GALAPAGOS RESEARCH (formerly *Noticias de Galápagos*)

Journal of Science and Conservation in the Galapagos Islands

Published by the Charles Darwin Foundation for the Galapagos Islands, an international organization created under the auspices of the Government of Ecuador, UNESCO and the World Conservation Union (IUCN).

Number 64 December 2006

CONTENTS

RESEARCH ARTICLES

GALAPAGOS COMMENTARY

***Galapagos Research* (formerly *Noticias de Galápagos*)** is the research journal of the Charles Darwin Foundation for the Galapagos Islands. It is available in printed form, and back issues may be found online at www.darwinfoundation.org/galres.

Information for subscribers: Please contact the Charles Darwin Foundation <cdrs@fcdarwin.org.ec> or your local Friends of Galapagos organisation with questions about subscriptions (addresses inside front cover). Annual or lifetime individual, and annual institutional subscriptions are available. *Galapagos Research* is sent free to current Friends of Galapagos, on request to their Friends of Galapagos organisation.

Information for authors: Manuscripts for consideration for publication in *Galapagos Research* should be submitted to the Editor (addresses below). Instructions for Authors are inside the back cover and online at www.darwinfoundation.org/galres.

Editor: Dr Alan Tye
Charles Darwin Research Station, Galapagos
Postal address: AP 17-01-3891, Quito, Ecuador
Email: galapagosresearch@fcdarwin.org.ec

Back cover map: Tom Giermakowski & Howard Snell (University of New Mexico)

RESEARCH ARTICLES

EFFECTS OF THE FERAL GOAT POPULATION EXPLOSION ON ALCEDO VOLCANO (ISABELA, GALAPAGOS) BETWEEN 1986 AND 1996

By: Konjev Desender[1], Léon Baert[1], Jean-Pierre Maelfait[2] & Peter Verdyck[1]

[1]Department of Entomology, Royal Belgian Institute of Natural Sciences,
Vautierstraat 29, B-1000 Brussels, Belgium <kdesender@kbinirsnb.be>
[2]Institute for Nature Conservation, Kliniekstraat 25, B-1070 Brussels, Belgium

SUMMARY

During the first week of April 1986, before the overwhelming presence of goats, we sampled terrestrial macro-invertebrates on Alcedo Volcano along an altitudinal transect from the seashore to the top. Vegetation composition and structure at all sampling sites were described and photographs were taken. In 1996, when the Alcedo feral goat population had exploded to an estimated 50,000 to 100,000 and before large scale goat control began, the same transect was resampled and redocumented. In this contribution, site descriptions are summarized, compared between 1986 and 1996 and illustrated with a series of photographs.

RESUMEN

Efectos de la explosión de la población feral de cabras en el Volcán Alcedo (Isabela,Galápagos) entre 1986 y 1996. Durante la primera semana de abril de 1986, antes de la abrumadora presencia de cabras, muestreamos los macro-invertebrados terrestres en el Volcán Alcedo a lo largo de un transecto altitudinal desde la costa marina hasta la cima. La composición y estructura de la vegetación en todos los sitios de muestreo fueron descritos y fotografiados. En 1996, cuando la población feral de cabras de Alcedo había repuntado hasta un estimado de 50.000 a 100.000, y antes de que el control de cabras a gran escala empezara, el mismo transecto fue muestreado y documentado otra vez. En esta contribución, las descripciones de los sitios están resumidas, comparadas entre 1986 y 1996, e ilustradas con una serie de fotografías.

INTRODUCTION

Until recently, Alcedo was one of the most pristine volcanoes in Galapagos, despite the presence of a tourist trail to the rim of the crater. Until 1968, the only introduced vertebrate grazers were donkeys, whose impact on vegetation has been considered less than that of the large tortoise population (Fowler 1980, Werff 1982, Adsersen 1989). Fowler (1980) estimated the population of donkeys on Alcedo as 500–700.

Goats were first seen on Alcedo about 1968 (Perry 1968). Corley Smith (1981), De Vries & Black (1983) and Hoeck (1984) mentioned that a small number of feral goats from southern Isabela succeeded in crossing the rugged lava fields of Perry Isthmus to reach Alcedo some time between 1968 and 1979, but it is unclear whether this introduction was successful, and until the mid-1980s, numbers remained small and distribution restricted. Duffy (1981) optimistically reported that "the northern volcanoes of Isabela seemed to be tougher than the goats". He recognized that the Galapagos National Park Service (GNP) was trying to eradicate these goats, and found no signs of a population explosion such as occurred on other islands in Galapagos such as Santiago and Pinta. Unfortunately, around 1990, goat populations on Alcedo rapidly increased to alarming numbers. Anecdotal evidence of habitat change on Alcedo, caused by the animals, began to be noted in the early 1990s (*e.g.* Freire 1992, Cayot & Snell 1996), especially destruction of the highland forests, increased erosion and possibly competition for food with tortoises. Feral goat numbers were estimated to be as high as 50,000 to 100,000 during the spring of 1996, before recent eradication efforts began, and more than 25,000 goats and some 680 donkeys were killed later in 1996 by GNP wardens (L. Cayot pers. comm). There was intermittent hunting from 1996 to 2000, and then suspension of the campaign until Project Isabela started hunting in 2004, when a goat population estimate of c. 40,000 was based on helicopter hunting kills that year (K. Campbell *per* A. Tye pers. comm.). Goats also moved to all the northern volcanoes, with groups spotted on Ecuador Volcano since 1999 (K. Campbell *per* A. Tye pers. comm.).

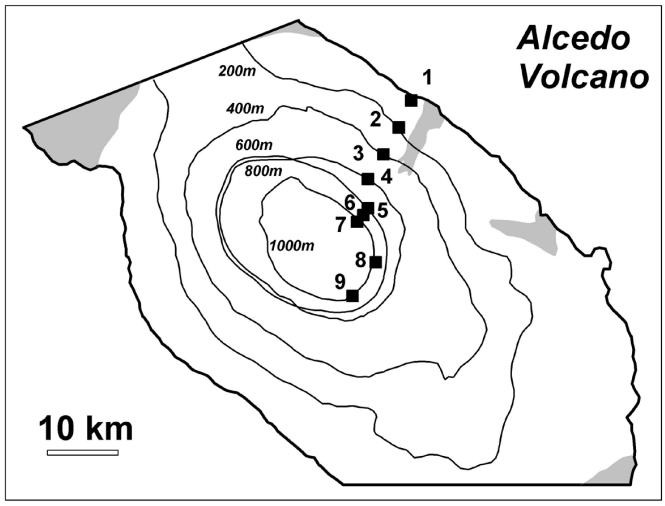


Figure 1. Location of the invertebrate sampling sites on Alcedo Volcano. Large bare lava fields are shaded grey.

Dramatic events have taken place on Alcedo (Cayot & Snell 1996). Feral goats have seriously altered the natural vegetation. On large parts of the eastern slope and rim of Alcedo we noted that they nearly wiped out large stands of native vegetation. Forest and scrub had by 1996 been converted to grassland, possibly leading to shortage of food and shelter for native species, as well as enhancing soil erosion. Although these devastating effects of goats on Alcedo are obvious, few comparative data are available and photographic comparisons have not been published.

During the first week of April 1986, before the overwhelming presence of goats, we sampled terrestrial macroinvertebrates on Alcedo in nine sites along an altitudinal transect from the seashore to the top, including the eastern rim to the fumarole area in the south of the crater (Fig. 1), with an emphasis on beetles (Coleoptera) and spiders (Araneae) (Baert *et al*. 1989, Desender *et al*. 1989). The most obvious introduced mammals on Alcedo at that time were feral donkeys, which were not very abundant. Vegetation composition and structure at all sampling sites were described and photographs were taken. Details of methods, sampling techniques, invertebrate species and data analysis are given by Desender *et al*. (1999). During the first week of April 1996, the transect was resampled and photographs repeated.

The vegetation on Alcedo is progressively more xerophytic towards the coast (Hamann 1981). Annual rainfall is usually lower near the coast, and soil looser and more humus-poor (Huttel 1995, Grant 1986, Wiggins & Porter 1971). Near the coast, the vegetation is relatively species-poor, with mainly *Scalesia affinis* or *Waltheria ovata* and some grasses during the wet season. Higher up on the eastern slopes, this semi-arid scrub gradually changes into a shrub savanna and deciduous forest, dominated by the tree *Bursera graveolens* and, somewhat higher, also by shrubs of *Scalesia microcephala*. From about 800 m altitude upwards, the vegetation gradually becomes evergreen steppe scrub, dominated by trees such as *Pisonia floribunda*, *Psidium galapageium* and *Zanthoxylum fagara*. Along the eastern and southern rim, treeferns and evergreen fern meadow originally occurred as patches between a dense and species-rich evergreen mossy forest, which was best developed above the former fumarole area (our site 9, cf. Hamann 1981).

To distinguish goat-induced changes in population dynamics from natural fluctuations related to climatic conditions, we investigated the response of invertebrates to the ecological gradient and/or climatic variability. By coincidence, meteorological conditions during both years appeared similar, especially precipitation, and both 1986 and 1996 could be classified as years with moderate rainfall. Even the timing of heavy rainfall prior to our sampling was more or less comparable: the most recent heavy showers took place about three to four weeks prior to each of the two sampling campaigns. Under such conditions it can be assumed that the majority of the terrestrial invertebrate species were equally abundant in the various habitats in the two years, another prerequisite for a meaningful quantitative ecological sampling and analysis. Our 1986 sampling sites had been damaged and overgrazed by feral goats to very different degrees by 1996, a prerequisite for any attempt to evaluate the influence of goats.

In the present paper, we describe and illustrate the Alcedo sampling sites by pictures taken during 1986 and 1996 at the same sites along the studied transect.

COMPARISON OF THE SAMPLING SITES IN 1986 AND 1996

The location of the sampling sites is shown in Fig. 1. Table 1 summarizes site data including elevation,

Table 1. Characteristics of invertebrate sampling sites on Alcedo Volcano. Numbers of sampling stations refer to Fig. 1.

Sampling station	1	2	3	4	5	6	7	8	9
Elevation (m a.s.l.)	10	200	400	600	800	900	1000	1060	1000
Vegetation type:									
desert scrub	x								
shrub savanna	(x)	x	x	(x)					
dry-season deciduous forest			x	x	(x)				
evergreen steppe scrub					x	x	x		
evergreen fern meadow						x	(x)	x	(x)
evergreen mossy forest								x	x
Vegetation cover:									
trees and shrubs (1986)	5	40	60	60	45	45	65	70	75
trees and shrubs (1996)	5	40	60	65	40	35	25	15	5
herb layer (1986)	5	10	40	40	50	55	30	25	20
herb layer (1996)	15	20	40	35	40	30	70	70	90
Goat damage* (1996)	0	0	0	0	1	1	2	2	2

*0 = no apparent alterations; 1 = slight but obvious damage; 2 = highly influenced.

Figures 2 (top) to 5 (bottom). NE slope and E crater rim of Alcedo Volcano. Left views (A) correspond to 1986, right views (B) to 1996. 2A–2B: Site 3, 400 m. 3A–3B: Site 4, 600 m. 4A–4B: Site 6, 900 m. 5A–5B: eastern crater rim from Site 7, 1000 m.

Figures 6 (top) and 7 (bottom). E crater rim of Alcedo Volcano. Left views (A) 1986, right views (B) 1996. 6A–6B: Site 8, 1060 m. 7A–7B: Site 9, 1000 m.

vegetation type (after Hamann 1981, Meyer & Adsersen 1990, Werff 1978), vegetation cover estimated by eye, and estimated habitat alteration due to goat damage (based on field descriptions, vegetation cover and photographic documentation).

Figure 8. 1060 m. Tree fern site on crater rim in 1996.

Changes in the vegetation between 1986 and 1996 were not obvious at elevations of 400 m and 600 m (Table 1, Figs 2–3). Changes became apparent from an elevation of about 800 m upwards to the rim: sites 5 and 6 (Fig. 4), both situated on the steepest parts of the volcano slope, appeared more open in 1996; reduction in vegetation appeared to be partially associated with increased erosion. Sites 7 to 9 (rim area, 1000–1060 m altitude) had been much more influenced (Figs 5–7): the evergreen steppe scrub and dense evergreen mossy forest had disappeared in many places, especially around the top (Fig 6) and at the rim (Fig. 7) above the fumarole that was active at the time, and had been replaced, at least during the wet season, by a more or less continuous short-grazed and species-poor meadow. Ferns and especially treeferns on many spots had been mostly destroyed; logs and stumps of dead wood were abundant (Fig. 8). At the rim we witnessed in 1996 the disappearing *Scalesia, Tournefortia* and *Zanthoxylum* patches (Fig. 7), bare patches of dying tree ferns (formerly nearly invisible due to luxuriant and dense woodland), increased erosion of the inner caldera slopes as well as a large part of the outer slopes of the volcano. Parts of the area had become dry and dusty during the annual dry season (L.

Figure 9. Giant tortoises: left view (A) 1986, right view (B) 1996.

Cayot pers. comm.), where formerly interception of the misty clouds of the *garúa* by the former woodlands deposited much more moisture on the vegetation of herbs, grasses, trees and shrubs with epiphytic mosses and lichens. Giant tortoises, once largely hidden by the luxuriant vegetation (Fig. 9A), were visible from great distances in 1996 (Fig. 9B); note goats in the background). The area around the easternmost fumarole in the caldera also appeared to have been influenced (Fig. 10), with more open foreground in 1996 and increased erosion, although the most striking difference here was that the fumarole had become almost inactive by 1996 (cf. Green 1994).

Our reference dataset of photographs and invertebrate results may be used for future monitoring in the area, especially the expected recovery of vegetation and associated invertebrate communities during and following goat eradication.

ACKNOWLEDGMENTS

Excellent cooperation and field logistic support were provided by the Charles Darwin Research Station, Santa Cruz, Galapagos (G. Reck and C. Blanton, Directors and their staff) and the Galapagos National Park Service (F. Cepeda and A. Izurieta, Superintendents, Dept. Forestry, Ministry of Agriculture). TAME airline kindly issued reduced price tickets. Our investigations and field work were financially supported by the Belgian DWTC (former Ministry of Education), the National Fund for Scientific Research (FWO) and the Leopold III Foundation. Help in field sampling was obtained from S. Abedrabbo and S. Sandoval. Information on Alcedo up to 1996 was kindly provided by L. Cayot. The manuscript was improved by comments from K. Campbell and A. Tye. This is Contribution 1020 of the Charles Darwin Foundation for the Galapagos Islands.

LITERATURE CITED

Adsersen, H. 1989. The rare plants of the Galápagos Islands and their conservation. *Biological Conservation* 47: 49–77.

Baert, L., Maelfait, J.-P. & Desender, K. 1989. Results of the Belgian 1986-expedition: Araneae and provisional checklist of the spiders of the Galápagos archipelago. *Bulletin de l'Institut Royale des Sciences naturelles de Belgique, Entomologie* 58: 29–54.

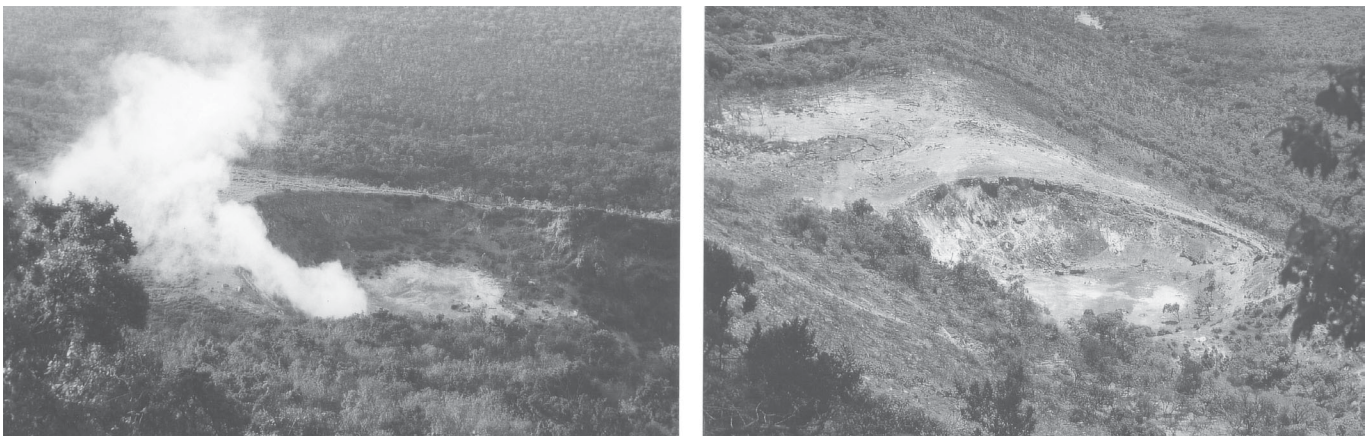


Figure 10. Former fumarole site (900 m) at S rim of Alcedo. Left view (A) 1986, right view (B) 1996.

Cayot, L. & Snell, H.M. 1996. Goats damage Volcán Alcedo. *Noticias de Galápagos* 56: 3.
Corley Smith, G.T. 1981. The significance of the Perry Isthmus. *Noticias de Galápagos* 33: 24.
De Vries T. & Black, J. 1983. Of men, goats and guava — problems caused by introduced species in the Galápagos. *Noticias de Galápagos* 38: 18–21.
Desender K., Baert, L. & Maelfait, J.-P. 1989. Contribution to the knowledge of the Carabid beetles of Galápagos (Ecuador). *Bulletin de l'Institut Royale des Sciences naturelles de Belgique, Entomologie* 58: 55–64.
Desender, K., Baert, L., Maelfait, J.-P. & Verdyck, P. 1999. Conservation on Volcán Alcedo (Galápagos): terrestrial invertebrates and the impact of introduced feral goats. *Biological Conservation* 87: 303–310.
Duffy, D.C. 1981. Ferals that failed. *Noticias de Galápagos* 33: 21–22.
Fowler, L. 1980. Donkey-work on Alcedo. *Noticias de Galápagos* 32: 20–22.
Freire, M.B. 1992. *Ecología de los Chivos Ferales (Capra hircus L.) en el Volcán Alcedo, Isla Isabela, Galápagos, Ecuador.* Tesis de Licenciado en Biología y Química, Universidad Técnica de Ambato.
Grant, P.R. 1986. *Ecology and Evolution of Darwin's Finches.* Princeton University Press, Princeton, NJ.
Green, J.R. 1994. Recent activity in Alcedo Volcano, Isabela Island. *Noticias de Galápagos* 54: 11–12.
Hamann, O. 1981. Plant communities of the Galápagos. *Dansk Botanisk Arkiv* 34: 1–163.
Hoeck, H.N. 1984. Introduced Fauna. Pp. 233–246 in Perry, R. (ed.) *Key Environments. Galápagos*. Pergamon Press, Oxford.
Huttel, C. 1995. *Vegetacion en Coladas de Lava, Islas Galápagos, Ecuador.* Fundación Charles Darwin para las Islas Galápagos, Quito.
Meyer, M. & Adsersen, H. 1990. Satellite images: a tool in vegetation studies, conservation, and management in Galápagos. *Monographs in Systematic Botany of the Missouri Botanical Garden* 32: 93–100.
Perry, R. 1968. *Charles Darwin Research Station, Galapagos: Scientific and Conservation Report Number 14.* Unpubl. report held at Charles Darwin Research Station, Puerto Ayora.
Werff, H. van der 1978. *The Vegetation of the Galápagos Islands.* Lakenman & Ochtman, Zierikzee.
Werff, H. van der 1982. Effects of feral pigs and donkeys on the distribution of selected food plants. *Noticias de Galápagos* 36: 17–18.
Wiggins, I.L. & Porter, D.M. 1971. *Flora of the Galápagos Islands.* Stanford University Press, Stanford, CA.

FISHERY BYCATCH OF THE WAVED ALBATROSS *PHOEBASTRIA IRRORATA*, A NEED FOR IMPLEMENTATION OF AGREEMENTS

By: Gustavo Jiménez-Uzcátegui[1], Jeffrey Mangel[2], Joanna Alfaro-Shigueto[2] & David J. Anderson[3]

[1]Charles Darwin Foundation, Santa Cruz, Ecuador. <gjimenez@fcdarwin.org.ec>
[2]Pro-Delphinus, Lima, Peru
[3]Department of Biology, Wake Forest University, U.S.A.

SUMMARY

The Waved Albatross, a threatened Ecuadorian endemic bird, is protected by national and international laws and agreements, in spite of which, 43 that had been ringed on the island of Española, Galapagos, were found killed off the coast of Peru, at least 34 of them by incidental fishing. International collaboration is required for the effective conservation of this species.

RESUMEN

Pesca incidental del Albatros de Onda *Phoebastria irrorata*, una necesidad para la implementación de acuerdos. El Albatros de Onda *Phoebastria irrorata*, es una ave amenazada, endémica del Ecuador, la cual está protegida por leyes nacionales y acuerdos internacionales, pese a esto, 43 individuos anillados en la isla Española, Galápagos, fueron encontrados muertos en la costa del Perú, al menos 34 de estos fueron por pesca incidental. La colaboración internacional es necesaria para una conservación eficaz de esta especie.

INTRODUCTION

The Waved Albatross *Phoebastria irrorata* is endemic as a breeding species to the Galapagos Islands (Jiménez & Wiedenfeld 2002), except for a few pairs that breed on Isla de la Plata off the coast of Ecuador (Granizo 2002). It is Vulnerable (IUCN 2006) but a proposed move to Critically Endangered (B1a,b(ii,iii,iv,v)) is currently under discussion.

In Galapagos, it breeds on Española Island, in colonies at Punta Suarez, Punta Cevallos and along the coast and inland areas in the southern part of the island (Harris 1973, Douglas 1998). Between January and March each year, virtually all Waved Albatrosses leave Galapagos, traveling more than 1200 km to spend the non-breeding season off the coasts of S Ecuador and N Peru, in the productive waters of the Humboldt Current (Fernández *et al*. 2001). It is threatened by oil spills, hunting for food, and fisheries bycatch in continental coastal waters (Granizo 2002, Awkerman *et al*. 2006, IUCN 2006).

Since 1960, Waved Albatrosses have been marked with metal identification rings (Lévèque 1962), and since 2002 with passive internal transponder (PIT) tags, allowing individual identification, which in turn permits long-term monitoring, demographic analysis, nesting studies, and evaluation of the species distribution within Galapagos and elsewhere. Tagging also provides information on mortality. Since 2003 the Peruvian group Pro-Delphinus has recorded ring numbers of albatrosses collected by Peruvian fishing vessels.

RESULTS

The identification numbers reported belong to 43 Waved Albatrosses (which include the 24 mentioned by Awkerman

Table 1. List of dead Waved Albatrosses collected from vessels fishing in Peruvian waters, ordered by date of death.

Ring scheme/number	Date ringed	Ringing site	Age when ringed	Date of death	Site where found dead	Cause of death
BTO 1089295	Nov 1975	Suárez	Juvenile	1998	Salaverry	Long-line
BTO 1089272	Nov 1975	Suárez	Juvenile	2000	Salaverry	Long-line
BTO 1135337	Nov 1988	Suárez	Juvenile	2000	Salaverry	Long-line
BTO 1135151	Jun 1994	Suárez	Adult	2000	Salaverry	Long-line
BTO 1135337	Nov 1988	Suárez	Juvenile	2000	Salaverry	Long-line
USFW 84827323	1999	Cevallos	Adult	Jun 2003	Salaverry	Long-line
USFW 84827432	1999	Cevallos	Adult	Jun 2003	Salaverry	Long-line
USFW 84830860	Jun 2002	Suárez	Adult	Jun 2003	Salaverry 9°20′S, 79°50′W	Long-line
BTO 1089237	Nov 1975	Suárez	Juvenile	Sep 2003	Salaverry	Long-line
USFW 84827569	2000	Cevallos	Adult	Sep 2003	Salaverry	Long-line
BTO 1019960	Dec 1970	Suárez	Juvenile	Sep 2003	Salaverry	Long-line
BTO 1100653	Nov 1978	Suárez	Juvenile	Jun 2004	Salaverry	Unknown
USFW 66881350	1996	Cevallos	Juvenile	Jun 2004	Salaverry	Unknown
USFW 84827042	1997	Cevallos	Adult	Jun 2004	Salaverry	Unknown
USFW 84827247	Jun 2002	Suárez	Adult	Jun 2004	Salaverry	Unknown
USFW 84827905	Dec 2001	Cevallos	Juvenile	Jul 2004	Salaverry 8°7′S, 79°6′W	Gillnet
USFW 84828758	Dec 2001	Cevallos	Juvenile	Jul 2004	Salaverry 8°7′S, 79°6′W	Gillnet
USFW 76806199	1996	Cevallos	Juvenile	Jul 2004	Salaverry 8°7′S, 79°6′W	Gillnet
USFW 84828758	Dec 2003	Cevallos	Adult	Jul 2004	Salaverry 8°7′S, 79°6′W	Gillnet
USFW 84827362	1999	Cevallos	Adult	Aug 2004	Callao	Long-line
BTO 1089345	Nov 1975	Suárez	Juvenile	Aug 2004	Salaverry	Long-line
USFW 84827333	1999	Cevallos	Adult	Oct 2004	Salaverry	Hook and line
Anderson 2365	Aug 2004	Cevallos	Unknown	Mar 2005	Salaverry	Hook and line
Anderson 2638	Aug 2004	Cevallos	Adult	Mar 2005	Salaverry	Hook and line
USFW 84828883	2004	Cevallos	Unknown	Mar 2005	Salaverry	Hook and line
USFW 84828193	2004	Cevallos	Unknown	Mar 2005	Salaverry	Hook and line
BTO 1100129	Nov 1979	Suárez	Juvenile	Apr 2005	Salaverry 8°14′S, 78°58′W	Hook and line
USFW 84827580	2000	Cevallos	Adult	May 2005	Salaverry	Hook and line
BTO 1089116	Oct 1974	Suárez	Juvenile	Jun 2005	Salaverry	Gillnet
BTO 1019668	Jul 1980	Suárez	Juvenile	Jul 2005	Salaverry 8°42′S, 79°32′W	Hook and line
USFW 84827471	1999	Cevallos	Adult	Jul 2005	Salaverry	Gillnet
USFW 84831707	Dec 2004	Suárez	Juvenile	Jul 2005	Salaverry	Hook and line
BTO 1072317	Jun 1994	Suárez	Adult	Aug 2005	Salaverry	Hook and line
USFW 85821377	Dec 2001	Cevallos	Adult	Aug 2005	Salaverry	Hook and line
BTO 5012268	Jun 1994	Suárez	Adult	Sep 2005	Salaverry	Unknown
BTO 1089908	Nov 1977	Suárez	Juvenile	2005	Salaverry	Unknown
BTO 1200004	Nov 1981	Suárez	Juvenile	2005	Salaverry 8°14′S, 78°58′W	Hook and line
BTO 1200167	Nov 1981	Suárez	Juvenile	2005	Salaverry	Unknown
BTO 1135127	Jun 1994	Suárez	Adult	2005	Salaverry	Unknown
USFW 84827521	1999	Cevallos	Adult	Oct 2006	San José	Unknown
BTO 5042585	Aug 1971	Suárez	Juvenile	Unknown	Salaverry	Long-line
BTO 1089141	Jun 1994	Suárez	Adult	Unknown	Salaverry	Hook and line
USFW 84830389	Jul 2001	Cevallos	Adult	Unknown	Salaverry	Long-line

et al. 2006), 34 (79%) of which died as bycatch and nine (21%) from unknown cause (Table 1). Of the fishery bycatch deaths, 15 (44%) were by long-line, 13 (38%) by hook and line, and six (18%) by gillnets. Age of the dead birds varied from one to 33 years. They had been ringed at Punta Suárez (23) and Punta Cevallos (20). At time of ringing, 20 were adult, 20 juvenile, and three of unknown age. Most (41) were collected in Salaverry marine zone, one in Callao and one in San José, all in Peruvian waters.

DISCUSSION

Without a doubt, many more albatrosses have been killed by these fisheries, accounting for reduced adult survival in recent years (Awkerman *et al*. 2006). This poses a high risk to the survival of this species, an effect that is being felt in other regions of the world by other species of albatrosses and petrels.

At least in part due to concern about this, long-line fishing has recently been forbidden in the Galapagos Islands. Unfortunately, this resolution is only local, whereas the issue requires international commitment. Several current conservation agreements and suggested measures for this species require enforcement or implementation, including: extend protection of the species beyond the areas in which it is currently protected, *i.e.* Galapagos and Machalilla National Parks, including implementing the hunting ban in accordance with Ministerial Resolution 105, 7 January 2000 (Granizo 2002); surveillance of fishing methods and techniques that could affect this species (Granizo 2002); inclusion in Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS; Anderson *et al.* 2002); inclusion in the Agreement on the Conservation of Albatrosses and Petrels (ACAP 2001). Some of these agreements have not been acted upon, particularly the ACAP, which has been in force in Ecuador and Peru (among other countries) since 2001.

We call upon the appropriate authorities to seek solutions to this problem and emphasize the importance of enforcing existing agreements to ensure the protection of this and other marine species that are being adversely affected by fisheries.

ACKNOWLEDGMENTS

We thank the Galapagos National Park Service, the Charles Darwin Foundation, Pro-Delphinus, collaborators, volunteers and friends. We are especially grateful to Mike P. Harris. This study is dedicated to the memory of Elizabeth Uzcátegui de Jiménez and Gustavo Jiménez-Cadena. This is Contribution number 1049 of the Charles Darwin Research Station.

LITERATURE CITED

ACAP. 2001. *Agreement on the Conservation of Albatrosses and Petrels*. ACAP2 Agreement: Final. Cape Town.

Anderson, D.J., Huyvaert, K.P., Apanius, V., Townsend, H., Gillikin, C., Hill. L.D., Joula, F., Porter, E.T., Wood, D.R., Lougheed, C. & Vargas, H. 2002. Population size and trends of the Waved Albatross *Phoebastria irrorata*. *Marine Ornithology* 30: 63–69.

Awkerman, J.A., Huyvaert K.P., Mangel, J., Alfaro-Shigueto, J., Anderson, D.J. 2006. Incidental and intentional catch threatens Waved Albatross. *Biological Conservation* 133: 483–789.

Douglas, H. 1998. Changes in the distribution and abundance of waved albatrosses in Española island, Galapagos Islands, Ecuador. *Condor* 100: 737–740.

Fernández, P., Anderson, D.J., Sievert, P. & Huyvaert, K. 2001. Foraging destinations of three low-latitude albatross (*Phoebastria*) species. *Journal of Zoology* 254: 391–404.

Granizo, T. 2002. Albatros de Galápagos. *En*: Granizo, T., Pacheco, C., Rivadeneira, MB., Guerrero, M. & Suárez, L. (eds.), *Libro Rojo de las Aves del Ecuador*, pp. 102–103. SIMBIOE/ Conservation International/EcoCiencia/Ministerio del Ambiente/UICN, Quito.

Harris, M.P. 1973. The biology of Waved Albatross *Diomedea irrorata* of Hood Island, Galapagos. *Ibis* 115: 483–510.

IUCN. 2006. Red list of threatened species. http://www.iucnredlist.org/

Jiménez-Uzcátegui, G. & Wiedenfeld, D.A. 2002. Aves Marinas. *En*: *Reserva Marina de Galápagos. Línea Base de la Biodiversidad*. Danulat, E. & Edgar, G.J. (eds.), pp. 343–372. Fundación Charles Darwin, Puerto Ayora.

Lévèque R. 1962. Bird-ringing on the Galapagos Islands. *The Ring* 32: 126–127.

CITRUS LEAFMINER *PHYLLOCNISTIS CITRELLA* STAINTON (LEPIDOPTERA, GRACILLARIIDAE) REACHES GALAPAGOS

By: Bernard Landry[1] & Lázaro Roque-Albelo[2]

[1]Muséum d'Histoire Naturelle, C.P. 6434, CH-1211, Geneva, Switzerland. <bernard.landry@mhn.ville-ge.ch>
[2]Charles Darwin Research Station, A.P. 17-01-3891, Quito, Ecuador; and Biodiversity and Ecological Processes Research Group, Cardiff School of Biosciences, University of Wales, Cardiff, U.K. <lazaro@fcdarwin.org.ec>

SUMMARY

We report the presence of the Citrus Leafminer *Phyllocnistis citrella* Stainton (Lepidoptera, Gracillariidae), a serious pest of citrus trees, for the first time in Galapagos, on Santa Cruz and San Cristóbal islands.

RESUMEN

El Minador de hojas de los cítricos *Phyllocnistis citrella* Stainton (Lepidoptera, Gracillariidae) llega a las Islas Galápagos. Reportamos la presencia del Minador de hojas de los cítricos, *Phyllocnistis citrella* Stainton (Lepidoptera, Gracillariidae), una seria plaga de los árboles de cítricos, por primera vez en Galápagos, en las islas Santa Cruz y San Cristóbal.

RESULTS

In January 2005, LR noticed two leaves of citrus trees that were mined by a lepidopteran on his property *c.* 5 km north of Puerto Ayora on the island of Santa Cruz, Galapagos Islands (0°42.595′S, 90°19.196′W, alt. 137 m). In February 2005, the two leaves were removed; one was pressed for reference and the other placed in a plastic bag for the purpose of trying to obtain an adult, but none emerged.

On 6 Feb 2005, BL went to a farm *c.* 1 km from the first site, along the old trail to Bellavista from Puerto Ayora (0°41.997′S, 90°19.195′W, alt. 186 m). There, a few new leaves of citrus with mines were taken and nine moths emerged. These were taken to Geneva for closer examination and dissection. Based on information in Heppner (1993), the reared specimens were identified as *Phyllocnistis citrella* Stainton.

On 20 Feb 2005, we went to Finca Escocia, a farm *c.* 2 km east of Bellavista at a higher elevation (320 m) in the agriculture zone of Santa Cruz (0°40.547′S, 90°18.274′W). On this property we found citrus trees of several varieties with leaves and some young shoots mined by *P. citrella*. From this lot two moths emerged, were prepared by BL, and were deposited in the Terrestrial Invertebrates Collection of the Charles Darwin Research Station, Galapagos.

Finally, BL, accompanied by José Loaiza, encountered citrus leaves mined by *P. citrella* on San Cristóbal island, on the property of Hacienda El Cafetal (0°55.366′S, 89°32.985′W, alt. 223 m) on 22 Feb 2005.

However, no moths emerged from these leaves before BL left the island four days later.

The arrival of the Citrus Leafminer in the Galapagos appears to be very recent. Trees that were found to be attacked in 2005 appear to have been free of the leafminer in 2004 (LR pers. obs., F. Arboleda pers. comm.).

DISCUSSION

Phyllocnistis citrella originates from SE Asia and has been dispersed widely on all continents and many islands where citrus trees grow (De Prins & De Prins 2005). It is a serious pest of *Citrus* and related genera of the Rutaceae (*e.g. Aegle*, *Atalantia*, *Citrofortunella*, *Fortunella*, *Limonia*, *Murraya*, *Poncirus*, *Severinia*). It has also been recorded to attack *Alseodaphne* and *Cinnamomum* (Lauraceae), *Pongamia* (Leguminosae), *Loranthus* (Loranthaceae), and *Jasminum* (Oleaceae), although some of the latter records need confirmation (De Prins & De Prins 2005).

Figure 1. *Phyllocnistis citrella* Stainton. Specimen reared from lemon in Italy (Asti).

The moth (Fig. 1) is very small (wingspan 4 mm) and mostly white with brown or tan linear markings and a black spot at the forewing apex. Although there are seven other species of Gracillariidae in the Galapagos (BL, unpubl.), none resembles *P. citrella* in wing pattern, all are larger, and none feeds on citrus.

The females of the Citrus Leafminer lay their eggs singly on the underside of their hosts' leaves. The flattened larvae make serpentine mines usually on the underside of young leaves (Fig. 2), but sometimes also on young shoots and fruits. The life cycle from egg to adult lasts 13–52 days depending on weather conditions and development is often continuous, resulting in up to 10 or more generations per year (Heppner 1993).

The attacks of the Citrus Leafminer on young trees may result in their death, but older trees survive even if their young leaves are attacked. Fruit development is not directly affected (Heppner 1993). The impact on Galapagos citrus is unknown. Young trees may not survive severe attack, especially in the absence of its natural enemies. Numerous species of Hymenoptera, in 37 genera of the Encyrtidae, Eulophidae, Eupelmidae, Eurytomidae, and Pteromalidae, are known to parasitize the Citrus Leafminer (De Prins & De Prins 2005).

The known distribution of the Citrus Leafminer in Galapagos is incomplete. An inventory should be carried out and in the event that it is not yet found on Floreana and Isabela islands, specific quarantine restrictions should be implemented.

With regard to the native Galapagos flora, the Citrus Leafminer should be looked for on the tree *Zanthoxylum fagara* (L.) Sarg., the only member of the Rutaceae that is native in Galapagos (Lawesson *et al*. 1987), and which is considered a potential hostplant according to Heppner (1993: 57). The presence of Citrus Leafminer on Lauraceae (no native species in Galapagos) and Leguminosae (many natives) should also be monitored.

Figure 2. Mines of *Phyllocnistis citrella* on citrus leaf at Finca Escocia, Santa Cruz Island (photo BL).

ACKNOWLEDGMENTS

We thank Maria Elena Guerra and Scott Henderson, as well as Georgina de Cruz and Augusto Cruz for their permission to sample on their farms. We are grateful to José Loaiza for his help and companionship on San Cristóbal. We thank Paolo Triberti (Museo Civico di Storia Naturale, Verona) for sending us the specimen shown as Figure 1. Finally, we thank Donald R. Davis (Smithsonian Institution, Washington, DC) for sending us a drawing of *P. citrella* and for critically reviewing the manuscript, and John B. Heppner (Florida Department of Agriculture and Consumer Services, Gainesville) for reviewing the manuscript as well. This is Contribution 1021 of the Charles Darwin Foundation for the Galapagos Islands.

REFERENCES

De Prins, J. & De Prins, W. 2005. *World Catalogue of Insects, Vol. 6, Gracillariidae.* Apollo Books, Stenstrup.

Heppner, J.B. 1993. Citrus Leafminer, *Phyllocnistis citrella*, in Florida (Lepidoptera: Gracillariidae: Phyllocnistinae). *Tropical Lepidoptera* 4: 49–64.

Lawesson, J.E., Adsersen, H. & Bentley, P. 1987. An updated and annotated check list of the vascular plants of the Galapagos Islands. *Reports of the Botanical Institute, University of Aarhus* 16: 1–74.

THE FARM AREA AND CULTIVATED PLANTS ON SANTA CRUZ, 1932–1965, WITH REMARKS ON OTHER PARTS OF GALAPAGOS

By: J.P. Lundh

Lofsrudhøgda 35 B, N-1281 Oslo, Norway. <jacop.lundh@c2i.net>

SUMMARY

The development of the agricultural area in the Santa Cruz highlands, including Bellavista and the farmlands above it, is described. During the 1930s and 1940s, there was on Santa Cruz an unusually high number of residents interested in experimenting with new plant species, and consequently the greatest variety of cultivated plants in the islands was found there. I present observations of 148 species or varieties of cultivated plants, made largely on Santa Cruz in the period 1946–54, along with other observations made mostly on San Cristóbal in 1952–3 and during my residence on the latter island in 1960–5, when I also made monthly trips around the islands. Of the taxa mentioned, 73 are probably pre-1930 introductions and another 17 possibly so. In the 1930s and 1940s, I found 55 new taxa, almost all of them on the farms in the highlands, and most on the properties of the Norwegians and Captain Castro. Three introductions of the 1950s or 1960s are also listed. Many of the taxa listed are first published records, either for the periods under consideration or earlier, since early botanical works left out nearly all the cultivated plants. Given that many former farmers have since gone over to raising cattle, some of the cultivated species registered during this early experimental period may since have disappeared from Galapagos.

RESUMEN

La zona de agricultura y las plantas cultivadas en Santa Cruz, 1932-1965, con algunas observaciones sobre otros sitios de Galápagos. Se describe el desarrollo del área de agricultura en la parte alta de Santa Cruz, incluyendo Bellavista y el área de cultivo inmediatamente arriba de ella. Durante los años 1930 y 1940, Santa Cruz conoció un número inusual de residentes interesados en experimentar con nuevas especies de plantas, y en consecuencia la mayor variedad de plantas cultivadas en las islas se encontró allí. Presento observaciones sobre 148 especie o variedades de plantas cultivadas en su mayor parte en Santa Cruz en el período 1946–54, juntamente con otras observaciones hechas en gran parte en San Cristóbal durante 1952–3 y durante mi residencia en esta última isla en 1960–5, cuando también realicé viajes mensuales alrededor del archipiélago. De los taxones mencionados, 73 son probablemente introducciones previas a 1930 y otros 17 posiblemente también. En los años 30 y 40, encontré 55 nuevos taxones, casi todos ellos en las granjas en la parte alta, y la mayoría en las propiedades de los noruegos y del capitán Castro. Tres introducciones de los años 50 o 60 también son mencionados. Muchos de los taxones enumerados son registros publicados por primera vez, ya sea de los períodos considerados o anteriormente, ya que los primeros trabajos sobre botánica omitieron casi todas las plantas cultivadas. Dado que muchos antiguos agricultores se han, desde entonces, cambiado a la cría de ganado, algunas de las especies cultivadas registradas durante este período experimental temprano podrían haber desaparecido de Galápagos desde entonces.

Our knowledge about the introduction of cultivated plants in the Galapagos is incomplete (Tye 2006). I attempt here to compile personal observations and information obtained at the time from older settlers, about the earliest farms on Santa Cruz Island and the plants cultivated there. I also include observations on San Cristóbal Island during several months in 1952–3 and during 1960–5, and on other islands where appropriate.

HISTORY OF THE FARM AREA ON SANTA CRUZ, 1932–1965

I have earlier (Lundh 1995, 1996) described the first farmers and settlers to arrive in the Bellavista and Puerto Ayora areas, between 1910 and 1938. A map made by Lt Gonzalo Villacís in 1937 (Fig. 1) shows nearly all the older farms on Santa Cruz. Lt Villacís was at the time the head of the first military garrison on the island as well as the local civilian authority and a good friend of my parents.

My visits and stays in the Galápagos have been as follows, and I describe the farm developments I noted during each period.

1932

We arrived to Santa Cruz for the first time, finding there a permanent population of about one dozen souls, most of them Europeans. We spent three months on Santa Cruz that year, while working on my father's sloop-rigged ship. Later, we sailed among the islands, fishing, then left for Guayaquil that same year. Farms that existed at the

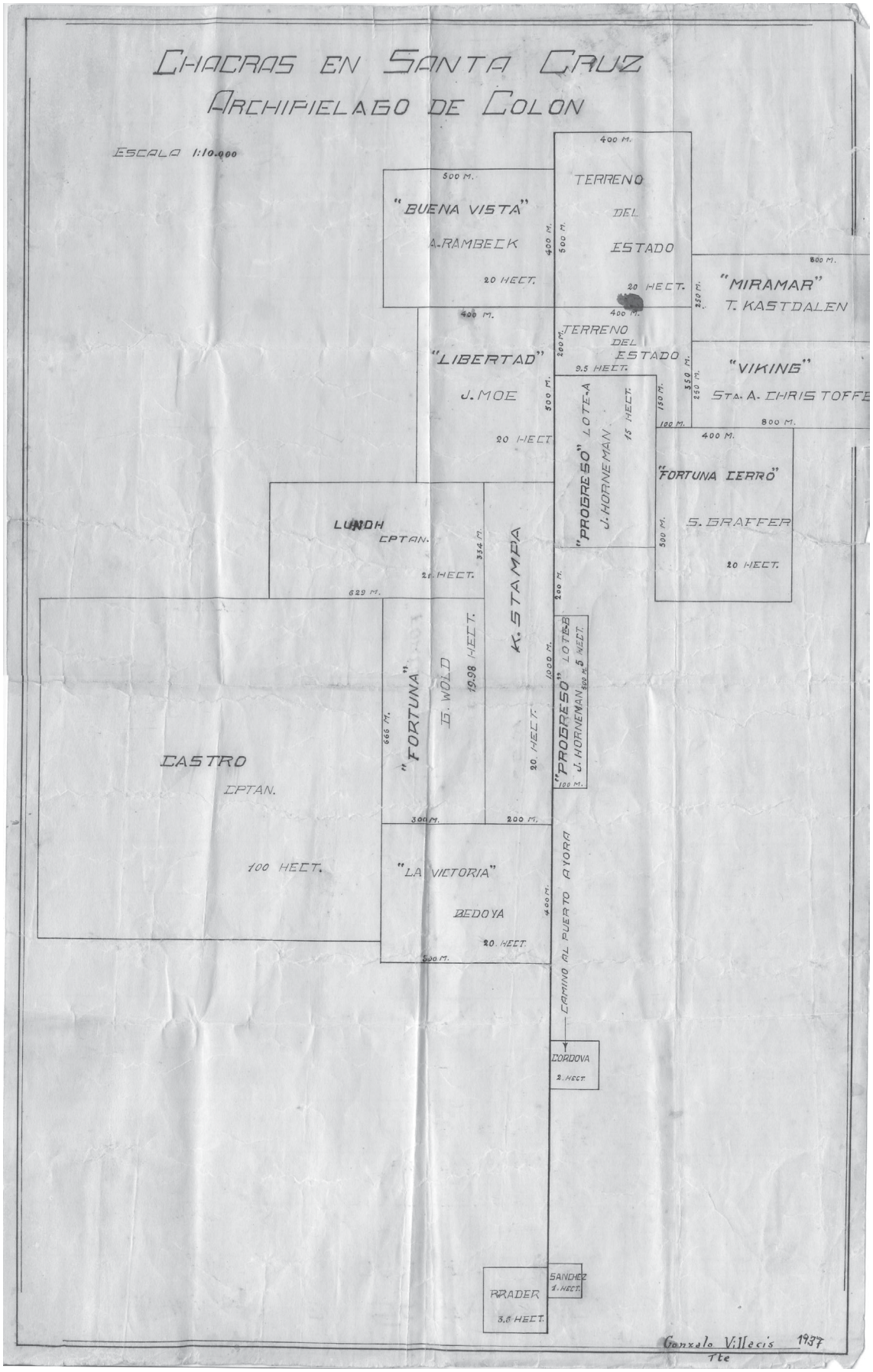


Figure 1. Map of the farm area on Santa Cruz in 1937, drawn by Lt. Gonzalo Villacis.

time (see Fig. 1) were Raeders' "El Rancho" (started 1931), Elías Sánchez's (1917), Gordon Wold's (1926, though there were earlier remains of cultivation left by people who had lived there a year or so before), Kristian Stampa's (1926, with plants such as cassava, bananas and taro left by earlier Ecuadorian settlers) and Jacob H. Horneman's Lote A (1927) and Lote B (probably 1931). These farms, except for Sánchez and Raeder, remained abandoned for several periods, such hardy plants as taro, cassava, bananas, papaya and citrus trees surviving on their own. In 1934, my father, Captain Herman von Hoff Lundh, returned to the islands. My mother Helga B. Lundh (who at the time was pregnant with my brother Eric) and I remained in Guayaquil.

1936–7

My mother, baby brother and I returned, remaining on Santa Cruz eight months, until August 1937. We spent some time on San Cristóbal before the old "Calderón" finished its cruise of the islands and returned to the mainland. At the time, it had a scientific expedition on board, which included Professor Acosta-Solís (the botanist) and Dr. Yehuda Sammandaroff (the geologist) among others. My father decided then to become a farmer in the highlands, while we three went back to the mainland. Aside from the farms mentioned above, there were those of Córdova and Bedoya (date unknown), Jens Moe (1934), Sigurd Graffer (1935), Amanda Christoffersen (1935), Thorvald Kastdalen (1935), Anders Rambech (a Norwegian horticulturist, who first came to the island for 18 months from 7 August 1926 as a member of the Academy Bay cannery group, established a new farm in 1935; his former land had been taken over by Wold and Stampa), Captain Rafael Castro (1937) and Captain Lundh (1937). Moe had first come to the island in 1926, and started his farm in 1934 after returning from several years in Colombia. The two "Terrenos del Estado" on Fig. 1 were originally the farm of the Swede Nilsson, who lived on the island in 1934 or 1935 and died later in Guayaquil. To the WNW of the farms on the map was the property of John Lundberg, a Swede who had arrived in 1934 with his wife and a daughter. In that area was the farm that was started by the Angermeyer brothers, who arrived in 1937.

1946–9

My brother and I returned in 1946, being joined by our mother the following year. We remained until 1949, when we went to the mainland and spent ten months there. It is during this period and the 1950's that I had closest contact with farming in the highlands. When we arrived in 1946, the population on Santa Cruz had increased to almost 120 inhabitants. A number of these new people were former Ecuadorian army men who had come out as settlers after leaving the service. By then, what was later called Bellavista had begun to take form a little below the older farms, and some distance inland from the Raeder, Sánchez and Córdova claims, which were by then abandoned, as Sánchez and Córdova had left the island in 1937 or 1938 and the Icelander Walter Finsen, who had taken over the Raeder farm, had died in 1945.

Most of the new settlers had established themselves in what became the village centre and a little below it. "El Pueblo", as we called it then, consisted of a series of houses with small gardens spread on both sides of the trail to Academy Bay, with a relatively short distance between them, on the flat lands below the older farm area. Most of the farming was done in small gardens behind the houses. The school was a little to the east of the upper end of this populated area. The new settlers had arrived in the 1940s, with the exception of the Andrades (Mrs Rosa Castro de Andrade and her two children Hortensia and Lautaro) who had arrived with Captain Rafael Castro (Rosa's brother) in 1937, and lived with him until Hortensia married former army nurse Carlos Játiva, who had settled in Bellavista. Also in *el Pueblo* and its vicinity lived Corporal Cando and Bolívar Cedeño and their families. Another former army man, Luis Aguirre, had his farm at the lower end of this area, where he lived with a number of children and his wife, Marina Fuentes. In 1949, Marina's brother, Enrique, started a farm a short distance above *el Pueblo*, settling there with his wife Teodora and their children. By the 1960s, this last family had moved to Puerto Ayora.

There was also a new farming nucleus that had formed in the area near Lundberg's claim, which in 1946 belonged to the daughter, Gloria Lundberg. Mrs Solveig Graffer, on leaving her family, had built a house and started farming on the edge of the grasslands, above the Angermeyer claim. Farther down, about level with Lundberg's place and more to the west were Augustina Buenaño and César Moncayo (two old settlers from San Cristóbal), Carlos Malo, who was married to the daughter of Augustina and César, and Håvard Henriksen, who had married Seimy, Lundberg's widow. This was an open area with chest-high herbaceous vegetation which was easy to clear and had a deep, dark soil. Somewhat to the SE of these lived a man by the name of Ramos, with his wife and a brother-in-law, César Campuzano. All these farms had been started in the 1940s and were already well established when we arrived in 1946. It was also in this area that Segundo Herrera and his family later became established, probably in the early 1950s.

There was a great diversity of vegetables produced on these farms in the 1940s, especially on the lands of the Norwegians and Captain Castro, who were those most interested in trying new products. The former imported seeds from Norway and Guayaquil, mainly in the 1930s, while the latter did so from Guayaquil from the end of that decade. Another important source was the Norwegian-American Captain Østrem, who brought plants and seeds from Panama, while he was master of the U.S. Army transport that supplied the base at Baltra (?1944–5).

The old farms at Santa Rosa and Salasaca, in the western part of the moist region, were, according to San Cristóbal tradition, established by order of Manuel Julián Cobos so that his archil (orchilla) collectors and tortoise

hunters in the area would have a supply of fresh food (see Lundh 1995). By 1946, these plantings were about to disappear, except for the orange and lime trees, as pigs and cattle, introduced to the south of the island in the 1920s, had by then spread to that part of the highlands.

1950–4

In March 1950 we returned from the mainland. During the earlier part of the decade I still kept in constant contact with people in the highlands, and went often up to work on the farm that my brother bought from Jorge Herrería a couple of years later. However, both my mother and I spent most of our time at what now is the site of the Charles Darwin Research Station, where we had built a house above the little beach where the director's residence would be built, in the next decade. I was absent a few months in 1952 and 1953, while I was employed in the office of Sociedad Nacional de Galápagos in Wreck Bay. Most weekends there I would go to the highlands, where I spent time with the Cobos family, who were old friends. I left for Colombia in 1954.

On the same ship on which we returned to the islands in 1950, came a small group of young city men from Guayaquil, who intended to set up a cooperative to fish and farm on Santa Cruz. Faced with reality and lack of capital, the group broke up shortly after arrival, only one of its members, Arturo Ramírez de Luca, remaining. He started a farm in the area east of the Bellavista school house, where the Herrería Malta brothers (Julio and Jorge) and their families had started farms towards the end of 1949. We found the Herrería brothers and their families already established, alongside Jorge's father-in-law, the Spaniard Isaac González. They had arrived towards the end of 1949, while we were away. Both the Herrería families had left after a couple of years, as did Ramírez, while González remained until his death, a few years later. As stated, my brother bought Jorge's log cabin and his farm, while Marina Fuentes left her husband Luís Aguirre and took off with Víctor Hugo Castro (no relation of Captain Castro), taking over the property left by Julio Herrería.

I assume that these homesteads were of 20 ha each, which was the usual size on Santa Cruz at that time. As an example, 20 ha was the area purchased by my brother from Jorge Herrería. The area NE of *el Pueblo* had been mostly *Scalesia* forest and the trees that were cut down to clear the land were used to build log cabins by these settlers. The area where most of the older farms were had originally been covered by mixed woodland, and as late as the 1960s there still were trees of *Psidium galapageium* and *Zanthoxylum fagara* on the farms belonging to Captain Lundh, Captain Castro, Wold, Stampa and Horneman. Moe was mostly interested in growing coffee and had left some of the original trees, mostly *Pisonia floribunda*, as shade for his crop.

1959

I made two visits to the islands, but had no time to visit the highlands, though I spent several days on Santa Cruz each time I went by. Most of my time was spent at Iguana Cove (Isabela) and James Bay (Santiago), where I camped two weeks while making a survey of the salt mine. Both these visits were made on behalf of Folke Anderson, the chairman of the Astral Group, who already had a ship running between the islands and the mainland.

1960–5

In 1960 I was appointed agent for Fruit Trading Corporation and Compañía Ecuatoriana de Turismo, both belonging to the Astral Group, and settled in Wreck Bay with my mother and my wife. During those years I visited the highlands on San Cristóbal very often, and made monthly cruises among the islands. A few times I stayed at Academy Bay for a week or two, working on our new house in Pelican Bay (on the site that became Hotel Galapagos). I once visited the Kastdalens, noticing some changes in the highlands, where the interest in cattle was beginning to take shape. There was also a farming community growing rather rapidly in the Santa Rosa area, where I obtained 200 ha, which I never had the opportunity to visit, as I moved to the mainland and later let Miguel Seminario and the Schiess family take it over.

CULTIVATED PLANTS

The plants marked with a [1] in the list below belong to species that were well established some places in the Galápagos before the 1930s, most of them at an early date. It may be safely assumed that most were introduced in the earliest years of colonization. Most of them are plants that are traditionally cultivated in subsistence farms along the Pacific coast of Colombia and in the coastal lowlands of Ecuador. Plants marked [2] in the list were probably first introduced in the 1930s and 1940s. Plants marked [3] are later introductions (1950s and 1960s).

Scientific names have in some cases been supplied by comparison of a common name or description with species identified (mostly by Charles Darwin Research Station botanists) as present in Galapagos since the period of my observations (*e.g.* the two species of *Chrysophyllum*). The local names (mostly Spanish, sometimes Quechua) given in parentheses after the English names are, as far as possible, the names used in Galapagos at the time.

Agavaceae

[1]*Furcraea hexapetala* (Jacq.) Urb. Undoubtedly an early introduction, Cabuya was reported from Floreana, Isabela, Santa Cruz and San Cristóbal by Stewart (1911). Its first appearance on Santa Cruz was in the Santa Rosa–Salasaca area, where Stewart (1911) found it already forming thickets. In 1946, it was found scattered elsewhere in the highlands, where it was introduced in the 1930s. It was also found wild in the Transition and upper Dry Zones of San Cristóbal in the 1960s, having been used for hedges in the highlands. In the 1960s I made arrangements with Cordelería Nacional of Guayaquil to provide machinery

to some of the settlers on San Cristóbal for the extraction of fibre from this plant. When I left the island in 1965, there were five machines working in the Transition Zone, with five or six people attending each, harvesting, cutting the thorny edges and feeding the machines.

Alliaceae

[2]*Allium ascalonicum* L. Shallots (Chalote) were grown at least in the highlands of Santa Cruz in the 1940s (I grew them myself).
[2]*A. cepa* L. A variety of Red Onion (Cebolla colorada) was tried repeatedly on Santa Cruz before 1946, but eventually given up as it did not form bulbs.
[2]*A. porrum* L. Leeks (Puerro) were grown, mainly on Santa Cruz, in the 1940s and 1960s.
[2]*A. sativum* L. On Santa Cruz there was limited production of excellent Garlic (Ajo) in 1946, but it was discontinued for some reason.
[2]*A. schoenoprasum* L. Chives (Cebollino) were widely grown in the highlands of all the inhabited islands from the 1940s onwards.

Anacardiaceae

[2]*Anacardium occidentale* L. The only Cashew (Marañon) I have observed in Galapagos was a tree that grew on the Horneman property. It was supposed to have been planted in the 1930s and still existed in the 1960s.
[2]*Mangifera indica* L. The Mango tree was introduced on several of the farms on Santa Cruz in the 1930s, but produced fruit only in years with an exceptional wet warm season, followed by a mild and relatively dry *garúa* season. I know of no earlier introduction. There was a small variety of mango grown at Puerto Baquerizo (San Cristóbal) with the help of irrigation, which produced fruit every year.
[1]*Spondias purpurea* L. The Red Mombin (Ciruela) was common in the highlands of Santa Cruz and San Cristóbal, as well as on Isabela and Floreana. It was often used to reinforce barbed wire fences, especially at the corners. Certainly a very early introduction. The trees at the spring above Black Beach, Floreana, were reputed to have been planted at the time of Gen. José Villamil, who settled there in 1832.

Annonaceae

[1]*Annona cherimola* Mill. The Cherimoya (Chirimoya) was found in the highlands of Santa Cruz from the 1930s and Captain Thomas Levick (who died in 1925) had some trees growing on his property in Wreck Bay, San Cristóbal.
[1]*A. glabra* L. I saw Pond Apple (Anona de lagarto) in a swampy brackish area near Puerto Villamil on Isabela, which may be the same area where Stewart (1911, 1915) found it. As far as I know, it is not found elsewhere in the islands. It may be native or a very early accidental introduction, as its flavourless flesh is seldom eaten.
[2]*A. muricata* L. The Soursop (Guanábana) was grown to a limited extent in the Santa Cruz highlands in the 1940s and later, and was popular for making drinks.

Apiaceae

[1]*Apium graveolens* L. Celery (Apio) was grown in the Santa Cruz highlands in the 1940s to 1960s, and is possibly an early introduction.
[1]*Coriandrum sativum* L. Coriander (Cilantro) is a much used herb in Ecuador, and therefore likely to be a very early introduction on all the inhabited islands. It was grown in the Santa Cruz highlands in the 1940s and later.
[1]*Cuminum cyminum* L. Cumin (Comino) is also very popular in Ecuadorian cooking and therefore likely to be an early introduction. It was present on Santa Cruz in the 1940s and said to be present on all the inhabited islands.
[1]*Daucus carota* L. Carrot (Zanahoria) was found on all the inhabited islands in the 1940s and much later. Very popular both in Colombia and Ecuador, for this reason expected to be an early introduction.
[2]*Pastinaca sativa* L. Parsnip (Pastinaca) was cultivated by some of the Norwegian settlers in the Santa Cruz highlands. It was not popular and may have been introduced in the 1940s.
[1]*Petroselinum crispum* (Mill.) A.W. Hill. Parsley (Perejil) was reported from Floreana by Andersson (1858) and by the 1940s was grown on all the inhabited islands. It is an important herb in Ecuadorian cooking so likely to be an early introduction.

Apocynaceae

[1]*Catharanthus roseus* (L.) G. Don. The Madagascar Periwinkle (Chabela) was common in gardens on San Cristóbal in the 1950s, both by the shore and in the highlands, and was probably one of the first pot and garden plants introduced. Two varieties were grown: a white and a purple-rosy. I grew it there in the 1960s.
[1]*Nerium oleander* L. Oleander (Laurel rosa) was often found in gardens of the San Cristóbal and Santa Cruz highlands, and occasionally by the seashore. A favourite in the Ecuadorian lowlands, it may be an early introduction.
[1]*Plumeria rubra* L. The Frangipani (Suche) was occasionally found in gardens on Santa Cruz and San Cristóbal. The time of its introduction is unknown, but its frequency in lowland gardens on the mainland makes it likely that it was brought to Galapagos at an early date.

Araceae

[1]*Colocasia esculenta* (L.) Schott. Taro (Papa china) has been grown in Galapagos since the earliest colonization. It was still found on all the inhabited islands in the 1960s. It was found in Santa Rosa and Salasaca in the western part of the Santa Cruz highlands, and it was also grown above Bellavista from very early on. It is little used in Ecuador, which leads me to believe that this plant was introduced by General José Villamil to the first colony on Floreana. Villamil had lived a number of years in Venezuela, and this plant is much used in the Caribbean region, so he may have thought it more useful than it actually was in Galapagos. The considerable shade produced by this plant makes it survive well on its own, once it has become established.

[1]*Xanthosoma sagittifolium* (L.) Schott. Tannia (Otoy) is probably another early introduction, similar in survival capacity to the preceding species. It was still found on all the inhabited islands in the 1960s.

Arecaceae

[1]*Cocos nucifera* L. What are believed to have been the oldest Coconut palms in Galapagos were a pair located next to the plantation house in Progreso, San Cristóbal. They were already large by the 1940s. Coconuts seem to have been introduced early in the Puerto Villamil area, on Isabela. There were a few palms a little to the west of the village, and a large group some distance inland, where there was a large pool of salt water. They are likely to be dead by now, as is the case with the palms planted by Dr Ritter in 1929, inland from Black Beach, Floreana. The species was a late introduction to Santa Cruz, where the first ones were planted by the Ræders, a Danish couple, in 1931 at what later became the site of the naval compound. Carlos Kübler planted a number of coconut palms in the "older" part of Puerto Ayora (the area near Laguna de las Ninfas), the first in 1934. Adolfo Haeni had a number of palms on his property in Pelican Bay, planted at the beginning of the 1950s.

[2]*Phoenix dactylifera* L. The earliest Date Palms (Datileros) known in the Galapagos were those planted in 1929 by Dr Ritter, inland from Black Beach, Floreana. In the early 1930s, Carlos Kübler planted his first Date Palms in Puerto Ayora, while Adolfo Haeni planted a few in Pelican Bay some 20 years later. While I lived above the little beach (now called "Director's Beach") east of Puerto Ayora, in the early 1950s, I planted a few Date Palms a short distance to the east of where the Research Station's buildings are now, inside a group of Manchineel *Hippomane mancinella* L. trees. It was a surprise to find them growing and well developed in the 1960s. The Date Palms in front of the navy's administration building in Puerto Baquerizo are of unknown date and would have been planted in the 1940s or perhaps later, as there was none when we spent two weeks there as guests of Col. Carlos Puente, in 1937

Asparagaceae

[2]*Asparagus officinalis* L. Asparagus (Espárrago) was produced in the Santa Cruz highlands by several Norwegians in the 1940s. Production was discontinued before the end of the decade, probably because of lack of demand.

Asphodelaceae

[1]*Aloe vera* (L.) Burm. f. Barbados Aloe (Sábila) was grown at least since the 1930s as an ornamental in the highlands of Santa Cruz and San Cristóbal, sometimes also by the seashore.

Asteraceae

[2]*Artemisia dracunculus* L. Tarragon (Estragón) was introduced on Santa Cruz in the 1940s. It was not much used and, as far as I know, cultivated only by the Norwegians.

[2]*Aster* spp. Two or three different forms or species of *Aster* were grown in the highland gardens of Santa Cruz, where they may have been introduced as early as the 1930s. Also found in gardens on San Cristóbal.

[2]*Cichorium endivia* L. Endive (Escarola) was grown in limited quantities in the Santa Cruz highlands. Introduced in the 1940s.

[2]*C. intybus* L. The European vegetable Chicory (Achicoria) was grown by some of the Santa Cruz Norwegians, and was probably introduced in the 1940s. Like the Endive above, never became very popular.

[1]*Lactuca sativa* L. Lettuce (Lechuga) has been grown since the earliest times, an open, leafy variety being the commonest on all the islands. The Kastdalens and Rambechs also had the Iceberg variety, which was introduced in the 1940s.

[1]*Matricaria* probably *recutita* L. A species of this genus, probably Sweet False Chamomile (Manzanilla) was grown on some of the farms on Santa Cruz and San Cristóbal as a medicinal herb, and may have been an early introduction.

[1]*Tagetes erecta* L. Aztec Marigold (Flor de muerto) is very popular in lowland Ecuador, and was grown as a garden and pot plant on all the inhabited islands at least from the 1940s.

[1]*Zinnia* sp. A common garden plant in the highlands of Santa Cruz and San Cristóbal, and in the lowlands of the latter. Probably an early introduction.

Bignoniaceae

[1]*Crescentia cujete* L. The Calabash Tree (Mate) was represented in the 1950s and 1960s by several small specimens at the Progreso cemetery, San Cristóbal. I did not see it elsewhere in the islands.

Bixaceae

[1]*Bixa orellana* L. Annatto (Achiote) was introduced early to Galapagos, as the colouring matter of its seeds is much used in Ecuadorian cooking. It was found on all the inhabited islands in the 1940s. It may also have escaped from cultivation in some parts, as there was a tree on the trail to Progreso, in the Transition Zone, in the 1950s and 1960s, in an area where no farming had ever been attempted.

Bombacaceae

[1]*Ceiba pentandra* (L.) Gaertn. The Silk-cotton Tree (Ceibo) was found scattered, in small numbers on both San Cristóbal and Santa Cruz. The trees observed in the 1940s were already quite large and must have been old by then. Most of them were still standing in the 1960s. A large group of these trees at the coconut grove, inland from Puerto Villamil, Isabela, seems to have been planted in the early days of colonization of that island. The species grows equally well in the highlands and the lowlands.

[2]*Ochroma pyramidale* (Cav. ex Lam.) Urban. The first Balsa was introduced on Santa Cruz in the 1940s. Lautaro Andrade found some seeds in a sack, identified them and

gave some to Captain Castro and Wold, who planted them. Wold had a slender tree, about 2.5 m high, growing in 1946. It has since spread in the highlands.

Brassicaceae

[2]*B. napus* L. A limited amount of Turnip (Nabo) was produced in the Santa Cruz highlands by the Norwegian settlers. They were cultivated as late as the 1960s.

[2]*B. oleracea* L. var. *botrytis* L. Caulifower (Coliflor) was planted a number of times in the Santa Cruz highlands in the 1940s, without success. No flower heads were formed, though the plants otherwise developed well.

[1]*B. oleracea* L. var. *capitata* L. Excellent Cabbage (Col) was produced in the Santa Cruz highlands, and was cultivated on all the inhabited islands. Probably an early introduction. Anders Rambech produced his first harvest of Cabbage in December 1926.

[2]*B. oleracea* L. var. *gemmifera* (DC.) Zenker. Brussels Sprouts (Col de Bruselas) were produced in the Santa Cruz highlands, and were probably introduced in the 1940s.

[2]*B. oleracea* L. var. *gongylodes* L. Kohlrabi (Colinabo) was cultivated in the Santa Cruz highlands and probably introduced in the 1940s. I have never seen it on the other islands.

[2]*Brassica rapa* L. var. *chinensis* (L.) Kitam. Pak-choi (Col china) was one of the two Chinese cabbages that was produced in the Santa Cruz highlands, mainly by the Norwegian farmers. Introduced in the 1940s and still grown in the 1950s.

[2]*B. rapa* L. var. *glabra* Regel. Pe-tsai (Col china) was the other Chinese cabbage that was produced in the Santa Cruz highlands. Introduced in the 1940s and still produced in the 1950s.

[1]*B. rapa* L. var. *rapa*. The Field Mustard was reported by Stewart (1911) from the San Cristóbal highlands and, was frequently found in the 1940s in open areas near houses in the highlands of the inhabited islands. It was probably introduced accidentally at an early date.

[1]*Raphanus sativus* L. Radish (Rábano) is one of the earliest introductions in Galapagos, and was grown from the first colonization on Floreana, in the 1830s (Andersson 1858). Stewart (1911) reported it from the San Cristóbal highlands and it was still found on all the inhabited islands in the 1960s. I grew them successfully, with irrigation, in Wreck Bay in the 1960s.

Bromeliaceae

[1]*Ananas comosus* (L.) Merr. Pineapples (Piña) were found in the highlands of all the inhabited islands as far back as I can remember (1937) and were probably an early introduction. Grown on the Santa Cruz farms at least as early as the 1930s.

Caesalpiniaceae

[1]*Caesalpinia bonduc* (L.) Roxb. This plant was probably introduced in the 19th century by tortoise hunters, to form hedges to keep their donkeys (also introduced by them) from eating their vegetables. The fact that it is introduced is obvious. The species reproduces by its seeds floating on currents, but I have never met with it along the coasts of Galapagos. Further, the two areas where it has been found, the coconut grove inland from Puerto Villamil (Isabela), far from the shore, and the western part of the Santa Cruz highlands, close to Santa Rosa, are far from places where it could be expected to be found naturally.

[1]*C. pulcherrima* (L.) Sw. Dwarf Poinciana was a popular garden plant on all the inhabited islands by 1946, sometimes grown even on the coast. Most likely one of the earliest gardening introductions.

[1]*Delonix regia* (Boger ex Hook.) Raf. There was a large Flamboyant tree in Pelican Bay, at the beginning of the road to the Research Station, in the 1960s. Nobody seemed to know how it came to be in that place.

Cannaceae

[1]*Canna* x *generalis* Bailey. Common Canna (Platanillo) was frequent in the San Cristóbal and Santa Cruz highlands.

Caricaceae

[1]*Carica papaya* L. An early introduction, reported by Andersson (1858) on Floreana and by Stewart (1911) on Isabela and San Cristóbal. Grown in the highlands on all the inhabited islands, occasional in gardens near the coast, usually near houses, where it reproduces spontaneously from fallen fruits. It was found at Santa Rosa and Salasaca. A red variety was introduced in the 1940s which was seen on Santa Cruz to cross-pollinate readily with the usual yellow variety.

Casuarinaceae

[2]*Casuarina equisetifolia* L. She-oak was introduced to Santa Cruz in the 1940s. A number of these trees were found on the Kastdalen property, in the highlands, and at the Haeni property in Pelican Bay. There were a few scattered specimens elsewhere in the highlands in the 1960s.

Combretaceae

[1]*Terminalia catappa* L. Indian Almond (Almendro) is popular as a shade tree in the Ecuadorian lowlands and therefore likely to be an early introduction in Galapagos. It was occasional in gardens on Santa Cruz and San Cristóbal.

Commelinaceae

[2]*Tradescantia spathaceae* Sw. A plant that seems to be this species was grown as an ornamental on San Cristóbal in the 1960s.

[1]Commelinaceae sp. There was also another ornamental species of this family grown in the area of the Norwegian farms on Santa Cruz in the 1940s.

Convolvulaceae

[1]*Ipomoea batatas* (L.) Lam. The Sweet Potato (Camote) is a very early introduction on the Galapagos, found on Floreana by Darwin (1839). It was found in Santa Rosa and Salasaca, and in the 1940s on practically all the farms

in the highlands of the inhabited islands. It survives well once it has become established, forming dense mats that cover the ground, shading out other plants.

Cucurbitaceae

[1]*Citrullus lanatus* (Thunb.) Matsun. & Nakai. Watermelon (Sandía) was grown in the highlands of all the inhabited islands, sometimes also by the sea. Undoubtedly a very early introduction (Andersson 1858, Stewart 1911).

[1]*Cucumis melo* L. The Musk Melon was by far the most popular melon in the islands, being grown on practically all the farms. It was also frequently grown in the lowlands. It was grown as far back as I can remember (1930s), and was undoubtedly an early introduction.

[1]*C. sativus* L. Cucumber (Pepino) is possibly one of the most popular vegetables, a very early introduction, grown on all the inhabited islands in the 1930s onwards, sometimes even in the lowlands.

[1]*Cucurbita moschata* (Duchesne ex Lam.) Duchesne ex Poir. or *C. pepo* L. Pumpkin (Zapallo) was probably a very early introduction, although the plants reported by Stewart (1911) on Isabela, proved to be *C. ficifolia* Bouché (Jørgensen & Léon-Yánez 1999). Pumpkins were grown in the highlands of all the inhabited islands in the 1940s, and sometimes even by the sea.

[1]*Luffa cylindrica* (L.) M. Roem. Smooth Loofah (Esponja) was very common near the houses in Puerto Baquerizo after the first warm season rains. It was also found in Puerto Ayora. It is an early introduction, used much for scrubbing. It was especially abundant in the warm season of 1964–5.

[1]*L. sepium* (G. Mey.) C. Jeffrey. I have not seen this species on Santa Cruz, but it was very common in Puerto Baquerizo. In 1959, I saw some plants in Iguana Cove (SW Isabela) that looked like this species. It is a very common warm season plant around Bahía de Caráquez and Manta, on the mainland coast. It may be an early introduction on Floreana. Its dry fruit is very handy for scrubbing pots and pans.

[1]*Momordica charantia* L. The Balsam Pear was, according to Stewart (1911), reported by Baur from Puerto Villamil, Isabela. I cannot recall seeing it there or at Puerto Baquerizo, but it was very common around Puerto Ayora in the 1930s, and in the 1940s I found it a little less common around Fortuna, a little above Bellavista. The Norwegian settlers called it "Mrs Ræder's weed", claiming that the plant had originated in her garden, which was in the site of the present naval compound in Puerto Ayora. The Ræders may have introduced it in 1931, when they built their house at this place.

[2]*Sechium edule* (Jacq.) Sw. The Chayote was grown by a few of the Santa Cruz farmers in limited quantities. It was introduced in the 1940s and I cannot remember seeing it on any of the other islands.

Dioscoreaceae

[1]*Dioscorea bulbifera* L. Potato Yam (Ñame) or a species much like it was grown in small quantity in the Santa Cruz highlands in the 1940s.

Dracaenaceae

[1]*Sansevieria trisfasciata* Prain. Bowstring Hemp (Lengua de suegra) was a common ornamental on all the inhabited islands, both in the highlands and on the coast. It was observed in and before the 1960s and may have been one of the first introduced ornamentals as it is popular on the mainland coast.

Euphorbiaceae

[2]*Aleurites fordii* Hemsl. Tung was introduced by Manuel Augusto Cobos on San Cristóbal towards the end of the 1940s. As far as I know this was the only introduction, and by the end of the 1950s there were none left, as they had been destroyed by Cobos's wife to plant something else, to the great disappointment of don Manuel, who happened to be on the mainland at the time.

[1]*Codiaeum variegatum* (L.) A. Juss. "Croton" was found in the 1940s and 1960s in gardens in the highlands of Santa Cruz and San Cristóbal. It is very popular on the mainland.

[1]*Euphorbia milii* Des Moul. Crown of Thorns was found in the 1950s and 1960s in the Santa Cruz and San Cristóbal highlands, as well as near the shore, often as a pot plant.

[1]*E. pulcherrima* Willd. ex Klotzsch. Poinsettia was probably found on all the inhabited islands. It was on Santa Cruz at least from the 1940s onwards.

[1]*Jatropha curcas* L. Physic Nut (Piñon) was common in the highlands of all the inhabited islands, and well established in the 1940s. It was used in Galapagos to establish dense, high hedges for cattle and other domestic animals.

[1]*Manihot esculenta* Crantz. Cassava (Yuca) was common in the highlands of all the inhabited islands, and is a very early introduction. It was also found at Santa Rosa and Salasaca.

Fabaceae

[2]*Arachis hypogaea* L. Peanuts (Maní) were introduced on Santa Cruz in the 1940s and grown for a short period in the highlands. Their size was large and the quality was good, but cultivation was discontinued. The reason may be that they were grown experimentally by one or two of the Norwegians and they thought they were not worth the extra work, peanuts not being a part of their food tradition. They would undoubtedly have had a market among the Ecuadorian settlers.

[2]*Glycine max* (L.) Merr. Some of the Norwegians and Captain Castro produced a limited amount of Soya beans in the Santa Cruz highlands. It seems to have been introduced in the 1940s, when it was receiving considerable publicity. It never became popular on the island.

[2]*Lablab purpureus* (L.) Sweet. Hyacinth Bean (Zarandaja) was introduced in the 1940s by Captain Castro as a tropical alternative to the Kudzu vine *Pueraria lobata* (Willd.) Ohwi, which was receiving considerable publicity at the time. It was often planted on Santa Cruz around vegetable gardens to keep down the weeds. It also made land clearing easier, as it formed dense carpets that could be rolled away, leaving fine clean soil for further cultivation. I have not seen it on the other islands.

[1]*Phaseolus vulgaris* L. Beans (Frejol) were grown to a limited extent on all the inhabited islands. It is however surprising that they were not produced in larger quantities considering the good quality and the ease with which they were grown.
[2]*Pisum sativum* L. A limited amount of Garden Peas (Arveja) was produced on Santa Cruz. They may have been grown from the 1930s.

Juglandaceae
[2]*Juglans neotropica* Diels. Andean Walnut (Tocte) was introduced to San Cristóbal by the Franciscan friars towards the end of the 1940s, and there was one tree growing in their garden in Progreso in the 1960s, which I believe was at that time the only one in Galapagos. More recently it has come to be called "Nogal" in the islands.

Lamiaceae
[2]*Lavandula* sp. Lavender (Lavanda) was grown in the garden of the Horneman family, it was probably introduced in the 1940s.
[1]*Mentha* x *piperita* L. Peppermint (Menta), a European herb, was common in the highlands of all the inhabited islands. Likely to be a very early introduction, as it is popular among Ecuadorians for making infusions. The Spearmint-flavoured "Hierbabuena" was another commonly cultivated mint, which could have been a variety of *M.* x *piperita* or perhaps *M. spicata*. While less popular than "Menta", it was also grown in the highlands of all the inhabited islands and much used for infusions by the Ecuadorian settlers.
[1]*Ocimum* cf. *campechianum* Mill. Basil (Albahaca) was found in the highlands of all the inhabited islands. It was probably this species rather than *O. basilicum* L. Likely to be an early introduction, as it is much used as a kitchen herb in the Ecuadorian lowlands.
[2]*Origanum majorana* L. The European herb Sweet Marjoram was grown by a few of the farmers in the Santa Cruz highlands. Possibly introduced in the 1940s.
[1]*Origanum* sp. probably *O. vulgare.* Oregano (Orégano) was much used by the Ecuadorian settlers. Probably an early introduction, found in the highlands of all the inhabited islands in the 1940s and 1960s.
[2]*Rosmarinus officinalis* L. Rosemary (Romero) was probably introduced in the 1940s and was found to a limited extent in the Santa Cruz highlands.
[2]*Salvia officinalis* L. Sage (Salvia) was introduced in the 1940s, and was found to a limited extent in the Santa Cruz highlands.
[2]*Thymus vulgaris*. L. The European herb Common Thyme (Tomillo) was grown in the Santa Cruz highlands by a few of the farmers. Probably introduced in the 1940s.

Lauraceae
[2]*Laurus nobilis* L. My father and his partner Wold had a bush of Sweet Bay (Laurel) in their vegetable garden. It is the only one I have seen in the islands. However, some of the other Norwegians may have grown this species, as it is used in Norwegian cooking. Introduced in the 1940s.
[1]*Persea americana* Mill. Avocado (Aguacate) was found on all the inhabited islands. Particularly abundant on Santa Cruz, where the Norwegian settlers planted it along the borders of their farms, thus causing it to spread far beyond what was the case on the other islands. There was a stand of this tree in the highlands of Santiago, which originated when a group of men went inland, probably to hunt for tortoises, in the 1920s. One of them, the Colombian César Moncayo, told me that they had eaten avocados, and that he planted the seeds. The wood is excellent for cabinet making, but I have never heard of it being used in the Galapagos.

Malvaceae
[2]*Abelmoschus esculentus* (L.) Moench. Okra (Quingombó) was grown by a few of the Norwegians in the Santa Cruz highlands. It was introduced in the 1940s, but never became popular.
[1]*Hibiscus rosa-sinensis* L. Hibiscus (Peregrina) was grown in the highlands of Santa Cruz and San Cristóbal and was seen occasionally in lowland gardens, especially in Puerto Baquerizo, where plenty of fresh water was available all year. This hardy species may have escaped cultivation in some places, as it would grow tall and bend over, its upper branches touching the soil and rooting there.
[1]*H. rosa-sinensis* var. *schizopetalus* Dyer. The same that is stated for the previous variety may be said for this one. There was a very large plant which produced abundant flowers every day, under my parents' bedroom window while we lived in the Ræder house in Puerto Ayora in 1936–7. This later became the port captain's residence. The specimen had been planted in 1931.
[1]*H. tiliaceus* L. The Cuban Bast (Majagua), grows wild along the coast in some parts of Galapagos. It was found in Pelican Bay (Santa Cruz), there was a small group of trees beyond the naval compound of Puerto Baquerizo, and I found a dense group above a steep beach at Point Essex (SW Isabela) in 1959. Below the trees, in the sandy soil, a couple of inches below the surface, there was excellent water, only very slightly brackish. The only instance I know of this tree being cultivated in the Galapagos was a small stand on the Graffer farm, in the Santa Cruz highlands. They had been planted in the 1930s to make use of the bark fibre.

Meliaceae
[2]*Cedrela odorata* L. The Cuban Cedar was introduced during the second half of the 1940s. During a visit to Santa Cruz, one of the sons of the Danish consul in Guayaquil, Emilio Holst, promised to send out seedlings and seeds of this species. His father, Dr Pedro Holst, and Mr von Buchwald, a long time German resident of Ecuador, had been promoting this tree during the previous years. There was another introduction in the same decade, made by Captain Castro.
[2]*Melia azederach* L. Chinaberry was introduced in 1938 with seeds brought from the Far East by my uncle, John Jacob Lundh, known among the Santa Cruz Norwegians

as "China-Lundh" because of his many years in the Far East. He brought a number of seeds of other species, but I am not certain which, or if they were successful.
[2]*Swietenia macrophylla* King. Mahogany (Caoba) was introduced in the 1940s.

Mimosaceae
[1]*Inga edulis* Mart. It was called "Huaba de mico" because of its terete pods that are reminiscent of a monkey's tail. This early introduction was never abundant on Santa Cruz and is used as shade for coffee on San Cristóbal.
[1]*I. spectabilis* (Vahl) Willd. Called "Huaba de machete" because of its flat pods. It is an early introduction found in the highlands of all the inhabited islands. It was common on Santa Cruz and even more so on San Cristóbal, where it is much used as shade for coffee.

Moraceae
[1]*Artocarpus altilis* (Parkinson) Fosberg. Breadfruit (Arbol de pan) was found occasionally on farms in the highlands of Santa Cruz and San Cristóbal. It was introduced to Santa Cruz in the late 1930s by Captain Castro, but seems to have existed much earlier on San Cristóbal.
[1]*Ficus carica* L. Fig (Higuera) was probably a very early introduction. It was found in the 1930s on all the inhabited islands, and occasionally in the lowlands of Santa Cruz and San Cristóbal. There was, in 1937, a very large tree on the Ræder property in Puerto Ayora, which may have been planted when they arrived in 1931.

Musaceae
[1]*Heliconia* sp. In the 1960s there was a dense thicket of Balisier (Platanillo) near the trail in the SE corner of Moe's property. When I first saw it in 1946, it looked as if it had been there for many years. Nobody could tell how it got there.
[1]*Musa* spp. The section *Eumusa*, which includes most of the cultivated bananas, is a taxonomically difficult group that no longer can be fitted into the former *M. paradisiaca* and *M. sapientum*. According to Champion (1968) and Purseglove (1972), most cultivars are descended from *M. acuminata* Colla and *M. balbisiana* Colla. The most common Banana (Guineo) variety grown in the Galapagos highlands was the excellent "Gros Michel" which no longer dominates the world market because it has been displaced by varieties that are more resistant to diseases. On Santa Cruz we also had two other varieties, the "Red" and a mutation derived from it called "Green Red". Neither was grown in quantity. Plantains were an important food on all the inhabited islands. Several varieties were grown, the most common being one called "Dominico". The Lady's Finger Banana (Orito), a diploid hybrid of *M. acuminata* and *M. balbisiana*, was well established on Santa Cruz by the 1940s and grown in limited amounts San Cristóbal.

Myrtaceae
[2]*Eucalyptus globulus* Labill. My father and his partner Wold planted several seeds of Tasmanian Blue Gum (Eucalipto), which I had sent them from Quito in 1939. The results were poor, and only one seedling prospered, turning into a scrawny tree that never amounted to anything much. The earliest *Eucalyptus* introduction in Ecuador was this species, in the second half of the 19th century.
[2]*Eucalyptus* sp. There were a few tall, beautiful eucalypts at the Lundberg property, obviously of a different species, which Gloria Lundberg told me her parents had planted from seeds received from friends in California in the 1930s.
[1]*Psidium guajava* L. Guava (Guayaba) has been introduced into most parts of the tropics, and with different results. It has been declared a noxious weed in Fiji. After the French took possession of Tahiti in 1844, they initiated a long and costly campaign to rid the island of this introduced plant, which had taken over much of the low land, where nearly all agriculture was carried out. The tree was introduced on San Cristóbal in the late 1800s, when Manuel J. Cobos brought out three small plants for his garden in Progreso. By the 1920s it was considered a serious problem by his heirs to the sugar plantation. Its spread to Floreana may have been caused by the animals brought over by the Norwegians in the 1920s and by Baroness von Wagner in the early 1930s. The Santa Cruz settlers, both Norwegians and Ecuadorians, were afraid to have the plant on their island, and killed any that looked remotely like it. However, the increase of colonization in the 1950s and later brought out people who were unaware of the danger, and now Guava is found on both Santa Cruz and Isabela. The wood makes very good firewood and may be a suitable source of charcoal, but is not much exploited in Galapagos.
[1]*Syzygium jambos* (L.) Alston. Rose-apples (Pomarosa) grew in the Santa Cruz highlands in the 1940s, but were not abundant. Very common in the San Cristóbal highlands, where it was found forming small groups in the guava forests in the 1950s and 1960s. Stakes from this tree were used for fencing, much in the same way as with *Jatropha curcas*, as they root easily in the moist soil.
[1]*S. malaccense* (L.) Merr. & L.M. Perry. Pomerac (Pera noruega) was common in the San Cristóbal highlands, but less so in the 1960s than *S. jambos*. It was also widely used for fence posts. The current local name which means "Norwegian Pear" seems to have been a later development.

Passifloraceae
[1]*Passiflora ligularis* Juss. Sweet Granadilla (Granadilla) has been grown on San Cristóbal and Santa Cruz since early times, but never in large quantities.
[2]*P. quadrangularis* L. Giant Granadilla (Badea) was introduced in the Santa Cruz highlands in the 1930s.

Poaceae
[1]*Coix lacryma-jobi* L. In the 1960s Job's Tears (Lágrimas de Moisés) was found occasionally along brooks in the highlands of San Cristóbal. Possibly an early introduction.
[1]*Cymbopogon citratus* (DC.) Stapf. Lemon Grass (Yerba Luisa) was grown in the highlands of all the inhabited islands,

and was much used for infusions. I have seen it growing near the coast only in Pelican Bay, Santa Cruz, where a clump grew in moist soil under some Manchineel trees.
[2]*Cynodon dactylon* (L.) Pers. Bermuda Grass (Bermuda) was found growing at the entrance to the Horneman farm, in the Santa Cruz highlands, in the 1940s. It had been introduced earlier in that decade.
[3]*Digitaria eriantha* Steud. Pangola was introduced in the 1960s, and first planted in the Santa Rosa area by Robert Schiess, from some cuttings I got him from Guayaquil.
[2]*Guadua angustifolia* Kunth. Giant Bamboo (Caña guadua) was imported as split bamboo from Guayaquil since the earliest colony. As late as the 1950s there was still a large two-storied bamboo building in Puerto Baquerizo (San Cristóbal) that had been built at the time of Manuel J. Cobos. The first floor was used to store coffee and sugar for shipment to Guayaquil. The upper floor served as living quarters. No bamboo was grown on the islands until its introduction on Santa Cruz in the 1940s. Several species were tried, one of them being eliminated early because it spread rapidly and had large spines. The only species that still survived in the 1960s was *G. angustifolia* as it was considered the most useful. In the 1960s I found a stand of this species in the San Cristóbal highlands, on the south side of the mountains, near a brook on the farm of León Buenaño. He may have got plants from Augustina Buenaño, his sister, who lived on Santa Cruz.
[1]*Panicum maximum* Jacq. Guinea Grass (Saboya) was common in the Santa Cruz highlands well into the 1950s. It was not as popular as Pará Grass because the animals liked it only when it was tender.
[3]*Pennisetum purpureum* Schumach. Elephant Grass (Hierba Elefante) was introduced at the end of the 1950s or beginning of the 1960s. Much of its popularity is due to the ease with which it spreads, a characteristic that should have warned the farmers that it might go out of control.
[1]*Saccharum officinarum* L. Sugar Cane (Caña de azúcar) is among the earliest introductions and was found at Santa Rosa and Salasaca in the western highlands of Santa Cruz. It was grown on all the inhabited islands, being often used to make moonshine rum and, occasionally, syrup.
[1]*Urochloa mutica* (Forssk.) T.Q. Nguyen. Pará Grass (locally known as Janeiro) was supposedly introduced from the coastal lowlands around Guayaquil. In the 1940s it was the preferred pasture on Santa Cruz, remaining so until the end of the 1950s, when Elephant Grass was introduced.
[1]*Zea mays* L. Indian Corn (Maiz) was the only cereal grown in Galapagos and was cultivated in the highlands since the days of the first colony, in 1832. All the farmers on the inhabited islands grew this crop, which was used from the moment the young cobs were full enough to be eaten as sweet corn, until they were dry and mature. The latter were used mostly to feed poultry.

Punicaceae

[2]*Punica granatum* L. Pomegranate (Granada) was produced in limited quantities in the Santa Cruz highlands. Probably introduced in the 1930s. The fruits are much smaller in Galapagos than those found in the Mediterranean countries.

Rosaceae

[1]*Eriobotrya japonica* (Thunb.) Lindl. Loquat (Nispero) is often found in gardens around Guayaquil, but was not very common in the Galapagos. In the 1940s it was found in the highlands of both Santa Cruz and San Cristóbal, sometimes wild on the latter. There were a few trees by the road, across from the Progreso cemetery, which still existed in the 1960s. Possibly an early introduction.

Rubiaceae

[2]*Cinchona pubescens* Vahl. Introduced by Captain Castro in the 1940s as a possible income for the farmers on Santa Cruz, though it is rather difficult to extract the quinine from this species, which has a low content of the drug. A second introduction was made during the same decade, attributed to Karl Angermeyer, who got some seeds he distributed to several farmers. The species had not spread much in the 1950s and was not thought of as a potential problem. The wood is said to be excellent for cabinet making.
[1]*Coffea arabica* L. Seems to be a very early introduction on Floreana and San Cristóbal. There was Coffee (Café) already growing in the Santa Cruz highlands when Horneman cleared considerable areas, planting a large number of seedlings in 1932. The other Norwegians made jokes about there being a Horniman's tea (a popular brand in Ecuador at that time) and that there soon would be a Horneman's coffee. It has been grown as a cash crop on all the inhabited islands since early colonization. During the severe drought in the warm season of 1933–4, nearly all the coffee on Floreana died, and new plants were brought over from Santa Cruz by the Norwegian Arthur Worm-Müller for his friend Dr Friedrich Ritter.

Rutaceae

[1]*Citrus* x *aurantiifolia* (Christm.) Swingle. The Lime (Limón) is very popular in Ecuador, and is certainly an early introduction. It was found at Santa Rosa and Salasaca and has been grown from the earliest times on all the inhabited islands. The species is found wild on San Cristóbal, and even in greater quantities in the highlands of Floreana.
[1]*C.* x *aurantium* L. Seville Orange (Naranja agria) was found wild on Floreana, growing scattered in semi-arid areas of the interior, where I saw it in the 1960s. It was probably introduced by the first settlers. I have never seen it on the other islands.
[1]*C.* x *limon* (L.) Osbeck. Lemon (Limón) was grown in the highlands of all the inhabited islands from the earliest times, though never in the same quantities as the much more popular *C.* x *aurantifolia*.
[2]*C. medica* L. The Hornemans and Rambechs had a very few trees of Citron (Cidra) in the Santa Cruz highlands, grown from seeds brought out in the 1930s.

[2]*C.* x *paradisi* Macfad. Grapefruit (Toronja) was grown in the highlands of Santa Cruz, San Cristóbal and Isabela in small quantities. It seems to be of later introduction than the other fruits of this group.
[1]*C. reticulata* Blanco. Mandarin (Mandarina) was introduced to the islands early and was, in the 1940s, found in the highlands of all the inhabited islands.
[1]*C.* x *sinensis* (L.) Osbeck. Sweet Orange (Naranja) was found at Santa Rosa and Salasaca, and has been grown in the highlands of all the inhabited islands since early colonization. It was found on all the Santa Cruz farms, but had already in 1946 been attacked by a scale insect, reputedly introduced from Panama via Baltra during the war. This is likely, for this insect was not found on the other islands at the time. The oranges were finally wiped out on Santa Cruz, giving origin to their importation from San Cristóbal from the end of the 1950s. Oranges have been growing wild on Floreana since the days of the first colony, and are also found wild in the San Cristóbal highlands. They were also abundant on Isabela.
[3]*Fortunella japonica* (Thunb.) Swingle. Carlos Kübler had a small bush of what seems to have been the round-fruited Marumi Kumquat (Naranja china) on his property in Puerto Ayora, planted from seeds imported in the 1950s. It was fruiting in the 1960s.

Sapotaceae
[2]*Chrysophyllum argenteum* Jacq. *panamense* (Pittier) T.D. Penn. In 1946 I found Smooth Star Apple (Caimito), with purple fruits, on the Horneman property, in the Santa Cruz highlands. As far as I know, this was the only tree of the species in Galapagos. It had been planted with seeds brought out from Guayaquil in the 1930s.
[2]*C. cainito* L. One tree of Star Apple (Caimito), with yellowish green fruits, was also present on the Horneman property in 1946, apparently also the only tree of the species in Galapagos, and planted at the same time as *C. argenteum*, with seed brought from Guayaquil in the 1930s.

Solanaceae
[1]*Brugmansia* x *candida* Pers. Angel's Trumpet (Floripondio) was found occasionally in gardens on all the inhabited islands, and sometimes even grown in the lowlands, as in Puerto Baquerizo.
[1]*Capsicum annuum* L. Sweet Peppers (Pimentón), var. "*grossum*" Sendt, have been cultivated since early times in the Galapagos highlands, on all the inhabited islands.
[1]*C. frutescens* L. Chili Peppers (Ají) in several varieties were grown in the highlands of all the inhabited islands. There was a small variety that was often found wild along trails and in open locations in the moist region. It was found on Santa Cruz, San Cristóbal and Floreana. Undoubtedly planted by the first colonists, as it is a traditional ingredient from pre-Columbian times.
[1]*Nicotiana tabacum* L. Tobacco was planted very early in the islands, and is likely to have been first introduced on Floreana with the first colony, in the 1830s. It was planted mainly for domestic consumption. Some settlers claimed it had escaped from cultivation, though the only wild tobacco I have seen were a few scattered plants of *N. glutinosa* L. in a semiarid area inland on Floreana, in the 1960s.
[2]*Petunia hybrida* Vilm. Occasional in highland gardens on Santa Cruz. Possibly introduced in the 1940s or earlier.
[2]*Solanum betaceum* Cav. Tree Tomato (Tomate serrano) was imported to Santa Cruz in the 1930s by some of the Norwegians, who used it as a substitute for apricots in preserves and pies. I have only seen it on Santa Cruz.
[1]*S. lycopersicum* L. Tomato (Tomate) was grown occasionally in the 1940s and 1950s on all the inhabited islands. The fruit rots very often in the highlands, as a drop of water remains permanently in the lower part of the fruit during the *garúa* season, on account of the constant drizzle. In the 1960s, I produced excellent tomatoes in Puerto Baquerizo with irrigation.
[2]*S. melongena* L. Aubergine (Berenjena) was probably introduced in the 1940s. The only plants I have seen in the islands were on the farms of the Norwegians in the Santa Cruz highlands.
[1]*S. quitoense* Lam. Since the 1940s, Naranjilla was grown in the highlands of all the inhabited islands. Probably a very early introduction. The presence of a few plants at the rim of the main crater on Santiago is not necessarily evidence for colonization there. Farming at that location would not be advisable, there being much better areas lower down, and it is likely that seeds were brought in the intestines of some tortoise hunter or other visitor.
[1]*S. tuberosum* L. Potatoes (Papa) were grown in the highlands of all the inhabited islands, especially on Santa Cruz, where they were produced in large quantities by the Kastdalen family in the 1950s. It has been claimed (*e.g.* Hoff 1985) that the Kastdalens produced "Norwegian" potatoes, but this is an error. Potatoes brought from Norway were planted by Anders Rambech at Fortuna (above Bellavista) in 1926, but the farming area was abandoned in 1927 and remained so for some time. Later plantings were made using mainly the Ecuadorian Papa chola, which is excellent. During the war, the Idaho Potato was introduced and displaced all prior varieties. I purchased a ton of Potatoes from Kastdalen in 1954, and they were all big, pale Idaho Potatoes.

Tropaeolaceae
[1]*Tropaeoleum majus* L. A small thicket of Nasturtiums (Capuchina) existed for many years in the open area at the entrance to the Rambech farm in the Santa Cruz highlands. Nobody could give a satisfactory explanation for their presence there, and as the farm began in 1935 it may have been an early introduction. This species was otherwise occasional in gardens. I can recall seeing it only in the Santa Cruz highlands.

Vitaceae
[1]*Vitis vinifera* L. Grapes (Uva) were grown on Santa Cruz and San Cristóbal in the 1960s, with varying degrees of

success. They did not do well in the highlands, but near the seashore, with irrigation, the vines grew well and fruited. The greatest production was obtained by Adolfo Haeni, in Pelican Bay. Carlos Kübler had a few vines in his property near the old landing in the Laguna de las Ninfas. I managed to produce some Muscatel Grapes in Puerto Baquerizo. Unfortunately, we left when they were bearing their first fruit, in 1965. This plant was introduced in the 19th century to Floreana (Robinson 1902), but there was no evidence for its presence there when I was in the islands.

DISCUSSION

The development of Galapagos agriculture may be divided into the following three phases.

Early colonization

This period started with the first colony, established in 1832, on Floreana. During this period, the commoner basic crop species still used today were introduced. This period extends to the 1930s, when the introduction of new cultivated species began. The only significant change in agriculture before the 1930s took place with the creation by Manuel J. Cobos of a sugar plantation on San Cristóbal in the 1860s, which was in production into the early 1930s.

There were, during this early period, several attempts at colonization, such as that made by José Valdizán on Floreana (1870–8), ending in failure, and that of Antonio Gil on Isabela (1897) which has survived until our days. Both these gentlemen were mainly concerned with the exploitation of tortoise oil, cattle and archil, rather than agriculture.

On 10 August 1925, a Norwegian settlement was established at Post Office Bay, Floreana. These men found an abandoned farm in the highlands with some useful plants. This had been a subsistence farm set up by cattle hunters left on the island by a Chilean sea captain the previous year. There are no records as to what, if anything, was planted by the Norwegians, and they soon left.

The following year, another Norwegian group set up the cannery in Academy Bay, Santa Cruz (Lundh 1996). When they arrived, there were a few Ecuadorians and the Mexican, Felipe Lastre, living in the highlands. Lastre had arrived about 1910, and one of the Ecuadorians, Elías Sánchez, had been there since 1917, while the others had lived there only since 1926, to look after some cattle that had been landed on the island for a Guayaquil businessman, Amador-Baquerizo. These people had been growing the products that then were usual in the islands, and their plantings were later used by the Norwegians, one of them the horticulturist Rambech. He started growing some European vegetables at Fortuna, above what is now called Bellavista (see under *Brassica oleracea capitata* above). This colony also broke up and only two of its members, Wold and Stampa, remained on the island. Since they were engaged mainly in fishing, their farms in the highlands remained more or less abandoned.

Later in 1926, another group of Norwegians arrived to San Cristóbal, most settling in the highlands. Of these, only two families remained on the island, after being successful at growing the plants that were used by the local people. Several others moved to Santa Cruz, devoting themselves to fishing the short time they were there.

These early Norwegian colonization projects thus had no lasting effect on Galapagos agriculture, and the assortment of plants grown on the islands remained mainly the same as in the first colony. The 73 species that we may count as early, and a further 17 that were possibly early introductions, not only made up the greater part of what would be grown by later settlers, but formed a very important part of their diet.

The 1930s and 1940s

During this period, when the next group of Norwegians arrived, the variety of vegetables and fruits increased considerably, as most of these people settled in the highlands, becoming full time farmers. However, this increase took place on Santa Cruz, with little if any effect on the other inhabited islands. Individuals such as Captain Castro and the Norwegian settlers were willing to try anything new, even if circumstances were then such that these plants had no commercial possibilities in the islands.

During the 1930s there was an increase in the population of Santa Cruz with the return of two of the earliest settlers and of Horneman, who had first arrived in 1927. These were followed by a number of new Norwegian settlers and a few other Europeans. In 1937 a military garrison was established on the island, Captain Castro and his numerous family arrived, and Captain Lundh decided to become a permanent settler.

The Norwegians actively introduced new cultivated plants, an activity which Captain Castro also took up with enthusiasm. This activity greatly increased in the 1940s, with the help of Captain Østrem. He had been captain on a California tuna clipper in the 1930s and not only knew the islands well, but had befriended Captain Lundh and Wold in 1932, when they had met at Marchena.

In the 1930s and 1940s, I found 55 new plants growing, almost all of them on the farms in the Santa Cruz highlands, and most on the properties of the Norwegians and Captain Castro, who were the only people with great interest in growing these new products. There could have been more that have been missed in this article, either because they had been discontinued by the time I became familiar with the farming on the island, or because I have forgotten them because they were not prominent in our diet.

A similar development was absent on the other inhabited islands, if we except the limited introduction of Tung and Andean Walnut on San Cristóbal.

Cattle raising

Later, fewer introductions were made, the main ones being Elephant Grass, introduced in the late 1950s, and Pangola Grass, introduced in the 1960s.

Towards the second half of the 1950s an experimental agricultural station was established by the government on San Cristóbal. All the products they tried, as far as I know, had already been tried during earlier years in the Santa Cruz highlands. There seemed to be no interest among the settlers on San Cristóbal to make changes in their agriculture, and this seems to have been the case with most other settlers in Galápagos, including most of those on Santa Cruz. We can therefore observe a decline in the variety of vegetables grown on this last island after the disappearance of the Norwegian farmers and Captain Castro. The increased interest in raising cattle may also have had something to do with it.

Raising cattle had been an important activity on both San Cristóbal and Isabela since the early years of settlement. However, on Santa Cruz agriculture was the main activity. In the 1950s, the Kastdalens imported a male Holstein-Friesian calf from Panama. When it became old enough, it was crossed with local wild cattle, with excellent results. But it was not until the following decade that a general interest in raising cattle took hold on the Santa Cruz farmers. They had seen how cattle shipments from Isabela and San Cristóbal had increased with improved communications with Guayaquil, where there has always been a good market for beef. The raising of cattle for export to the mainland developed steadily from the middle of the 1960s, and my brother, Captain Eric Lundh, who visited Santa Cruz after many years in the 1980s, told me how great areas in the highlands had been deforested to plant pasture for the animals, and that some of his favourite former pig- and cattle-hunting areas were under grass.

LITERATURE CITED

Andersson, N.J. 1858. Om Galapagos-öarnes vegetation. Kongliga Svenska fregatten Eugenies resa omkring jorden, 1851–1853. *Kongliga Svenska Vetenskaps-Akadamien Handlingen Botanik* 1: 1–256.

Champion, J. 1968. *El Plátano.* Blume, Barcelona.

Darwin, C.R. 1839. *The Voyage of the Beagle*. J.M. Dent & Sons, London.

Jørgensen, P.M. and León-Yánez, S. (eds) 1999. Catalogue of the Vascular Plants of Ecuador. *Monographs in Systematic Botany from the Missouri Botanical Garden*. 75.

Lundh, J.P. 1995. A brief account of some early inhabitants of Santa Cruz Island. *Noticias de Galápagos* 55: 2–3.

Lundh, J.P. 1996. The Colonia de Santa Cruz of 1926. *Noticias de Galápagos* 57: 21.

Purseglove, J.W. 1972. *Tropical Crops. Monocotyledons*. Longman, London.

Robinson, B.L. (1902) Flora of the Galapagos Islands. *Proceedings of the American Academy of Arts and Sciences* 38: 79–270.

Stewart, A. 1911. Expedition of the California Academy of Sciences to the Galápagos Islands, 1905–1906. II. A botanical survey of the Galápagos Islands. *Proceedings of the California Academy of Sciences* 1: 7–288.

Stewart, A. 1915. Some observations concerning the botanical conditions on the Galapagos islands. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 18: 272–340.

Tye, A. 2006. Can we infer island introduction and naturalization rates from inventory data? Evidence from introduced plants in Galapagos. *Biological Invasions* 8: 201–215.

POLLEN MORPHOLOGY OF THE GALAPAGOS ENDEMIC GENUS *SCALESIA* (ASTERACEAE)

By: P. Jaramillo[1] & M.M. Trigo[2]

[1]Department of Botany, Charles Darwin Research Station, Isla Santa Cruz, Galapagos, Ecuador. <pattyj@fcdarwin.org.ec>
[2]Department of Plant Biology, University of Malaga, P.O. Box 59, E-29080 Malaga, Spain. <aerox@uma.es>

SUMMARY

Pollen grains from herbarium specimens of 22 taxa of the genus *Scalesia* Arn. (Asteraceae, Heliantheae) were examined by scanning electron and light microscopy. *Scalesia* present trizonocolporate, isopolar, radiosymmetric pollen grains, which are medium sized, oblate-spheroidal to prolate-spheroidal, circular in polar view and from circular to slightly elliptic in equatorial view. The exine is thick (*c.* 5–7 μm), with long, acute, conical echinae to 10 μm as supratectal elements.

RESUMEN

Morfología del polen de *Scalesia* (Asteraceae), género endémico de Galápagos. Se examinaron granos de polen tomados de muestras de herbario de 22 taxa pertenecientes al género *Scalesia* Arn. (Asteraceae, Heliantheae), con el microcopio óptico y el microscopio electrónico de barrido. *Scalesia* presenta granos de polen trizonocolporados, isopolares y radiosimétricos. Son de tamaño medio, de oblado-esferoidales a prolado-esferoidales, de contorno circular en vista polar y de circular a ligeramente elípticos en vista ecuatorial. La exina es gruesa (*c.* 5–7 μm), presentando espinas cónicas y agudas de hasta 10 μm de largo como elementos supratectales.

INTRODUCTION

Galapagos is a large and complex archipelago of volcanic islands located on the equator, *c.* 800–1000 km west of the S American coast of Ecuador. They include over 120 islands, islets and rocks that bear terrestrial vegetation. There are about 500 native plant species in the islands, with *c.* 260 endemic taxa (including infraspecies). In the Asteraceae there are 20 autochthonous genera in Galapagos (Eliasson 1974), four of them, *Darwiniothamnus*, *Lecocarpus*, *Macraea* and *Scalesia*, endemic to the islands (Wiggins & Porter 1971, Eliasson 1974, 1984, Adsersen 1980, Lawesson & Adsersen 1987).

Scalesia Arn. (Heliantheae, subtribe Verbesininae) is the largest and most diverse of the four and is present on most of the larger islands where the different species show allopatric distributions (Wiggins & Porter 1971) (Fig. 1). The genus comprises 15 species and 20 taxa including subspecies and varieties (Eliasson 1974), twelve of which are shrubs and three are trees. Some are rare and endangered (Tye 2000 and in press). In general, the habit of the genus is heliophilous and pioneer, growing at all altitudes from sea level to 1700 m, from the lowest semi-arid to the highest humid zones of the islands.

MATERIAL AND METHODS

We used pollen obtained from plant specimens deposited in the Charles Darwin Research Station Herbarium (CDS), Galapagos, Ecuador. The pollen grains were acetolysed following the method of Erdtman (1960) and Kearns & Inouye (1993), mounted in glycerine jelly for light microscopy (LM). For scanning electron microscopy (SEM) the pollen after being acetolysed was mounted on cover slips previously attached to aluminium stubs with silver paint, then coated with evaporated gold by ion sputtering and examined with a JEOL JSM 840 microscope. Measurements were made with the light microscope on a minimum of 25 pollen grains per sample (see Appendix for list of samples). The light-microscope slides (four duplicates) were de-posited in the pollen collection at CDS and the Department of Plant Biology of the University of Malaga, Spain (MGC). The terminology used for descriptions follows Punt *et al*. (1994).

Scalesia pedunculata var. *parviflora* was excluded because the taxon is of dubious value and the sample was poor with few pollen grains in equatorial view; nevertheless, the measurements obtained were included with those of var. *pedunculata*.

RESULTS

Scalesia is a stenopalynous genus (Fig. 2) with little variation between species, these differences being mainly in size.

Pollen type is trizonocolporate, isopolar and radiosymmetric. Shape is more or less circular in polar view, with the colpi slightly intruding, from circular to slightly elliptical in equatorial view. Polar axis (P) = 21–32 μm; equatorial axis (E) = 21.5–32 μm, excluding echinae. P/E

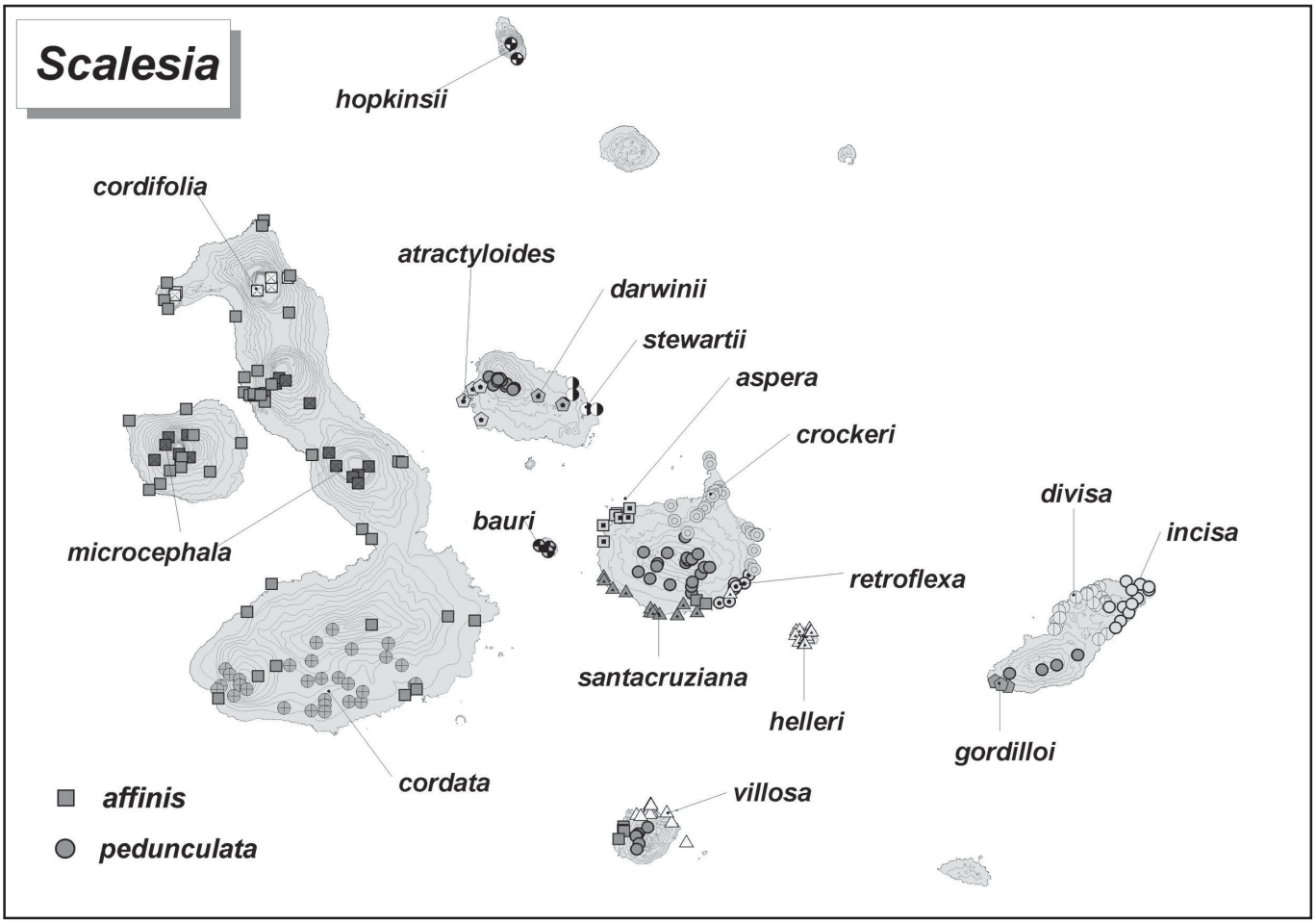


Figure 1. Distribution of the different species of *Scalesia.*

ratio = 0.90–1.12, from oblate-spheroidal to prolate-spheroidal. Ectoaperture is a subterminal acute colpus tapering towards the ends and with distinct margins; mesoaperture is lolongate (parallel to the colpus), conspicuous only in SEM, endoaperture is lalongate (perpendicular to the colpus), with acute ends and generally centrally constricted. The apertural membrane is granulated. Exine is thick, 2.5–4 μm normally, but sometimes thicker. Sexine is 1–3 times as thick as nexine, sometimes spanning a small cavea, nexine forming costae at the level of the endoapertures. Ornamentation is echinate; the echinae are generally straight but sometimes slightly bent, 2.5–7.5 μm long, acute at the apex, with conical base. Tectum is perforated, especially at the bases of the echinae. Measurements of the different species can be seen in Table 1 and Fig. 3.

DISCUSSION

Scalesia is not well studied from a palynological point of view; in fact there are few such studies of the subtribe Verbesininae. The only study of *Scalesia* pollen morphology is that by Takahashi (1990), in which two species, *S. affinis* and *S. baurii* were studied. The present paper is the first in which all the species and infraspecific taxa of this genus are studied.

Heliantheae is a stenopalynous taxon whose pollen grains present a characteristic exine morphology called "helianthoid type" by Stix (1960). The structural pattern consisting of caveate exine with internal foramina was called "helianthoid pattern" by Skvarla & Turner (1966). These characteristics are shared with other tribes of Asteraceae such as Eupatorieae, Astereae, Helenieae, Calenduleae, Inuleae and Senecioneae and less so in Anthemideae (Skvarla & al. 1977).

The pollen morphology of Scalesia does not differ from that described for other genera of the tribe, and few differences can be observed between the species of *Scalesia* regarding pollen size, spine length and density, and the foramina situated at the spine bases. These features can vary within a species, such that the measurements of the different taxa overlap (Fig. 3) and pollen morphology is not useful for the taxonomy of the group. Nevertheless, some differences can be observed. The pollen grains of S. *microcephala* ssp. *microcephala* together with those of *S. helleri* ssp. *helleri* and *S. cordata* were smaller, and the grains of *S. incisa*, *S. atractyloides* var. *darwinii*, *S. aspera* and *S. divisa* bigger. Spine length is variable, the shortest being those of *S.*

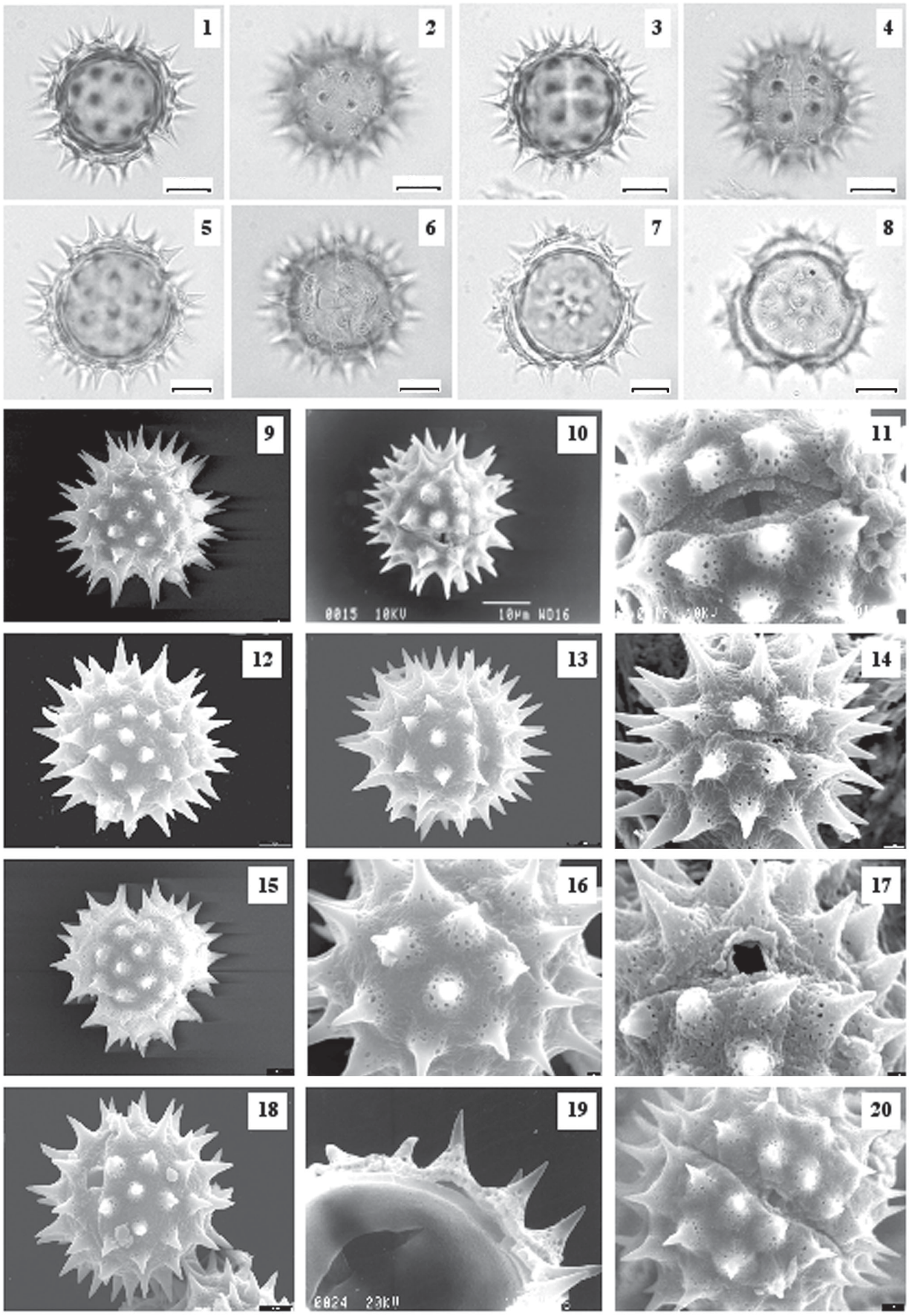


Figure 2. Pollen morphology of the genus *Scalesia*. 1–4: *S. atractyloides*. 5–6: *S. aspera*. 7–8: *S. gordilloi*. 9–11: *S. atractyloides*. 12–13: *S. helleri*. 14: *S. retroflexa*. 15, 19: *S. baurii*. 16–17: *S. microcephala*. 18: *S. stewartii*. 20: *S. pedunculata*. 1–8: LM, 9–20: SEM.

Table 1. Morphometrical analysis of *Scalesia* taxa pollen. P = polar axis. E = equatorial axis. All values in μm.

	P	E	P/E	Spines	Exine
S. affinis Hook. f.	25.5–27.5	24.5–27.5	1–1.03	5.5–7.5	3–4
S. aspera Andersson	28–32	27–32	1–1.03	4–6.5	3.5–4.5
S. atractyloides atractyloides Arn.	22.5–26.5	23–26.5	0.93–1	4.5–5.5	2.5–4
S. atractyloides darwinii (Hook. f.) Eliasson	28–31	28–31	1–1.03	5.5–7.5	3–3.5
S. bauri bauri B.L. Rob. & Greenm.	25–26.5	24–25.5	0.98–1.03	4.5–6.5	2.5–3
S. bauri hopkinsii (B.L. Rob.) Eliasson	24–31.5	23–29.5	1.01–1.12	4.5–5	2.5–3
S. cordata A. Stewart	22.5–25	21.5–24.5	0.95–1.04	4.5–5.5	2.5–3
S. crockeri Howell	24–28	24–26.5	1–1.09	3–6	3–4
S. divisa Andersson	28.5–30.5	28.5–30.5	0.96–1.03	5–6.5	4–5
S. divisa/incisa hybrids	24.5–26.5	24.5–28	0.94–1	4–5	3–4
S. gordilloi O.J. Hamann & Wium-And.	25.5–28	25.5–28.8	0.94–1	4	4.5–5.5
S. helleri helleri B.L. Rob.	21.5–23.5	23–25	0.90–0.96	4.5–5.5	3–3.5
S. helleri santacruziana Harling	23–28	24.5–27.5	0.95–1.06	4.5–6.5	2.5–3.5
S. incisa Hook. f.	27.5–29	29.5–31	0.92–0.97	5–6	4
S. microcephala microcephala B.L. Rob.	21–25.5	21.5–25.5	0.94–1	4–7.5	2–4
S. microcephala cordifolia Eliasson	23.5–25.5	23–26.5	0.97–1.05	5.5–6.5	3–3.5
S. pedunculata Hook. f.	23–28	24–28	0.94–1	4.5–5.5	2.5–4
S. retroflexa Hemsl.	22.5–26	21.5–26	0.97–1.04	5- 6.5	3–3.5
S. stewartii Riley	25–27.5	25.5 -27	0.98–1.03	4.5–6	3–3.5
S. villosa A. Stewart	23–26	22.5–26	0.94–1.11	2.5–3.5	3

villosa (2.5–3.5 μm) and the longest in *S. affinis*, *S. atractyloides* var. *darwinii*, and *S. incisa*, with length up to 7.5 μm. Exine thickness is also variable, from 2.5 to 5.5 μm, the last value reached by *S. gordilloi*. We found little difference in number and arrangement of spine base foramina using SEM, but these can vary from grain to grain even in the same sample. Transmission electron microscopy might reveal further differences.

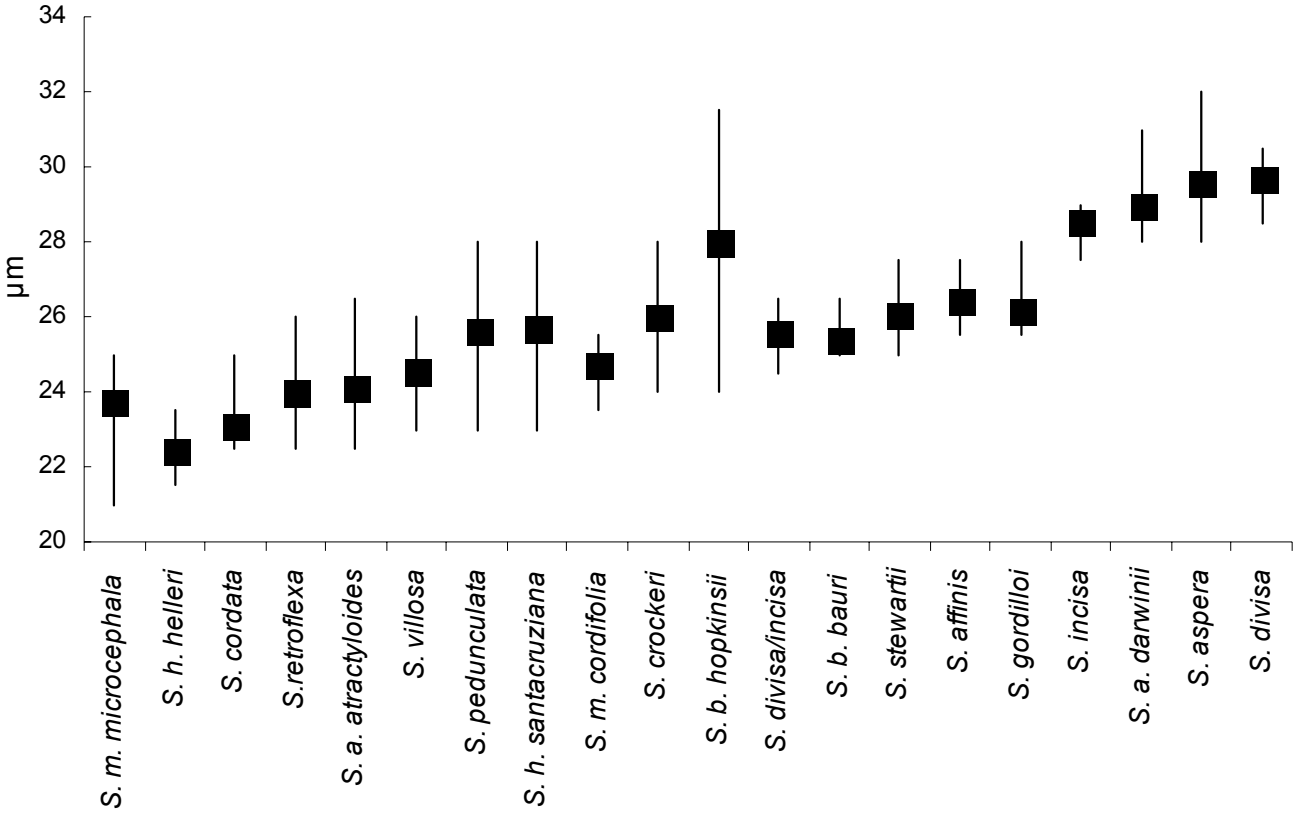


Figure 3. Measurements of the polar axis of *Scalesia* taxa (mean, with bars from minimum to maximum value) in order of minimum polar axis value.

Our results for S. *affinis* and S. *baurii* (sspp. *bauri* and *hopkinsii*) mostly coincide with those reported by Takahashi (1990) except that the size values given by this author for S. *affinis* from Floreana Island (P = 39 μm, E = 39–43 μm) are higher than those obtained by us for specimens from Fernandina and Isabela (P = 25.5–27.5 μm; E = 24.5–27.5 μm). These two populations have been separated as sspp. *affinis* and *gummifera* respectively. Takahashi (1990) reported some bent spines in this species; bent spines are common in *Scalesia* pollen, even coexisting with straight spines in the same sample or in the same pollen grain.

ACKNOWLEDGMENTS

We are especially grateful to Alan Tye and Baltasar Cabezudo, who gave us the opportunity to conduct this study, and to Julie Callebaut for the map. This is Contribution 1041 of the Charles Darwin Foundation.

LITERATURE CITED

Adsersen, H. 1980. Revision of the endemic Galapagos genus *Lecocarpus* (Asteraceae). *Botaniske Tidsskrifte* 75: 63–76.

Eliasson, U. 1974. Studies in Galapagos plants XIV. The genus *Scalesia*. *Opera Botanica* 36: 1–117.

Eliasson, U. 1984. Chromosome number of *Macraea laricifolia* Hooker fil. (Compositae) and its bearing on the taxonomic affinity of the genus. *Journal of the Linnaean Society, Botany* 88: 253–256.

Erdtman, G. 1960. The acetolysis method. A revised description. *Svensk Botanisk Tidskrifte* 54: 561–564.

Itow, S. 1995. Phytogeography and ecology of Scalesia (Compositae) endemic to the Galapagos Islands. *Pacific Science* 49: 17–30.

Kearns, C.A. & Inouye, D. 1993. *Techniques for Pollination Biologists*. Colorado University Press, Niwot, CO.

Lawesson, J.E. & Adsersen, H. 1987. Notes on the endemic genus *Darwiniothamnus* (Asteraceae, Astereae) from the Galapagos Islands (Ecuador). *Opera Botanica*: 7–16.

Lawesson, J.E., Adsersen, H. & Bentley, P. 1987. An annotated checklist of the vascular plants of the Galapagos Islands. Reports from the Botanical Institute, University of Aarhus 16.

Mauchamp, A. 1996. *Scalesia atractyloides*: one bite from extinction. *Noticias de Galápagos* 60: 24–25.

Punt, W., Blackmore, S., Nilsson, S. & Thomas, A. le. 1994. Glossary of pollen and spore terminology. LPP Contribution Series, 1. LPP Foundation. Utrecht.

Skvarla, J.J. & Turner, B.L. 1966. Systematic implications from electron microscopic studies of Compositae pollen—a review. *Annals of the Missouri Botanical Garden* 53: 220–256.

Skvarla, J.J., Turner, B.L., Varsha, C.P. & Spencer Tomb, A. 1977. Pollen morphology in the Compositae and in morphologically related families. *In* Heywood, V.H., Harborne, J.B. & Turner, B.L. (eds). *The Biology and Chemistry of the Compositae*, vol. 1: 141–248. Academic Press, London.

Stix, E. 1960. Pollenmorphologische untersuchungen an Compositen. *Grana Palynologica* 2: 41–104.

Takahashi, K. 1990. Pollen morphology of the woody Compositae of the Galapagos Island (I) Tribe Heliantheae: *Scalesia affinis* Hooker fil. and *S. baurii* Robinson & Greenman. In Chanda, S. (ed.). *Current Perspectives in Palynological Research. Journal of Palynology* 26–27: 113–122.

Tye, A. 2000. Galápagos species accounts. Through pp. 33–430 *in:* Valencia, R., Pitman, N., León-Yánez, S. & Jørgensen, P.M. (eds), *Libro Rojo de las Plantas Endémicas del Ecuador 2000*. Herbarium of the Pontificia Universidad Católica del Ecuador, Quito.

Tye, A. in press. Galapagos species accounts. *in:* León-Yánez, S. (ed), *Libro Rojo de las Plantas Endémicas del Ecuador*. Second edition. Herbarium of the Pontificia Universidad Católica del Ecuador, Quito.

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

APPENDIX: SPECIMENS EXAMINED

S. affinis. Isabela, Volcán Sierra Negra, Camino al Muro de las Lágrimas, Jaramillo & Guerrero, 21 Nov 1999 (CDS 9813); Fernandina, NE Cape Hammond, Adsersen, 17 Jun 1974 (CDS 1391).

S. aspera. Eden, Jaramillo & Coronel, 9 Nov 1999 (CDS 9666); Eden, Huttel, 19 May 1992 (CDS 7483).

S. atractyloides atractyloides. Santiago, Cabo Nepean, Jaramillo & Ramírez, 4 Jan 2001 (CDS 11587).

S. a. darwinii. Santiago, Aguilar, 5 Oct 1995 (CDS 6814); Santiago, Bahía Sullivan, Simbaña, 25 Apr 2001 (CDS 11871).

S. bauri bauri. Pinzón, Weber, 15 Feb 1970 (CDS 883).

S. b. hopkinsii. Pinta, McMullen, 2 Jul 1990 (CDS 7055); Wolf Island, Harris, 22 Feb 1971 (CDS 1031).

S. cordata. Isabela, Cerro Azul, Huttel, 21 Mar 1985 (CDS 4243).

S. crockeri. Santa Cruz, Cerro Colorado, Adsersen, 17 Jan 1998 (CDS 8934); Santa Cruz, Barranco del Canal de Itabaca, Huttel, 29 Oct 1984 (CDS 4336).

S. divisa. San Cristóbal, west side of Sappho Cove, Jäger & Tye, 6 Jun 2002 (CDS 13913).

S. divisa/incisa hybrids. San Cristóbal, entre Punto Pitt y Bahía Rosa Blanca, Tye & Jaramillo, 14 Apr 1999 (CDS 9474); San Cristóbal, entre Punta Pitt y Bahía Rosa Blanca, Tye & Jaramillo, 14 Apr 1999 (CDS 9472).

S. gordilloi. San Cristóbal, La Lobería, Hagemann, 15 Mar 1994 (CDS 6252); San Cristóbal, Camino a las Negritas, Jaramillo, 1 Apr 2002 (CDS 13006).

S. helleri helleri. Santa Fe, Barranco, Adsersen, 17 Jan 1998 (CDS 8931); Santa Cruz, Bahía Las Palmitas, Arsiniegas, 28 Apr 1995 (CDS 6789).

S. h. santacruziana. Santa Cruz, Cerro Gallina, Arsiniegas, 7 Sep 2000 (CDS 6784).

S. incisa. San Cristóbal, Tye & Jaramillo, 12 Apr 1999 (CDS 9467); San Cristóbal, entre punta Pitt y Bahía Rosa Blanca, Simbaña, 1 Feb 2001 (CDS 11860).

S. microcephala microcephala. Isabela, Volcan Darwin, Weber, 25 Nov 1969 (CDS 885); Isabela, Volcán Darwin, Aldaz, 15 Feb 1999 (CDS 9581); Isabela, Volcán Wolf, Aldaz & Robayo, 24 Aug 1999 (CDS 14005).

S. m. cordifolia. Isabela, Volcán Wolf, Weber, 15 Jan 1970 (CDS 887).

S. pedunculata. Floreana, Cerro Pajas, Perry, 21 Nov 1966 (CDS 634); Floreana, Lawesson, 11 Feb 1986 (CDS 4824).

S. p. pedunculata. Santa Cruz, Los Gemelos, Jaramillo & Ramírez, 16 Apr 2001 (CDS 11731).

S. pedunculata parviflora J.T. Howell. San Cristóbal, Cerro Pelado, Jaramillo, 23 Sep 1999 (CDS 9531).

S. retroflexa. Santa Cruz, near Punta Núñez, Adsersen, 13 Jan 1998 (CDS 8968).

S. stewartii. Santiago, Bahía Sullivan, Simbaña, 3 Mar 2000 (CDS 11033).

S. villosa. Floreana, Cerro Salinas, Adsersen, 19 Jan 1998 (CDS 8562).

INVASIVE PLANTS IN THE *SCALESIA PEDUNCULATA* FOREST AT LOS GEMELOS, SANTA CRUZ, GALAPAGOS

By: Jorge L. Rentería & Chris Buddenhagen

Botany Department, Charles Darwin Research Station, Santa Cruz, Galapagos <jrenteria@fcdarwin.org.ec>

SUMMARY

Volunteers were used to map invasive plants in 25 ha of one of the best remnants of *Scalesia pedunculata* forest at Los Gemelos, Santa Cruz Island, Galapagos. The most dominant invaders were the trees *Cestrum auriculatum*, *Cedrela odorata* and *Cinchona pubescens*, a vine *Passiflora edulis*, and the shrub *Rubus niveus*. Forest structure at the site suggests that further cyclical stand-level dieback, reportedly characteristic of *S. pedunculata* forests, is unlikely to occur in the near future. Although the invasion at Los Gemelos is continuous, we conclude that dieback provides extra opportunity for the establishment of invasive plants. Management is required to reduce invasive species impacts on the forest.

RESUMEN

Plantas invasoras en el bosque de *Scalesia pedunculata* de Los Gemelos, Santa Cruz, Galápagos. Con el trabajo de voluntarios, se realizó mapas de plantas invasoras presentes en 25 ha del mejor remanente del bosque de *Scalesia pedunculata* de Los Gemelos, Isla Santa Cruz, Galápagos. Las especies invasoras dominantes fueron las especies arbóreas *Cestrum auriculatum*, *Cedrela odorata* y *Cinchona pubescens*, la trepadora *Passiflora edulis* y la arbustiva *Rubus niveus*. La estructura del bosque en el sitio sugiere que un episodio de muerte regresiva, que se sugiere es característico del bosque de *S. pedunculata*, es improbable en el futuro próximo. Aunque la invasión en Los Gemelos es proceso continuo, se concluye que los eventos de muerte regresiva crean más oportunidad para el establecimiento de especies introducidas. Un manejo es requerido para reducir el impacto de las plantas invasoras en el bosque.

INTRODUCTION

Scalesia (Asteraceae) is a genus endemic to Galapagos comprising *c.* 20 taxa. The tree *Scalesia pedunculata* Hook. f. is the tallest of the genus reaching up to 15 m in height and 15 cm in trunk diameter (Wiggins & Porter 1971). It is found in the humid zone on four high-altitude Galapagos islands: San Cristóbal, Floreana, Santiago and Santa Cruz. It forms dense forests 400–600 m above sea level on Santa Cruz (Itow 1965, Hamann 1979, 2001). Soft wooded, it can grow to 4 m in its first year and 7 m in its second (Itow 1995) and can reach reproductive maturity within two years, though it is short lived, at 20–30 years (Hamann 1979). It experiences periodic stand-level dieback and regeneration (Hamann 2001), so the presence of larger long-lived invasive tree species in *S. pedunculata* forest on Santa Cruz could result in potentially catastrophic changes in forest structure if a further mass die-back event were to occur.

Serious threats to the *S. pedunculata* forests are the expansion of agricultural activities and competition with introduced plants on inhabited islands (Santa Cruz, San Cristóbal and Floreana), and goat and donkey browsing on Santiago Island (Snell *et al*. 2002). Invasive species and direct modification via land use are the biggest agents of human mediated change in the Galapagos terrestrial ecosystem. Settlement and agriculture are restricted to designated areas on the inhabited islands, and the rest of the land area is National Park. Invasive species have been deliberately planted and have spread more widely on their own, even to uninhabited islands. Worldwide, invasive species are regarded as the second biggest threat to biodiversity after direct modification through land use (Williamson 1999).

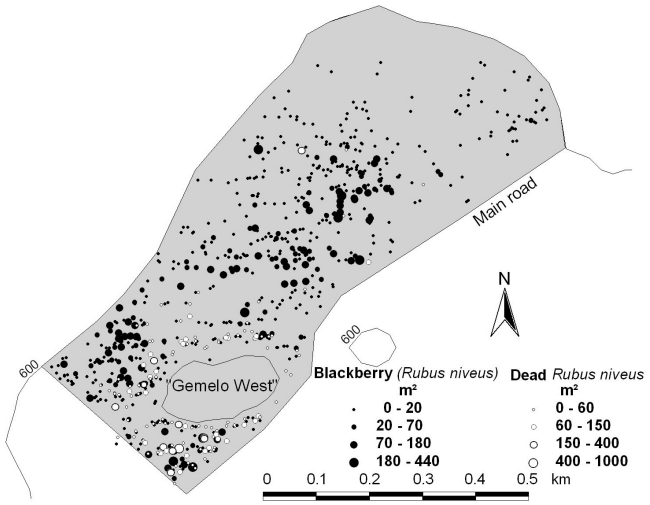
The biggest remnant of *S. pedunculata* forest is found on Santa Cruz, at the site Los Gemelos (*c.* 600 m above sea level). The forest extends over *c.* 140 ha and has been invaded by a number of introduced plant species including the trees Cuban Cedar *Cedrela odorata* L., Guava *Psidium guajava* L., Sauco *Cestrum auriculatum* L'Hér. and Quinine *Cinchona pubescens* Vahl, the shrub Hill Blackberry *Rubus niveus* Thunb., the passionfruit vine *Passiflora edulis* Sims. and the herbs *Tradescantia zebrina* hort. ex Bosse, *Hyptis pectinata* (L.) Doit., Elephant Grass *Pennisetum purpureum* Schumach., Guinea Grass *Panicum maximum* Jacq. and Molasses Grass *Melinis minutiflorus* P. Beauv. Hamann (2001) predicted that Cuban Cedar will replace *S. pedunculata* as the dominant species in the humid and transition vegetation zones (*sensu* Wiggins & Porter 1971), due to its longer life cycle, greater stature and shade tolerance. Quinine now dominates other parts of the island (Buddenhagen *et al.* 2004) and has started to invade Los Gemelos. Hamann (2001) suggests that, due to its stand-level dieback cycle, *Scalesia* forest is vulnerable to invasion by alien plants and should receive high priority for conservation management (Shimuzu 1997).

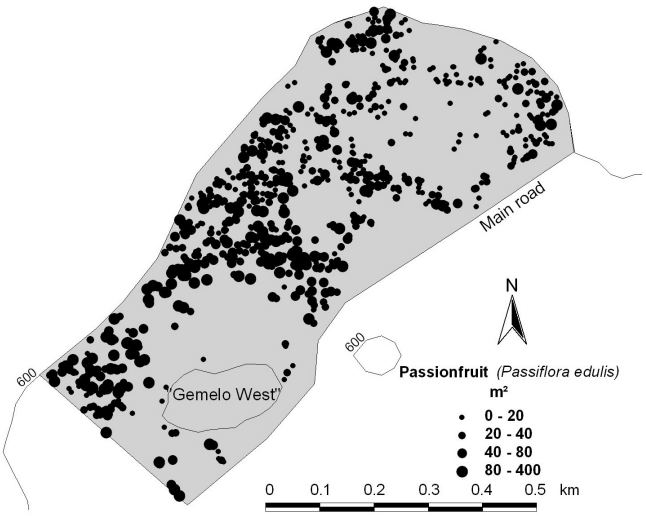
A project to restore the *S. pedunculata* forest at Los Gemelos was initiated in May 2005, using short-term volunteers to provide most of the labour required for control of the most important invasive plant species. Initially, 50 ha were selected for intensive management over two years. The impact of management on the forest will be monitored. As the main invasive species in Los Gemelos are widespread on Santa Cruz, reinvasion is likely and continued surveillance and control will be necessary. Although intermittent management of invasive species at Los Gemelos has been carried out previously, this project represents the first systematic attempt to document the extent of the invasive plant problem at this site before and after management. Here, we describe the distribution and abundance of invasive plant species in 25 ha of the *Scalesia* forest at Los Gemelos, in May–June 2005. This information will act as a baseline to monitor the long term success of management actions.

METHODS

The study area included 25 ha around the western of the two Los Gemelos craters and on the small volcanic cone Cerro Maternidad to the north (Fig. 1). We mapped individuals of the invasive species *Cedrela odorata*, *Cestrum auriculatum*, *Cinchona pubescens*, *Hyptis pectinata*. *Passiflora edulis*, *Psidium guajava*, *Rubus niveus* and *Tradescantia zebrina*. The grasses *Melinis minutiflorus*, *Panicum maximum*, *Paspalum conjugatum* Bergius (regarded as doubtfully native in Galapagos), *Pennisetum purpureum* and *Oplismenus* spp. (up to three species possible, introduced or doubtfully native) were grouped together without distinguishing species. Distribution and abundance were mapped by volunteers following 69 pre-established parallel transects 15 m apart, extending from the adjacent road *c.* 300 m into the forest. Transect lines were generated in GIS and uploaded to hand-held Global Positioning System (GPS) units. Transects were followed in the field by creating routes between points. Along each transect the location of each species was saved in the GPS. Abundance was recorded either as number of plants counted, or, where individuals could not be distinguished due to clumping and growth form, the length and width in meters of each infestation along the largest axes were estimated. For tree species, all stems were counted and for those over 2 m tall diameter at breast height (DBH) was measured. Volunteers were aware of the spacing between transects and tried to map only species that corresponded to their swath. However, some infestations may have been missed or others mapped twice. This type of error was minimized by checking for overlap when mapping the data in GIS.

The structure of the *S. pedunculata* population was also assessed to predict the likelihood of stand level die-back occurring in the near future. The size class distribution of *S. pedunculata* was measured in twenty 5 × 5 m quadrats





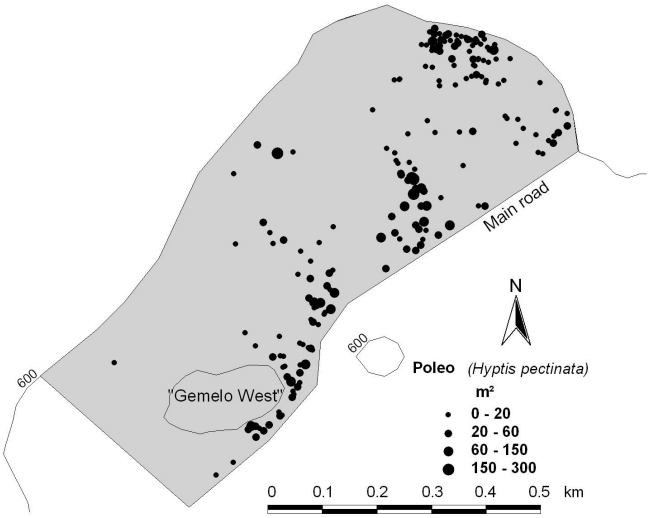


Figure 1 (a–c above, d–i opposite, reading from top left across then down on each page). Area (a–e) and point (f–i) distributions of nine invasive plants at the Los Gemelos site.

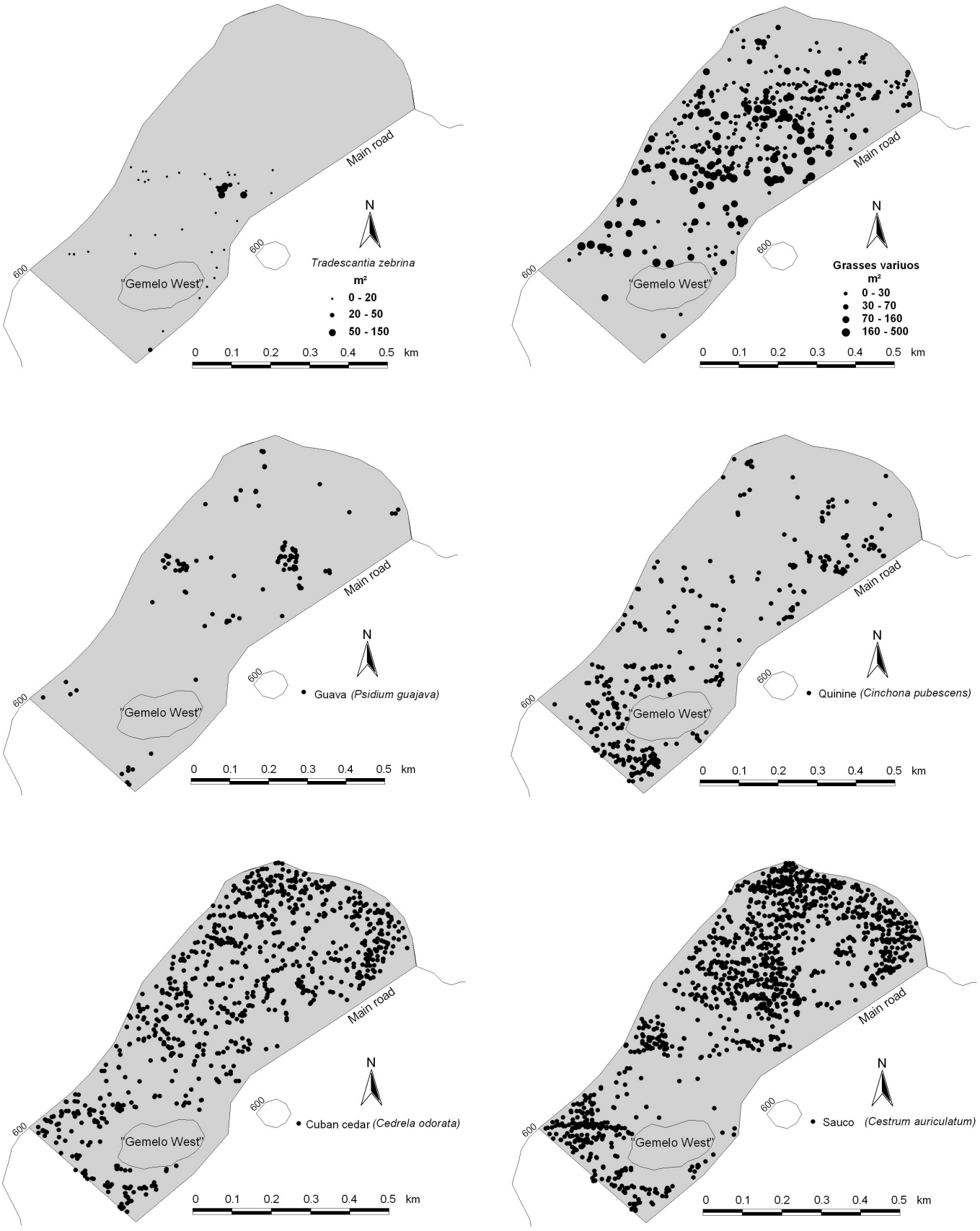


Figure 1 continued (caption opposite).

Table1. Size of infestations for thicket-forming invasive species at Los Gemelos. Data are n (%) of observations.

Area of infestation (m²)	*P. edulis*	*R. niveus*	Grasses	*H. pectinata*	*T. zebrina*	dead *R. niveus*
0–25	444 (62.4)	574 (79.6)	218 (52.1)	125 (66.5)	32 (72.7)	27 (21.4)
25–50	151 (21.2)	69 (9.6)	70 (16.7)	38 (20.2)	10 (22.7)	54 (42.9)
50–100	84 (11.8)	59 (8.2)	89 (21.3)	20 (10.6)	1 (2.3)	30 (23.8)
100–200	25 (3.5)	14 (1.9)	23 (5.5)	2 (1.1)	1 (2.3)	11 (8.7)
200–500	7 (1.0)	5 (0.7)	18 (4.3)	3 (1.6)	0	4 (3.2)
Total n	711	721	418	188	44	126
Total area (ha)	2.328	1.431	2.242	0.536	0.083	0.839

along parallel east to west transects spaced 100 m apart. The first quadrat along each transect was located at a random distance between zero and 100 m and subsequent quadrats were located 100 m apart. Total *Scalesia* stems were counted and DBH was measured of all stems over 2 m tall in each quadrat.

RESULTS

The whole of the 25 ha study area was heavily infested with the eight invasive species (Fig. 1). Dead *R. niveus* occupied 0.8 ha, in an area controlled by the Galapagos National Park service within the last 1–2 years (Fig. 1a). Most infestation patches of all patch-forming species were smaller than 25 m² (Table 1).

More than half the stems of all tree species were more than 2 m tall (Table 2). *C. odorata* included the largest individuals, which overtopped the 6–8 m *S. pedunculata* canopy when they attained *c.* 5 cm DBH. About 66% of *C. odorata* stems had DBH>5 cm. *C. auriculatum* was the smallest of the tree species with only 3% of stems > 5 cm DBH. *P. guajava* had a restricted number of foci (Fig. 1f).

The varied size class distribution of *S. pedunculata* trees suggests that there were multiple cohorts of trees present in 2005, rather than a single, even-aged stand (Figure 2).

DISCUSSION

The Los Gemelos forest appears at first glance to be completely native, due to the structural dominance of *Scalesia pedunculata*. However, the site is actually heavily invaded by at least ten alien plant species. J. Runkle (pers comm.) did not notice many invasive plants in his Los Gemelos study site in 1998, apart from the distinctive *Cinchona* (Runkle & Runkle 2005). However, we do not know whether this indicates that the invasive plant problem has recently become worse.

The cyclical stand-level dieback and regeneration supposedly typical of *Scalesia* forest has been suggested to occur every 20–30 years, linked to major El Niño events (Hamann 2001). The forest may be particularly vulnerable to invasion during canopy dieback. However, despite a suggested initiation of this cycle at Los Gemelos in 1985 exactly 20 years prior to our study (Hamann 2001) there was no evidence of mass dieback during the 1997–8 major El Niño event (Tye & Aldaz 1999) nor since, as the *S. pedunculata* size class distribution appears to be varied (Fig. 2). The typical size class distribution of trees with continuous regeneration is a curve with small individuals being most numerous and old large trees being relatively uncommon. Regeneration of *S. pedunculata* at Los Gemelos

Table 2. Height-diameter classes of four tree species in 25 ha at Los Gemelos. Data are n (%) of trees in each size class.

	Cinchona	*Cedrela*	*Psidium*	*Cestrum*
< 2 m height	106 (19.1)	54 (6.8)	74 (26.1)	1002 (20.4)
0.5–5 cm DBH	307 (55.3)	219 (27.6)	189 (66.8)	3746 (76.2)
5–10 cm DBH	94 (16.9)	214 (27.0)	15 (5.3)	133 (2.7)
10–25 cm DBH	48 (8.6)	195 (24.6)	5 (1.8)	34 (0.7)
25–50 cm DBH	0.0	106 (13.4)	0.0	0.0
50–100 cm DBH	0.0	6 (0.8)	0.0	0.0
Total stems	555	749	283	4915
Mean density (stems per ha)	22	30	11	196

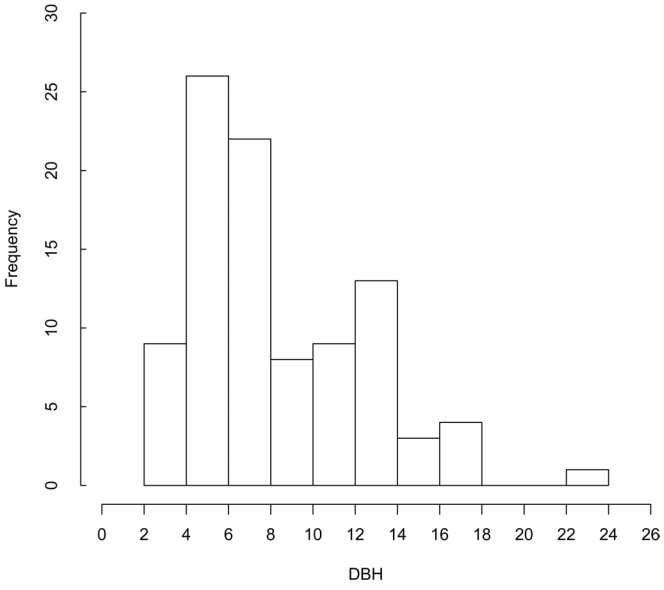


Figure 2. Size class distribution of 95 *S. pedunculata* trees in twenty 5 × 5 m plots.

has not been constant, and two distinctive cohorts have been formed (Fig. 2), possibly during the 1997–8 and 2002 El Niño events. However, the current size class distribution (Fig. 2) suggests that even if there were an extreme El Niño in the coming years, which could trigger death of senescent trees, the effect would be patchy since large old trees are not common.

All of the species in this study site except *Cestrum auriculatum* are known to be naturalized or invasive elsewhere (http://www.hear.org/pier/, 2006). It is likely that most of them had dispersed from the nearby agricultural zone. *C. odorata* and *C. pubescens* are wind dispersed, *R. niveus* and *C. auriculatum* are bird dispersed. *P. edulis*, *P. guajava* and grasses are also dispersed by birds (Buddenhagen & Jewell 2006, Guerrero 2002) and large animals including people, cattle, pigs and tortoises (pers. obs.). Apart from people, there was no sign of large animals at the site.

Some of the larger invasive trees may have established during the 1982–3 *Scalesia* dieback. Most individuals of the invasive trees in this study were large and long established with few seedlings < 2 m tall (Table 2). The largest *C. odorata* trees (up to >50 cm DBH) could have established at this time, since they can grow 2 m in height and add 2.5 cm of DBH per annum in good conditions (Citrón 1990) . However, even intact forest appears to be vulnerable to invasion at periods other than during diebacks. Our data suggest that there several more years are required before *Scalesia* trees reach senescence or self-thinning leads to loss of smaller trees. However, a patchy or extensive dieback at the site could lead to invasive species gaining a greater foothold than they would by the current gradual attrition.

Without intervention, this site is likely to transform into a forest of tall *C. odorata* with an understorey of *R. niveus*. Of the eight invasive species studied, these two will potentially cause the greatest impacts. *C. odorata* has huge potential to change the site because it is long-lived and can form a dense canopy up to 30 m high. A mature *C. odorata* forest would out-compete the smaller short-lived *S. pedunculata*. *R. niveus* is a scrambler that forms dense thickets up to 4 m high and will probably eventually take over the whole understorey, leaving little opportunity for the light-demanding *S. pedunculata* seedlings to establish.

Invasive species control is urgently required if we expect to maintain natural regeneration in this forest. Even with effective control, reinvasion is inevitable from surrounding areas, necessitating permanent control.

ACKNOWLEDGMENTS

We thank Ulrich Reinhardt and Jennifer Young who instigated this project under the Earthwatch programme. Alan Tye provided detailed editorial input, making the whole process run smoothly. Jennifer also played a key role in working in the field with the Earthwatch volunteers. Special thanks go to the Earthwatch volunteers. Pablo Cuenca helped with data collection. This is contribution number 1042 of the Charles Darwin Foundation for the Galapagos Islands.

LITERATURE CITED

Citrón, B.B. 1990. *Cedrela odorata* L. Cedro hembra, Spanish cedar. Pp. 250–257 in *Silvics of North America: 2. Hardwoods*. Eds R.M. Burns and B.H. Honkala. Agriculture Handbook 654., U.S. Department of Agriculture, Forest Service, Washington, DC.

Hamann, O. 1979. On climatic conditions, vegetation types, and leaf size in the Galápagos Islands. *Biotropica* 11: 101–122.

Hamann, O. 2001. Demographic studies of three indigenous stand-forming plant taxa (*Scalesia*, *Opuntia*, and *Bursera*) in the Galápagos Islands, Ecuador. *Biodiversity and Conservation* 10: 223–250.

Itow, S. 1995. Phytogeography and ecology of *Scalesia* (Compositae) endemic to the Galápagos Islands. *Pacific Science* 49: 17–28.

Runkle, J.R. & Runkle, W.A. 2004. Structure and development of a *Scalesia pedunculata* stand in the Galapagos Islands. *Galapagos Research* 63: 12–15.

Shimizu, Y. 1997. Competitive relationships between tree species of *Scalesia* (*S. pedunculata, S. cordata, S. microcephala*) and introduced plants (*Cinchona succirubra, Psidium guajava, Lantana camara*) with reference to regeneration mechanism of Scalesia forests in the Galapagos Islands. *Regional Views* 11: 23–173.

Snell, H.L., Tye, A., Causton, C.E. & Bensted-Smith, R. 2002. The status of and threats to terrestrial biodiversity. In: *A Biodiversity Vision for the Galapagos Islands*. Ed. R. Bensted-Smith, Charles Darwin Foundation and World Wildlife Fund, Puerto Ayora.

Tye, A. 2000. Invasive plant problems and requirements for weed risk assessment in the Galapagos Islands. Pp. 153–175 in *Weed Risk Assessment*. Eds.R.H. Groves, F.D. Panetta & J.G. Virtue.CSIRO, Collingwood.

Tye, A. & Aldaz, I. 1999. Effects of the 1997–98 El Niño event on the vegetation of Galápagos. *Noticias de Galápagos* 60: 22–24.

Van der Werff, H. 1979. Conservation and vegetation of the Galapagos Islands. Pp 391–404 in *Plants and Islands*. Ed. D. Bramwell. Academic Press, London.

Wiggins, I.L. & Porter, D.M. 1971. *Flora of the Galapagos Islands*. Stanford University Press, Stanford, CA.

Williamson, M. 1999. Invasions. *Ecography* 22: 5–12.

GALAPAGOS COMMENTARY

GALAPAGOS FUR SEAL COMMON NAME

The pinnipeds, including the eared seals (family Otariidae), the "true" seals (family Phocidae) and the walrus (family Odobenidae), are mammals in the order Carnivora. According to most recent studies, sub-familial divisions within the Otariidae (fur seals Arctocephalinae and sea lions Otariinae) are no longer recognized (Rice 1998, Wynen *et al.* 2001, Brunner 2003). Nevertheless, the common names "fur seal" and "sea lion" persist in the literature, primarily for convenience and familiarity.

There are two otariid taxa on the Galapagos, namely the Galapagos Fur Seal *Arctocephalus australis galapagoensis* and the Galapagos Sea Lion *Zalophus californianus wollebaeki* (Brunner 2003). Over the years, naturalists from the Galapagos have generally been consistent in the application of these common names for the two pinnipeds on the islands. Most scientific and quasi-scientific publications on marine mammals support the application of Galapagos Fur Seal as the common name for *A. a. galapagoensis* (King 1983, Gentry 1987, Reeves *et al*. 1992, 2002, Bonner 1994, Dellinger & Trillmich 1999, Brunner 2003).

Recently, the name "fur sea lion" has surfaced as an additional name for *A. a. galapagoensis*, in an attempt to recognize that fur seals do not belong to the true seals Phocidae, and this name recently appeared in print (Charles Darwin Foundation 2004). However, "fur sea lion" is misleading and inconsistent with the longstanding nomenclature used for *Arctocephalus* spp. Outside of Galapagos, the name "fur sea lion" has not been applied to any other pinniped. In light of the overwhelming use of the common names "fur seal" and "sea lion", there is no justification for using any common name for *A. a. galapagoensis* other than Galapagos Fur Seal.

Special thanks are due to Thomas Dellinger, Randall Reeves and Fritz Trillmich who kindly reviewed the original draft of this note and provided us with valuable suggestions. We also thank John Simcox, librarian at the Charles Darwin Research Station, for his valuable assistance.

Bonner, W.N. 1994. *Seals and Sea Lions of the World*. Facts on File Inc., New York.

Brunner, S. 2003. Fur seals and sea lions (Otariidae): identification of species and taxonomic review. *Systematics and Biodiversity* 1: 339–439.

Dellinger, T. & Trillmich, F. 1999. Fish prey of the sympatric Galapagos fur seals and sea lions: seasonal variation and niche separation. *Canadian Journal of Zoology* 77: 1204–1226.

Charles Darwin Foundation 2004. *Annual Report 2003*. Charles Darwin Foundation for the Galapagos Islands, Puerto Ayora.

Gentry, R.L. (1987). Seals and their kin. *National Geographic* 171: 475–501.

King, J. 1983. *Seals of the World*. Cornell University Press, Ithaca NY.

Reeves, R.R., Stewart, B.S. & Leatherwood, S.J. 1992. *The Sierra Club Handbook of Seals and Sirenians*. Sierra Club Books, San Francisco.

Reeves, R.R., Stewart, B.S., Clapham, P.J. & Powell, J.A. 2002. *National Audubon Society Guide to Marine Mammals of the World*. Alfred A. Knopf, New York.

Rice, D.W. 1998. *Marine Mammals of the World: Systematics and Distribution.* Special Publication 4, Society for Marine Mammalogy, Lawrence KA.

Wynen, L.P., Goldsworthy, S.D., Insley, S., Adams, M., Bickham, J.W., Francis, J., Pablo Gallo, J., Hoelzel, A.R., Majluf, P., White, R.W.G., & Slade, R. 2001. Phylogenetic relationships within the eared seals (Otariidae: Carnivora): implications for the historical biogeography of the family. *Molecular Phylogeny and Evolution* 21: 270–284.

Jack Grove[1] & Sylvia Brunner[2]

[1]Section of Ichthyology, Los Angeles County Museum of Natural History, 900 Exposition Blvd, Los Angeles, CA 90007, U.S.A. <jsgimages@aol.com>

[2]Marine Mammal Research, University of Alaska Museum of the North, 907 Yukon Drive, Fairbanks, AK 99775, U.S.A. <fnsb@uaf.edu>