

in the tortoise and land iguana programs. Several theses have been written based on such studies. Many of the students have gone on to work for the CDF, the GNPS, or other conservation and natural resource management organizations throughout Ecuador and the world.

### THE FUTURE

With the eradication of introduced mammals, many of the giant tortoise populations are nearing the point when the breeding and rearing center will no longer be required. Monitoring their populations and restoring their habitat will now be part of larger island restoration programs. On Española, restoration of the *Opuntia* cactus forests that were decimated by goats is beginning. On Santiago, regeneration of the vegetation in the absence of goats, pigs, and donkeys will need to be monitored to ensure that the plant communities return to near-pristine condition, allowing the tortoise population to complete its recovery on its own. When rats are finally eliminated from Pinzón, island restoration and a naturally reproducing tortoise population will become a reality. Work on southern Isabela, where introduced mammals still exist and where poaching of tortoises is more common than elsewhere in the islands, will continue. Current genetic analyses may also highlight small remnant populations that will need intensive management in the future.

On Pinta, where the return of the Pinta tortoise is questionable if not impossible, a plan for restoring the

island, including the return of giant tortoises, has been approved. Since genetic studies determined that the Española tortoise is genetically the closest to the Pinta tortoise, hatchlings from the Española breeding and rearing program will be used to initiate the restoration of that island and re-establish a tortoise population there, on an island now free of introduced mammals.

The land iguana populations are doing well. If we are able to eradicate the cats one day, land iguanas will also be out of danger.

There are now land iguanas back on Baltra and tortoises will soon be back on Pinta. After nearly 50 years of integrated research and management aimed at the conservation of the biodiversity of Galapagos, most land iguana populations are in good shape and all of the tortoise populations are in better condition than when the Galapagos National Park was established in 1959.

### ACKNOWLEDGMENTS

A research and management program with more than 40 years of success is only possible with the passion and dedication of many scientists, park wardens, consultants, students and volunteers. I am indebted to all of them, for their work in the field and in the tortoise and iguana centers, for our many discussions, and for their many reports and publications.

## BOTANICAL RESEARCH IN THE GALAPAGOS ISLANDS: THE LAST FIFTY YEARS AND THE NEXT FIFTY

By: Conley K. McMullen<sup>1</sup>, Alan Tye<sup>2</sup> & Ole Hamann<sup>3</sup>

<sup>1</sup>Department of Biology, MSC 7801, James Madison University, Harrisonburg, Virginia 22807 U.S.A.  
<mcmullck@jmu.edu>

<sup>2</sup>Secretariat of the Pacific Regional Environment Programme, PO Box 240, Apia, Samoa

<sup>3</sup>Botanic Garden, University of Copenhagen, Oster Farimagsgade 2B, DK-1353 Copenhagen, Denmark

### SUMMARY

We review recommendations made since the founding of the Charles Darwin Foundation in 1959, concerning botanical research for the conservation of Galapagos, and present our suggestions for priorities for the immediate future.

### RESUMEN

**La investigación botánica en las Islas Galápagos: los últimos cincuenta años y los próximos cincuenta.** Revisamos las recomendaciones hechas desde el establecimiento de la Fundación Charles Darwin en 1959, acerca de la investigación botánica para la conservación de Galápagos, y presentamos nuestras sugerencias para el futuro inmediato.

## INTRODUCTION

Since the establishment of the Charles Darwin Foundation (CDF) in 1959, a tremendous amount of botanical research has been accomplished through the collaborative efforts of the Charles Darwin Research Station (CDRS), the Galapagos National Park (GNP), visiting scientists, and local and international volunteers. The direction of this research has often been influenced by the suggestions of experts who have, from time to time, met to discuss and prioritize botanical studies in the archipelago. In this paper, we briefly discuss the history of botanical planning, the major research areas that have been suggested or initiated as a result, and our recommendations for future directions.

### BOTANICAL RESEARCH PLANNING SINCE 1959

A landmark in the history of Galapagos botany was the Galapagos International Scientific Project, in 1964. For several weeks, experts from a variety of fields attempted to gather as much information as possible about the natural history of the islands. Botanists participating in the project included E. Yale Dawson, F. Raymond Fosberg, Syuzo Itow, Charles M. Rick, William A. Weber, and Ira L. Wiggins, who generated many ideas for future studies in the archipelago, and contributed to the production of the islands' flora (Wiggins & Porter 1971).

Eight years later, the Galapagos Science Conference, held at the Smithsonian Institution in Washington DC, 6–8 October 1972, attracted botanists including Rick, Wiggins, Paul A. Colinvaux and Duncan M. Porter, and encompassed research planning discussions that recommended: 1) vegetation mapping and quantitative sampling, 2) studies of plant-animal interrelationships, 3) phytogeography, 4) reproductive ecology, and 5) population biology (Simkin *et al.* 1972).

The next and largest gathering of botanists in the Galapagos Islands was the Workshop on Botanical Research and Management held at CDRS, 11–18 April 1987, whose participating scientists are listed in the proceedings (Lawesson *et al.* 1990). The purpose of this meeting was to compile botanical information of use in managing and conserving the flora of the islands. Major recommendations were summarized as: 1) eradication of introduced animals, 2) eradication of introduced plants, 3) protection of endangered species, 4) development of a documentation system, 5) a mapping program, and 6) conservation of Galapagos species outside the islands.

In May 1999, an international workshop of conservation biologists was held at CDRS and GNP headquarters, to produce a "Biodiversity Vision for the Galapagos Islands", with major input from staff and visiting botanists and resulting in more recommendations for the next 50 years (Bensted-Smith 2002). Most recently, the CDRS Botany Department produced a report on recent research and more specific plans for the future (Tye 2003), including: 1) completion of baseline inventories, 2)

establishment of long-term monitoring programs, 3) design and implementation of invasive plant prioritization systems and completion of the Galapagos plant red list, 4) invasive species research and management, 5) habitat protection and restoration, and 6) research and restoration of endangered species.

Aside from the publications mentioned above, which resulted directly from these workshops, other landmark works stimulated by these planning exercises have included major studies of Galapagos vegetation (Werff 1978, Hamann 1981), studies of non-vascular taxa (Weber & Gradstein 1984), a revised checklist of the flora (Lawesson *et al.* 1987) and a field guide (McMullen 1999). Research stimulated by the recommendations listed above has resulted in hundreds of journal articles and book chapters. The Galapagos bibliography up to 1995 (Snell *et al.* 1996) includes more than 1000 references to botanical keywords.

### RECOMMENDATIONS FOR FUTURE DIRECTIONS

Although many of the research topics suggested by previous groups have been at least partially tackled, most have yet to be completed and others remain to be initiated. Taking into account the previous recommendations cited above and placing priority on research applied to conservation, we list here some important areas that need to be addressed or continued in the next 50 years. These are listed, as far as possible, to correspond with the order of the research framework of the CDF Strategic Plan (Charles Darwin Foundation 2006), *i.e.* baseline, monitoring, prioritization, research on priorities, experimental management.

#### Support services

Maintain a comprehensive herbarium collection, as an important reference tool for botanical research, especially floristic and systematic studies.

Establish an efficient information management and geographical information system for all herbarium collections at CDRS and incorporating data from elsewhere.

Establish an information management platform to make plant specimen and other data from CDRS collections and elsewhere accessible via the internet, including high resolution scans of specimens.

Complete and publish comprehensive checklists for all Galapagos plants, including non-vascular taxa, fungi and lichens.

Produce a revised flora of Galapagos.

Produce illustrated identification materials accessible in both English and Spanish, covering vascular and non-vascular plants, fungi and lichens.

#### Baseline studies

Complete comprehensive surveys of all islands to improve knowledge of the status and distribution of Galapagos plants, including non-vascular taxa, lichens and fungi, and with emphasis on endemic and threatened species.

Produce new and improved digital vegetation maps of the archipelago.

#### Monitoring

Implement and expand community and species monitoring for high priority threatened species and habitats, and for invasive species including monitoring for new introductions.

#### Prioritization

Complete and periodically revise red lists, including non-vascular species, lichens, fungi and marine plants, and produce Galapagos Plant Red Data Books.

Maintain and update the Galapagos Weed Risk Assessment system.

#### Studies of priority species, communities and problems

Implement studies to determine the threats to and causes of population declines of the highest priority threatened endemic plants (Critically Endangered species and "lost" species with no recent records).

Continue taxonomic revisions of endemic plant groups, to clarify conservation priorities and species distributions.

Investigate the biology, ecology and population dynamics of Galapagos native plants, especially endemic and threatened taxa, including pollination ecology, herbivory, seed dispersal and the impacts of introduced plants and animals.

Investigate the biology and impacts of high risk invasive and potentially invasive species, and design effective control measures.

Conduct studies of vegetation dynamics, including primary and secondary succession, especially in relation to disturbance, invasive species and the outcomes of management practices, to improve the latter.

#### Management

Establish a seed bank of endemic plants.

Implement restoration projects for the highest priority threatened endemic plants (Critically Endangered) and vegetation communities.

Implement management projects for high risk invasive species, using best practice design for the choice of management goals and techniques, including monitoring to determine effectiveness of control and recuperation of the native habitat and communities.

To realize these goals, a continuation of the CDRS botanical research program, with close collaboration with the GNP and productive research alliances with outside experts, universities and research institutes, is

essential. Equally important is the continued training of young scientists, which has been a strength of CDRS. The interest and voices of future generations of Ecuadorian and other botanists and conservationists are the best insurance that this work will continue for the next 50 years.

#### ACKNOWLEDGMENTS

We thank Henning Adersen, Frank Bungartz and Mark Gardener for valuable comments on an earlier version of this paper. As always, appreciation is extended to CDF, CDRS and GNP for the support of botanical research in Galapagos over the years, including our own work in the islands.

#### LITERATURE CITED

- Bensted-Smith, R. (ed.) 2002. *A Biodiversity Vision for the Galápagos Islands*. Charles Darwin Foundation and World Wildlife Fund, Puerto Ayora.
- Charles Darwin Foundation 2006. *Charles Darwin Foundation Strategic Plan 2006–2016*. Charles Darwin Foundation, Quito.
- Hamann, O. 1981. Plant communities of the Galápagos Islands. *Dansk Botanisk Arkiv* 34(2): 1–164.
- Lawesson, J.E., Adersen, H. & Bentley, P. 1987. An annotated check list of the vascular plants of the Galápagos Islands. *Reports of the Botanical Institute, University of Aarhus* 16: 1–74.
- Lawesson, J.E., Hamann, O., Rogers, G., Reck, G. & Ochoa, H. (eds) 1990. Botanical research and management in Galápagos. *Monographs in Systematic Botany from the Missouri Botanical Garden* 32.
- McMullen, C.K. 1999. *Flowering Plants of the Galápagos Islands*. Cornell University Press, Ithaca NY.
- Simkin, T., Reeder, W.G., & MacFarland, C. (eds) 1972. *Galápagos Science: Status and Needs*. Unpubl. rep. of Galapagos Science Conference, October 6–8, 1972, to Smithsonian Institution, Washington DC.
- Snell, H.M., Snell, H.L., Davis-Merlen, G., Simkin, T. & Silberglied, R.E. 1996. *Bibliografía de Galápagos 1535–1995 — Galápagos Bibliography*. Charles Darwin Foundation, Quito.
- Tye, A. 2003. *Plant Research for Conservation in Galapagos. Report for the years 1998–2003 and challenges for the future*. Charles Darwin Foundation, Puerto Ayora.
- Weber, W.A. & Gradstein, S.R. 1984. Lichens and bryophytes. Pp. 71–84 in Perry, R. (ed.), *Key Environments: Galápagos*. Pergamon Press, Oxford.
- Werff, H. van der 1978. *The Vegetation of the Galápagos Islands*. Ph.D. Thesis, University of Utrecht.
- Wiggins, I.L. & Porter, D.M. 1971. *Flora of the Galápagos Islands*. Stanford University Press, Stanford, CA.