresh water is restricted to drinking). There is a dining-room where meals can be obtained. Arrangements can be made for laundry. There are no facilities on the Station for families or children.

Laboratories are equipped with permanent electricity of 115/230 VAC, 60 cycles (electrical equipment brought by visitors should not exceed a current consumption of 1 KW; in case it does, the Station should be consulted beforehand); standard laboratory glassware, instruments, and collecting apparatus; microscope (Zeiss Standard binocular, and Nachet dissecting binocular); limited refrigeration; dark-room; slide- and film-projection equipment; library of Galapagos references and charts; a small general library, and some reference collections. Workshop facilities are available. The CDRS operates meteorological and seismograph stations.

Ham radio connections can be obtained from the Galapagos, and the National Park Service maintains a transceiver at Academy Bay so that schedules can be maintained with radio-equipped field parties (specifications: SSB/AM, crystal-controlled; crystals used are: 2136.5, 2171.5, 2786.5, 3131.5, 4126.5, 5086.5, 5282.5 KC. USB/5086.5 KC is used with best success.).

Tents and backpacks are often available for rent by the National Park Service.

The Station is represented by scientific observers on Southern Isabela and San Cristobal.

Fees during Stay

Accomodations at the Station cost U.S. $2.00 per day per single person, and U.S. $3.00 is charged for two persons occupying one room. Visitors wishing to maintain their room when temporarily away from CDRS are charged U.S. $1.00 per day. Accomodations may also be found in the village of Academy Bay at comparable costs.

An additional per diem charge of U.S. $1.00 per scientific mission is made throughout stay on the Islands to cover the use of laboratory, equipment, and facilities provided by the Station.

INFORMATION FOR SCIENTISTS

These charges are not made to scientists holding research appointments from the institutions supporting a research table with the Charles Darwin Foundation (Smithsonian Institution, Belgian Ministry of Education, Royal Society (London), Stiching Int. Nat. Amsterdam, and Nordske Videnskaaps Akademie). Each of these research tables may be used by one scientist and an assistant at a time. Applications for the use of a research table should be made to the supporting scientific body.

Meals may be taken in the dining-room at the following prices: Breakfast U.S. $0.50; lunch U.S. $1.00; dinner U.S. $1.00.

Camping is not permitted on Darwin Station grounds. There is a small camping ground between the Station and the village.

Travel within the Archipelago

The Station's Research Vessel, Beagle III, is a 70 ft. motor-yacht and has accomodations for 8 passengers in two-berth cabins. Her cruising speed is 8 knots. The charter rates for her are $100.00/day (not exceeding 10 hours cruising as an average), plus $1.00/mile, plus $5.00/person/day (for food and services). Costs can be shared by different groups and transport may be arranged in conjunction with an official journey by CDRS employees. However, cost of an empty return to Academy Bay will be charged to a party dropped on an island (unless the boat is used by other groups) and the above costs may be revised at any time.

Inter-island travel can also be undertaken in locally chartered boats. Rates are from 25 to 350 U.S. dollars per day. These boats carry from four to nine persons in varying degrees of comfort and travel at 5-6 knots (the more expensive ones 8-10 knots).

Distances from Academy Bay to other islands are as follows, in miles: Santa Fe (Barrington) 18; Plaza 17; Baltra 34; Pinzon (Duncan) 28; James Bay, Santiago (James) 56; Genovesa (Tower) 73; Marchena (Bindloe) 75; Wolf (Wenman) 171; Pinta (Abingdon) 104; San Cristobal (Chatham) 44; Espanola (Hood) 52; Floreana (Charles) 35; Punta Espinosa, Fernandina (Narborough) 133; Villamil Isabela (Albemarle) 48; Caleta Iguana, Isabela 78; Caleta Tagus, Isabela 136.

Camping alone in areas distant from human settlements is strongly discouraged. Scientists planning to come alone and work in the field should always budget for a locally employed assistant (paid about 60 sucres a day).

The CDRS has skiffs with 20 HP outboards for work within Academy Bay.

The Station arranges guides for scientists visiting inland regions. Guides are paid 60 sucres per day. A field station (including living accomodation) is maintained by CDRS at Santo Tomas 13 KM NNW of Villamil at an elevation of 350 M on Southern Isabela.

Jeep transportation is possible on San Cristobal from Puerto Baquerizo to

Progreso, on Santa Cruz from Academy Bay to Bellavista and Santa Rosa, and on Isabela from Villamil half way to Santo Tomas.

Basic food supplies may be purchased in the Islands. Dehydrated foods and other special items are not available. Water supplies are arranged by the Station. Care should be exercised in drinking untreated freshwater in the islands.

Horses can be hired (at about 40-50 sucres per day) for travel to the inland areas of Santa Cruz and Isabela. For transportation of equipment, donkeys can be hired at about 25-40 sucres per day. The driver is paid about 60 sucres per day.

Apart from Santa Cruz, regular hotel accomodation is available only on Floreana.

Scientists used to long summer field days should remember that equatorial sunset is around 6:30. Local time in the Galapagos is 6 hours behind Greenwich or Universal time.

Transport of Live Material

Responsible scientists are aware of the extreme care needed to prevent the artificial intermingling of island populations. We must emphasize that inconspicuous transfer, such as ticks and burrs on persons or seed-containing soil in rubber soles, can be a great hazard to biotic integrity.

Communications

Mail is now transferred from a Post Office box in Guayaquil to most of the twice-weekly Galapagos flights. Delays still occur, however, and 1-2 weeks should be allowed for air mail letters from the U.S. or Europe to the CDRS. Only letters should be addressed to:

Estacion Cientifica Charles Darwin
Casilla 58-39
Guayaquil, Ecuador, S.A.

Books and packages should be addressed to:

Estacion Cientifica Charles Darwin
Santa Cruz, Galapagos
Ecuador, S.A.

Cables should be addressed to: Estacion Darwin, Galapagos, Ecuador. Cables reach the Station within 1 to 3 days, from abroad as well as from the Ecuadorian continent.

In really urgent cases, ham radio calls can be received after settling time and call frequency by correspondence.

Medical Care

An adequate medical kit and the ability to render first aid are indispensable for scientists working in the field any length of time.

There are no poisonous snakes on Galapagos, only scorpions and centipedes, which may cause inflammations comparable to those from bee stings.

One strongly poisonous tree occurs on all larger islands: Hippomane mancinella, "manzanillo." Its apple-like fruits are extremely poisonous and the latex of the plant causes severe dermatitis.

Common visitor's maladies include bacterial dysentery, sunburn, sea sickness, and bacterial surface infections.

Hospital facilities are available on Santa Cruz and San Cristobal. A dentist is normally resident at the hospital on Santa Cruz.

Many visitors arrange general accident insurance to cover their stay in the islands.

Currency

The monetary unit in Ecuador is the sucre. The current rate of exchange is around 26 sucres per U.S. $1. There are no banking facilities on Santa Cruz. Some of the stores (and the CDRS) will accept bank and travellers cheques for payment, but ready cash is essential for small purchases and charter boats. Sucres are usually in short supply in the islands and should be brought (in denominations of 100 sucres and smaller) by visitors from the mainland.

Clothing and Equipment

The climate can be conveniently divided into a hot season (January-May), when there is a possibility of heavy showers, and the garua time (June-December), characterized by overcast skies and drizzling rains, particularly in the southern parts of the islands with higher elevations. However, continuous strong sunshine is possible any time of the year, and maximum daily temperature is generally in the range 23°-31° C. (74°-88° F.).

In general, daytime clothing should be light-weight. At night, however, particularly at higher altitudes and at sea, temperatures may fall below 15° C. (60° F.) and warm clothing is required. Protection against sun, rain, and wind should be provided. Boots and shoes wear out quickly on lava terrain; lava tends to cut into

stitching and sturdy boots are advised. Canvas shoes are the most practical for use on boats, in camps, and close to shore.

Cameras and instruments should be stored in silica gel. Light-weight tents and rucksacks, sleeping-bags, camp-beds and water carriers (small) should be brought if much work in the field is anticipated.

Medicine, films, pipe tobacco, writing paper, insect repellents, and water sterilizing tablets can not be bought in the Islands.

The information here included is intended only as a guide to scientists visiting the Darwin Station and it is subject to revision.

Dr. P. Kramer, Director
Charles Darwin Research Station
Santa Cruz, Galapagos
Ecuador

Dr. T. Simkin
Secretary for the Americas (Science)
c/o Smithsonian Institution
Washington, D. C. 20560
United States

Last revision: January, 1973

APPENDIX IV

REFERENCES

Bowman, Robert I. (editor). 1966. The Galapagos. Proceedings of the Galapagos International Scientific Project. University of California Press, Berkeley and Los Angeles.

Dorst, J. and Laruelle, J. 1967. "The first seven years of the Charles Darwin Foundation for the Galapagos Isles, 1959-66." Palais des Academies, 1, rue Ducale, Brussels 1.

Kramer, P. 1973. Comprehensive report, covering the period September, 1970 to December, 1972, of the UNESCO expert and director of the CDRS. Report submitted to UNESCO headquarters December 1972. Mimeo, 29 pages.

Lack, D. 1947. Darwin's Finches. Cambridge University Press. Cambridge, England.

McBirney, A. R. and Williams, H. 1969. "Geology and petrology of the Galapagos Islands." Geol. Soc. Am. Memoir 118.

Slevin, J. R. 1959. "The Galapagos Islands: A history of their exploration." Occ. Papers Calif. Acad. Sci., No. 25.

Thornton, I. 1971. Darwin's Islands. A natural history of the Galapagos. Nat. Hist. Press. Garden City, New York.

Townsend, C. H. 1925. "The Galapagos tortoises in their relation to the whaling industry." Zoologica. 4:55-135.

Wiggins, I. L. and Porter, D. M. 1971. Flora of the Galapagos Islands. Stanford University Press, Stanford, California.