

NOTICIAS de Galápagos

No. 59 April 1998

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We are grateful for your steadfast support and help.

NOTICIAS DE GALÁPAGOS

*A Publication about Science and Conservation in the Galápagos Islands,
the Galápagos National Park Service, and the Charles Darwin Foundation*

No. 59 April 1998

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NEWS FROM ACADEMY BAY

NEW FACES AND NEW PROJECTS IN A NEW CDRS DEPARTMENT

Following the incorporation in late 1996 of the invertebrate and quarantine programs into the Department of Botany of the Charles Darwin Research Station (CDRS) to form the new Department of Plant and Invertebrate Biology, several new appointments and staff changes have been made.

In August 1997, Dr. Charlotte Causton, an expert in biological control and entomology, arrived to take charge of the quarantine and invertebrate programs. Her first priorities are to establish the quarantine program on a firm footing and to strengthen the invertebrate program by seeking additional funding, especially for studies of the ecology and control of introduced insects. She is assisted in this by Lázaro Roque, entomologist at CDRS since 1994, and by another new appointment to the quarantine program, Carlos Zapata, who arrived in mid-January 1998. Paulina Viteri, a new volunteer in invertebrates (the first for many years), arrived in August to assist with the entomological projects.

In September 1997, the longest-serving member of the department, Lenin Prado, left the Station. He had held various posts over the past 8 years, most recently taking charge of the forestry program. His replacement in this position, William Swan, arrived in September and will be responsible for broadening the program to tackle the problems of agricultural zone management in a more complete fashion than has been possible to date. Scott Shouse, a Peace Corps volunteer engaged in the program on Isabela, left in May at the end of his Peace Corps service, only to return in August for a four-month period to assist in the design of the new project. In the broader project, the role of the two nurserymen (Felix Burgos and Jefferson Quiñonez) will be expanded, and they will be trained in extension work and experimental monitoring. Mónica Soria continues her thesis project in this program, investigating the reproductive and regeneration biology of the native timber tree matazarno.

The two plant programs (native and threatened plants, and introduced plants) continue to be managed by the head of the department, Alan Tye, and botanist Iván Aldaz, but they have been assisted by several recent volunteers. One of these, Sarah Wilkinson, an expert in botanical survey, experimental design, and invasive plant control, returned in November to help with two projects: a monitoring system for newly introduced species and a new series of trials on methods for the control of invasive species. Another new appointment, to the threatened plants program, is envisaged for early 1998. Thesis student Patricia Jaramillo finished her field work on the distribution of introduced plants at sites subject to human influence in the National Park, and expects to graduate in 1998.

During 1997, a succession of volunteers, both Ecuadorian and international, assisted with these two programs. They included Paúl Carcelén, Dr. Joe Fail, Janell Loving, Ben Ruttenberg, Adolfo Verdugo, Katty Villacís, and Jhony Yumisaca. Most of them assisted with general department tasks and with development and maintenance of the CDRS Herbarium and database of the flora of Galápagos. Janell helped initiate a project to revise the threat status of the Galápagos endemic flora according to new IUCN criteria, Ben (an expert in database management) redesigned the flora database, while Adolfo reviewed the Herbarium collections and brought the database up to date.

All these changes have resulted in a far stronger department, with much greater capacity for tackling the problems facing Galápagos. The quarantine program is entirely new, and the invertebrate program is rapidly expanding after several years of comparative neglect. The major objectives of the department remain the conservation of the Islands' native flora and fauna, the control of alien species, and the prevention of new introductions.

Alan Tye

INTERNATIONAL WORKSHOP: FERAL GOAT ERADICATION PROGRAM

A workshop aimed at developing a strategic plan for the eradication of feral goats from the island of Isabela was held from September 9th to the 18th, in the Galápagos Islands. A fundamental part of the Isabela Project for the long-term restoration of the island is the control and eventual eradication of introduced organisms. One of the most destructive animals for the Isabela ecosystem is the goat. Goats reached Alcedo Volcano, in the northern part of Isabela, at the end of the 1970s. Since then, their numbers and distribution have increased until today the population on the three northern volcanoes of Isabela is estimated at between 75,000 to 100,000 animals (prior to the hunting campaign of 1996-97). This explosion in the goat population has resulted in the destruction of critical habitat of the giant tortoise, which includes the tree fern, an endemic species. The vegetation is under substantial pressure and many native plant and animal species are threatened.

In the last 30 years, the Galápagos National Park Service (GNPS) and the Charles Darwin Foundation (CDF) have succeeded in eradicating goats, using simple hunting, on five islands in the Galápagos Archipelago (Española, South Plaza, Santa Fe, Marchena, and Rábida). These islands are relatively small in size and the use of the same methodology on Isabela, the largest island of the Archipelago, will not achieve the same success. New methodologies, technologies, and knowledge must be applied to this problem to find a definitive solution.

To develop an effective plan for the eradication of goats on Isabela, the GNPS and the CDF invited 14 experts in the eradication of introduced mammals and the restoration of islands to participate in a workshop aimed at developing the definitive plan for the eradication of goats from northern Isabela. The experts, from New Zealand and the United States, are employed in governmental institutions, universities, and consulting companies connected with conservation. In many cases, their institutions financially supported their participation. In addition to the invited experts, key personnel of the GNPS and the CDF participated.

The workshop began with one day of orientation talks and discussions, followed by a 3-day field trip, and finally 4 days dedicated to the development of the plan for the eradication of ungulates from northern Isabela. During the field trip, we made short excursions at Elizabeth Bay, Urvina Bay, Tagus Cove, and west of Piedras Blancas, and a 1-day climb of Alcedo, to give participants an idea of scale and terrain.

The 4-day planning workshop was facilitated by Peter Jenkins, a lawyer from New Mexico, who works in conservation related issues. All of the participants dedicated their time and expertise to producing the best plan possible for the eradication of goats. All of the experts involved in goat eradication in other parts of the world unanimously agreed that eradicating goats from northern Isabela is possible, given sufficient funding and planning and using new technologies.

The final plan for the eradication of goats is currently under review both internally and externally. The following documents, complementary to the plan, were discussed and will be developed.

- Fund-raising plan
- Public relations plan
- Evaluation of the use of recreational hunting in Galápagos with recommendations
- A detailed plan for the preliminary, capacity-building phase

The event was financed by CDF, Inc./Alcedo Fund, WWF, and contributions by some of the participants and/or their institutions. TAME provided discounted air fares for the participants.

Linda J. Cayot

GEOLOGISTS TO INVADE GALÁPAGOS

From June 4-12, 1998, sixty-five of the world's foremost experts on ocean-island volcanism will gather in the Galápagos for a special field excursion and scientific conference on the "Evolution of Ocean Island Volcanism." The meeting is part of the Penrose Conference series of the Geological Society of America and is being co-sponsored by the Charles Darwin Foundation and the International Association for Volcanology and Chemistry of the Earth's Interior. Support for students and Latin

American scientists is being funded by GSA, IAVCEI, and the U.S. National Science Foundation, with logistic support by the CDRS and Galápagos Travel.

The eruptive styles and magma compositions at most oceanic volcanoes change as the volcano ages, and the Galápagos is one of the planet's greatest examples of this volcanic evolution process. The conference will begin with a 5-day field excursion, where the geologists will progress from the ancient volcanoes of San Cristóbal and Española to historically-active Sierra Negra, Alcedo, and Santiago. Then 4 days will be spent in Puerto Ayora presenting and discussing models to explain the variations in volcanic behavior, evolution, and growth patterns observed both in the Galápagos and at other island chains throughout the world.

The conference is being convened by long-term Galápagos researchers Dennis Geist (University of Idaho), Karen Harpp (Lawrence University), and Wendy Bohrsen (University of California).

Dennis Geist

GIS IN GALÁPAGOS

The Charles Darwin Research Station (CDRS) is participating in efforts to revive a moribund multi-institutional agreement to develop a comprehensive GIS (Geographic Information System) for Galápagos. GIS uses computerized databases and maps that permit the exploration, interconnection, and analysis of data through the superimposition of various types of information. GIS can contribute to the understanding and clarification of environmental problems.

The development of a GIS for Galápagos will involve a great deal of effort and investment, especially the inventory of data collections and the preparation of accurate base maps. Once established, the system can be a powerful tool for ecological analysis and management decisions, for example, in studying the spread of introduced species or planning campaigns of control or eradication.

Two initial steps were taken in 1997 to achieve this goal. First, a cooperative project was established between the Charles Darwin Foundation (CDF) and the University of Southampton in England, financed by the "Darwin Initiative" of the British Government. The main objective of the project, which will last for 3 years, is to provide technical support for the revision of the Plan of Management and Zonification of the Galápagos Marine Reserve. As part of the project's training component, Dr. Ken Collins, coordinator of the Darwin Initiative Project in the UK, organized a training course on GIS at the Geodata Institute of the University of Southampton. During November two CDRS staff members, Priscilla Martínez (Marine Biology) and Hernán Vargas (Protection) were trained in the use of the SPANS program.

The second step took place in Ecuador. The Panamerican Center of Geographic Studies and Research

organized an international course on GIS from November 24 to 12 December, with economic help from WWF, Fundación Natura, the Galápagos National Park Service, and the CDF. The theoretical part of the course took place in Quito and the practical portion on southern Isabela in the Galápagos. Course participants, who became familiar with the program CAMRIS, included personnel from several national and international institutions, CDRS staff members Evangelina Duranona, Eduardo Espinoza, and Washington Llerena and Galápagos National Park Service personnel Mario Piu, Patricia Puebla, and Washington Tapia. Further post-course training was provided by George Powell, of World Wildlife Fund-US, who is an expert in the use of CAMRIS for conservation planning.

The next steps will be to make use of the limited GIS skills and software that we have gained, whilst looking for funds for the full development of the system.

Hernán Vargas, Priscilla Martínez, and Washington Llerena

THE ISABELA PROJECT: OFF AND RUNNING

The Isabela Project, whose primary goal is the restoration of the island of Isabela to as near a pristine condition as possible, has made many advances during the past year. In the August 1996 issue of *Noticias de Galápagos* (No. 57), the "Alcedo Update" explained our initial advances. Since then the project has included:

- continued monitoring of the flora and fauna of Alcedo Volcano,
- the protection of endangered vegetation on the southern rim of Alcedo,
- major reductions in the goat and burro populations on the southern rim and slopes of Alcedo,
- improvements in field work conditions and logistics,
- improvements in the administration of the project, making it a totally bi-institutional effort (CDRS - GNPS), and
- major improvements in the financial support of the project.

In addition, an international workshop was held in Galápagos in September 1997, to develop the definitive plan for the eradication of ungulates from northern Isabela.

The monitoring work on Alcedo has continued with trips every six months (begun in November 1995). The focus of the trips, originally on tortoises, goats, and vegetation, has been gradually expanded to include the avifauna and terrestrial invertebrates. Of particular interest was the discovery (during one of the hunting trips) of nests of the dark-rumped petrel (*Pterodroma phaeopygia*), as well as adult birds. Although it was previously thought they nest on Alcedo, this was the first confirmed report. Since then, the ornithologists have put much effort into finding more nests and birds. As a result of the vegetation

monitoring, two patches (approximately 300 m² and 500 m²) of the endemic tree fern (*Cyathea weatherbyana*) were fenced as large herbivore-exclusion zones in January 1997. In addition, nearly 200 trunks (mostly *Zanthoxylum* and *Tournefortia* trees) were wrapped with chicken wire to prevent the goats from scraping the bark with their horns and thus killing the trees.

While Brian Bell's report (see "Alcedo Update" in *Noticias de Galápagos* No. 57) was under review by other experts in the field, we initiated a holding-pattern phase of operation. The plan was to first eliminate as many goats as possible in the most threatened zone (the south-southeast rim and slopes of Alcedo); this meant concentrating on the males, as they were doing the greatest damage. The May 1996 trip resulted in 12,272 goats (76% male) and 366 burros (55% male) eliminated during 10 days of hunting (1.5 bullets/animal). The plan for the second trip was to concentrate on female goats, and in November 1996, 13,061 goats (41% male) and 322 burros (60% male) were eliminated during 6 days of hunting (1.6 bullets/animal). This gives a total of 25,333 goats and 688 burros eliminated in 1996.

In the first half of 1997, the elimination of goats and burros on Alcedo was less than optimal, primarily due to heavy precipitation and fogs, which caused the goats to disperse and created adverse hunting conditions. During the March 1997 trip, a total of 4377 goats (50% male) and 39 burros were eliminated during 8 days (1.6 bullets per animal). In the grasslands on the rim, herds of up to 80 goats were seen, while in the lowlands, where females were concentrated, the herds numbered 10-20 animals. On some hills and cliffs, herds of up to 200 animals were observed. The second trip, in June, resulted in the elimination of 4218 goats (72% male) and 60 burros during 12 days (1.9 bullets per animal; the decrease in efficiency was due to adverse hunting conditions). This gives a total of 8595 goats and 99 burros eliminated during the first half of 1997, or more than 30,000 goats and nearly 800 burros in the first 14 months of effort.

In early 1997, a cabin (6 x 8 m) was constructed on the southern rim of Alcedo to facilitate field work. More than 50 men were involved in the transport of materials and subsequent construction of both the cabin and the fencing of the threatened vegetation. A new, more direct trail was established from the eastern coast of Alcedo to the rim, circumventing the difficult Devil's Elbow section, both to facilitate the transport of construction materials and to protect that fragile section of the rim from further erosion. Many backbreaking days and nights were needed to move lumber, cement, posts, fencing, and other materials to the rim of the caldera.

In June 1997, the CDRS and the GNPS signed an official agreement establishing the Isabela Project as a bi-institutional project and creating the post of Coordinator of the Project. The Coordinator is responsible for the project for both institutions, reporting to and working directly with both directors and their staffs.

The financial base for the Isabela Project has increased dramatically since our last update. Prior to 1997, the funding came primarily from the Ecuadorian Government, INEFAN/GEF, CDF, Inc., Friends of Galápagos organizations in Europe, several small- to medium-size grants by organizations and individuals through the CDF, Inc., the British Embassy, the British Foreign and Commonwealth Office (FCO), and local donors. The Ecuadorian Government, within the budget allocated to the GNPS, and INEFAN/GEF financed a major part of the hunting trips; the government also provides several key positions in the GNPS that are involved in the project. CDF, Inc. and the various Friends of Galápagos organizations in Europe have provided us with general funds for the project. The British Embassy donated field equipment. The British FCO provided funding for the cabin and fencing. At the local level, we have received support from a group of Galápagos artists, a local youth (Sebastian Cruz), the naturalist guides, and others. TAME airlines provides discounted fares. In 1997, the project has seen a several-fold increase in its operating budget with large contributions from two new donors, USAID/PL-480 and WWF. The initiative of all of the people involved in fund raising and the interest of all of the donors are greatly appreciated.

Linda J. Cayot

A PIG-FREE SANTIAGO: IS IT A DREAM OR ON THE HORIZON?

During the last couple of years, while we have been worrying about sea cucumber fishing, goats on Alcedo, the Galápagos Marine Reserve, the extremely threatened mangrove finch and *Scalesia atractyloides* populations, Marek's disease, dying tortoises in El Chato, and so on and so forth, the Galápagos National Park Service (GNPS) has been steadily and consistently eliminating pigs from Santiago Island. An intensive control campaign began in 1985, followed by an increase in intensity of effort in the 1990s, and is now close to reaching the goal of complete eradication.

The results of the campaign during 1996 did not prepare us for the success evidenced in 1997. During 8 trips in 1996, each ranging from 15 to 20 days, with anywhere from 6 to 12 hunters with 6 to 13 dogs, a total of 390 pigs were eliminated. After the first 4 trips, when a total of 231 pigs were eliminated, success dropped to 24 and then 12 pigs eliminated during the 5th and 6th trips, suggesting a diminishing population. However, when more hunters and more dogs were employed for the final 2 trips of the year, 60 and 63 pigs were eliminated, respectively.

The first 3 trips of 1997 (January, February, and March) resulted in declining numbers of pigs eliminated, from 39 to 31, to 24. The total of 94 pigs eliminated during these three trips would equal 71% of all pigs killed during the first 10 trips of the year. The 1997 trips were generally 13

hunting days and involved 6 to 13 hunters with 13 to 22 dogs. In April (6 hunters with 14 dogs), the kill was only 6 pigs. Successful eradication was on the horizon. It was time to carefully review the progress of the campaign and increase the effort to assure success.

In late May, the trips to Santiago began to regularly include a special group of contracted hunters led by a GNPS official, each with more dogs than used previously. Most of these men had been working with the GNPS on this and other campaigns. Between May and October, this group made 6 trips to Santiago, resulting in an average kill per trip of only 5.3 pigs (less than half a pig a day). In mid-October, the hunters knew of only 4 adult females, 2 adult males, less than 10 juveniles, and a few piglets left on the island. Obviously, there are more than this, but the number seen gives an idea of how few are left.

On each trip, the hunters cover all of the zones to look for sign of pigs. They then concentrate in the zones with sign, but continue to check other zones. To facilitate the field work, the GNPS repaired and improved all of the permanent campsites in November. The hunters can now work from 3 different base camps to cover more area.

The role of the dogs (all males) is critical to success. At the current low density of pigs, it is doubtful that more than 1 or 2 pigs, if any, would be taken without the dogs. Of the 22 dogs currently in use, 10 are excellent trackers, while the others work with those 10 to hold the pig once it is located. Wounded and ill dogs are a concern and the dog component (purchase, veterinary care, etc.) is an ever-increasing line in the budget.

A review of the results of the last several trips has resulted in a decision to maintain a minimum of one trip per month to Santiago during the next 2 years. The rains of 1997 have made it very difficult for the hunters, man and dog alike, due to the extremely dense vegetation, the high density of introduced fire ants, and the constantly wet conditions. To assure success, it will be critical to maintain this effort well into the period of drought expected to follow El Niño of 1997-98.

The park wardens/hunters are working very hard and are enthusiastic that they will be able to remove the last pig from Santiago. Support for this hard-working team comes in many forms: payments for hunters, better equipment, first aid courses for hunters to patch up themselves and their dogs, improved field conditions, and more. The basic funding for the trips (transportation, camps, etc.) comes directly from the GNPS budget (Ecuadorian Government), while additional funds (contracts, field per diem, equipment, bounties, etc.) come from CDF, Inc./Alcedo Fund, the Iris Darnton Trust (via Galápagos Conservation Trust), Friends of Galápagos-Switzerland, and the Galápagos Darwin Trust (Luxembourg), all via the CDRS.

The task of eliminating pigs from Santiago is a job for all of us, though the hunters have the hardest work of all. This will be the first successful eradication on one of the larger islands of the Galápagos Archipelago. It demonstrates the commitment and dedication of the GNPS, the

CDF, and the hunters, to the conservation of the Islands. Due to the extremely high cost, both financial and ecological, of not continuing the hunting trips, both the GNPS and the CDF are committed to the required support during 1998. The eradication of pigs from Santiago will help many of the native species, including tortoises, sea turtles, dark-rumped petrels, and Galápagos rails. It will pave the way for a goat eradication campaign, and it will be a major step towards the restoration of Santiago.

Linda J. Cayot and Sixto Naranjo; Data from GNPS internal reports by Kléber Aguilar, Sixto Naranjo, Lorgio Vaca, René Valle, and Telmo Zúñiga

THE SPECIAL LAW FOR GALÁPAGOS

In March 1998, after years of effort and a lengthy consultative process in which the Charles Darwin Foundation participated, Ecuador enacted special legislation for the Galápagos Islands. The overall effect of the law should be very beneficial for the biodiversity of the Islands, for it addresses several issues on which conservationists have long called for action.

The law aims to promote conservation of biodiversity and sustainable development of the Province of Galápagos. The principal obstacle to the aim of harmonious coexistence between people and the unique flora and fauna of Galápagos is the problem of introduced species. The salient features of the law that help solve this are:

- Reference to introduced species control in the basic principles of the law and the definition of sustainable development.
- Regulations relating to introduction and transport of alien species, eradication of pest species in farmland, quarantine inspection, and environmental impact assessment.
- Regulations and incentives to strengthen environmental education and training.
- Promotion of locally-based tourism and other incentives, in order to encourage support for and participation in conservation.
- Requirement for local institutions and individuals to contribute to the control of introduced species.
- Retention of 95% of visitor entry fee, set at US\$ 100, for distribution between Park (40%), local authorities (40%), Marine Reserve (5%), Navy (5%) and quarantine system (5%).
- Reform of INGALA (Instituto Nacional Galápagos) as coordinator of policies and planning throughout Galápagos.
- Establishment of a system for regulating residence in Galápagos and reduce inward migration.

The law is no panacea, however, and there are several aspects for which the Foundation will be advocating im-

provement through detailed regulations and, where necessary, reforms. In particular:

- The residence control section has a number of deficiencies which make the goal of a stable population (natural growth balanced by net outward migration) very hard to achieve.

- The law creates powerful economic and social incentives for people to live in Galápagos. These may motivate people to conserve and defend their islands, but will also put pressure on the residence control system and discourage outward migration.

- The law incorporates the "precautionary principle," which says, in essence, that in case of doubt one should adopt the alternative least likely to harm the environment. However, it should have had stronger guarantees to ensure that it is applied in the event of conflicts between INGALA and other authorities (Park, Marine Reserve, Municipalities).

- The law includes an article which restricts sales outlets for local handicrafts, thereby harming both local craftsmen and the Station's shop.

The second major threat to Galápagos biodiversity, after alien species, is the misuse of marine resources. The Charles Darwin Research Station and the Galápagos National Park Service (GNPS) initiated in mid-1997 a participatory planning process, which generated a consensus within Galápagos on the principles for marine conservation. After much debate and opposition from the industrial fishing sector, these principles were adopted in the law, which provides for:

- Establishment of the Marine Reserve as a protected area, to be managed by the GNPS in collaboration with local stakeholders, under the overall authority of an inter-institutional committee composed of 4 ministries and 3 stakeholder groups (tourism, fisheries and a science/biodiversity/education group).
- Expansion of the Reserve boundaries to 40 miles around the whole archipelago, within which area only tourism and local artisanal fishing are permitted.

There will still be difficult negotiation ahead, for example on the definition of "artisanal." Nevertheless, the law provides a historic opportunity to protect one of the world's largest, most important marine protected areas.

In conclusion, the law provides an excellent framework for conservation of the Marine Reserve and represents an important advance in conservation of the terrestrial component of Galápagos biodiversity, notwithstanding weaknesses in measures to curb the population growth, which underlies the central threat of introduced species. And the law will do much to encourage all the Islands' residents to participate in and take responsibility for the conservation of Galápagos.

Robert Bensted-Smith

VOYAGE OF THE FRIGATE *EUGENIE*

By: J. P. Lundh

Almost half a century ago, a childhood friend, the late Alf Kastdalen of Santa Cruz Island, lent me a copy of Alban Stewart's "A Botanical Survey of the Galapagos Islands." One of the things that aroused my curiosity in this book was the abbreviation "Anderss." that is often found next to plant names. I guessed correctly that it stood for Andersson, but a number of years would pass before I knew more about this Swedish botanist. Still more went by before I held his book on Galápagos plants in my hands and could read it, thanks to the kindness of Roger Perry, who lent it to me shortly after he became Director of the Charles Darwin Research Station. Since my return to Europe, I have learned much about Professor Andersson and the voyage around the world of His Swedish Majesty's Frigate *Eugenie*, mainly in the botanist's letter from the voyage and the two-volume narration by Lt. Carl Johan Gustaf Skogman (1820-1907), a distinguished naval officer with roots in the Swedish nobility of Finland.

Nils Johan Andersson (1821-1880) had taught at the University of Uppsala – where Linnaeus had studied and taught – before sailing on the *Eugenie*. After his return, he spent a period at the University of Lund, from where he went to the Riksmuseet in Stockholm in 1856. Andersson wrote several botanical works besides his Galápagos flora, among them his *Monographica Salicum* (1867). He was also editor of the periodical "Botaniska Notiser."

The zoological work aboard the *Eugenie* was the responsibility of Dr. Johan Gustaf Hjalmar Kinberg (1820-1908). Although he was the ship's physician, he also held degrees in zoology and veterinary science. The commanding officer of the frigate on this long voyage (1851-53) was Rear Admiral Christian Adolf Virgin (1797-1870), an outstanding naval officer and diplomat, who at the time held the rank of captain. Virgin came from a noble Pomeranian family established in Sweden since 1731, which gave their adopted country a number of army and naval officers of distinction.

The frigate *Eugenie* sailed from Karlskrona, Sweden, on September 30, 1851, accompanied by the corvette *Lagerbjelke*. After a visit to Copenhagen, a storm forced the ships to seek shelter in Farsund, in the south of Norway, from where the vessels sailed to Spithead. Their next port of call was the island of Madeira, followed by Rio de Janeiro, where they anchored on the 9th of December. After stops at Montevideo and Buenos Aires, the corvette *Lagerbjelke* headed back for Sweden, while the *Eugenie* returned to Montevideo, before sailing south to Patagonia and the Straits of Magellan. They reached Valparaíso on February 22, 1852.

In several of his letters from the voyage, Prof. Andersson praises Captain Virgin for his many good

qualities, especially his kindness and his support to the scientists on the frigate, whom he gave every opportunity to collect, even providing them with boats and crew to reach places that were outside the route followed by the ship.

After leaving Valparaíso, the frigate sailed to the Chincha Islands, outside Pisco, then visited Callao and headed for the Gulf of Guayaquil, where they arrived on March 24, 1852. On the following day, the Swedes encountered the *George Howland*, an American whaler that had been captured at Floreana by Manuel Briones and his gang, who had been serving an eight-year sentence in the Galápagos because of their depredations in the Daule region, above Guayaquil. The Swedes boarded the whaler, but the escaped convicts had already abandoned the ship, seeing their only escape route blocked by the frigate. The captured ship was sailed the next day up the Guayas River, its capture being duly reported to the respective officials and the vessel turned over to the American consul. It was at this time that Prof. Andersson and several Swedish officers witnessed the execution of Briones and some members of his gang, who had been captured by Ecuadorian soldiers in the Gulf.

The *Eugenie* continued to Panama, then a Colombian province, sailing later to the Pearl Islands for water and firewood. San Francisco was to be their next port of call, but Captain Virgin changed his plans to give the scientists an opportunity to collect specimens in the Galápagos, since both Andersson and Kinberg were familiar with Darwin's collections from the Islands and were hoping to visit them. Andersson expresses great admiration for Charles Darwin.

The men on the *Eugenie* sighted San Cristóbal at sunset on April 28th, but the unfavorable wind conditions left them drifting between that island and Santa Cruz. A boat was lowered to take the scientists ashore, while the frigate managed to reach anchorage at the entrance to Stephens Bay (Puerto Grande), thanks to a weak breeze that helped them in early afternoon. On San Cristóbal, the visitors met with the half-dozen inhabitants who were still on the island, and some of the officers were invited to a meal of tortoise meat, which was eaten with bread and fine French wine brought ashore from the ship. No visit was made to the interior.

The next stop was Black Beach, where the frigate anchored on May 14th. Hunting and collecting was done during the following three days. Then, the ship set course for Santiago. East of Pinzón, a boat was lowered and a crew provided to take the scientists ashore on Santa Cruz, where a few hours were spent at Whale Bay, where the Swedes saw some men running inland at the sight of their

boat. They found a woman in one of the shacks at the foot of the hill by the beach, but could not communicate with her, as they spoke no Spanish.

After a visit to the southeastern part of Isabela, the scientists rejoined the frigate in James Bay in the afternoon of the 19th. During his visit to Whale Bay, Prof. Andersson became the first botanist known to have collected plants on Santa Cruz. In his letter from this part of the voyage, he mentions that the vegetation was similar to that seen elsewhere, giving the impression that he was not much impressed by the place, but he complains in his flora that he had too little time to spend there, having no doubt realized later that he had collected a disproportionately high number of new plants.

Unfavorable wind conditions induced Captain Virgin to head for Hawaii for supplies. The frigate remained in Honolulu from June 21st to July 3rd, finally heading for San Francisco and a long sojourn there. On the voyage across the Pacific, the *Eugenie* stopped once more at Ho-

nolulu, later visiting Tahiti and other Polynesian islands before arriving at Port Jackson (Sydney) on October 21st and spending ten days there.

Several stops were made in Micronesia, then the frigate headed for Whampoa (Huangpu) on the Canton (Pearl) River, Hong Kong, Manila, then south to Singapore, Batavia (Jakarta), Keeling, Mauritius, and Capetown. Once back to the Atlantic, stops were made at Santa Helena, Plymouth, and Cherbourg.

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VENICE IN THE GALÁPAGOS ISLANDS

By: J. P. Lundh

Venice and the Galápagos Islands may be two most fascinating places, but they are certainly not alike. Even the water around them is very different – the turbid waters of the Venetian lagoon are hardly as inviting as the clear, cool sea water surrounding Galápagos. However, while strolling just east of the Doge's Palace on a hot summer day, between Rio di Palazzo and Rio di Ca' di Dio, I was startled to find myself in a place called Riva degli Schiavoni. In my mind's eye, I suddenly saw the waves breaking at low tide over Schiavoni Reef, as I had so often seen them from my windows in Puerto Baquerizo Moreno, on San Cristóbal Island, in the 1960s.

I had often wondered about the origin of Galápagos place names such as Schiavoni Reef, Malamocco Point, and Lido Point. All I knew is that they can be traced to the Italian corvette *Vettor Pisani*, which visited the Galápagos from March 20 to 31, 1884, under the command of Captain Giovanni Palumbo. A survey that was made of Wreck Bay (Puerto Baquerizo Moreno) left us these names.

Lido Point is obviously named after the Lido, or Lido de Venezia, the long, narrow island between the lagoon and the Adriatic Sea. Malamocco is a small village on the lagoon side of the Lido de Venezia, near its eastern end. Bassa Point, about 6.5 nautical miles northeast of Wreck Bay, gets its name from the Italian word meaning low and narrow.

Lieutenant Gaetano Chierchia wrote a 174-page paper on the specimens collected during the voyage of the *Vettor Pisani*, pages 69 to 74 being mainly dedicated to Galápagos. Sixty-three zoological specimens are described from the islands and their neighboring waters, while fifty-six botanical specimens were reported from Floreana and San Cristóbal. On page 74, Lt. Chierchia makes the erroneous claim that the only other scientific collection from Galápagos in Europe besides his own is that of the illustrious Darwin. He was obviously unaware of the collections brought back in 1853 on the Swedish frigate *Eugenie*. At least the botanical material from Galápagos from that voyage had been identified, described, and published as early as 1858.

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THE MONARCH BUTTERFLY IN THE GALÁPAGOS ISLANDS: IS IT A NATIVE OR AN INTRODUCED SPECIES?

By: Lázaro Roque

When I returned to the water party I saw two monarch butterflies flying slowly about, and we stopped work for a moment, but lacking a net, found it impossible to capture them. There was not the remotest chance of being mistaken in the species, and therefore *Danais* (sic) *plexippus* (or *Danais archippus* as I knew it when a boy) is definitely added to the fauna of the Galápagos Archipelago. On several islands I had seen a milkweed in blossom, so this wide-ranging butterfly should have no difficulty in establishing itself.

William Beebe, 1924, *Galapagos: World's End*

One of the favorite topics in the study of insular biology is the analysis or speculation about the arrival and establishment of a species on oceanic islands. The Galápagos Islands, located 1000 km off the coast of Ecuador, are a singular place for such biogeographic and

evolutionary studies. Determining if species of insects were introduced by humans or if they have naturally colonized the islands is not always an easy matter. For the monarch butterfly (*Danaus plexippus*), the answer to that question remains uncertain.

Hickin (1979) mentioned that it may have been introduced to San Cristóbal Island as a result of the frequent visits of commercial ships to the island. However, Peck (1991) wrote that the only mechanism for butterflies to arrive at the Galápagos Islands was by air, flying actively or passively. The only report of this species prior to this publication was that of Beebe (1923).

Zimmerman (1948) recognized four mechanisms by which insects could arrive at an oceanic island:

- a) transported by other animals,
- b) on natural rafts,
- c) transported intentionally or accidentally by human beings, and

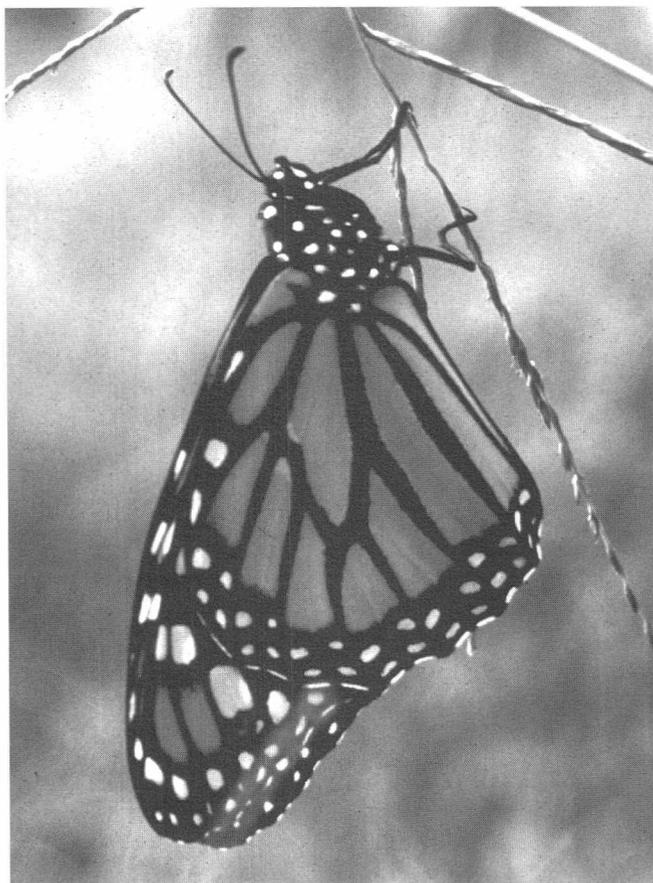


Figure 1. Adult *D. plexippus* at rest, Floreana, April 1996 (photo by Lázaro Roque).



Figure 2. Caterpillar 5th instar in *A. curassavica*, Floreana, April 1996 (photo by Lázaro Roque).

d) through the air, flying actively or passively.

Only the last three modes of transport are likely to apply to diurnal butterflies.

1. *Rafts*: The transport of insects on natural rafts has been documented (Palmer 1944, Heatwole and Levins 1972, Peck 1994). This mechanism is less probable for adult butterflies. Nevertheless, it is possible that rafts, driven by either the Humboldt Current (during the dry season) or the Panama Flow (during the rainy season, especially during a strong El Niño year) could arrive with eggs, larvae, or pupae. It should be emphasized that the probability of successful establishment of the immature stages transported on rafts is low due to the fact that at least one male and one female must survive and find a milkweed to ensure the establishment of the species. Peck and Kukulová-Peck (1990) pointed out that another factor affecting the establishment of native insects after raft transport is the predation pressure of native lizards and birds. The intense activity of these insectivorous predators has been observed along many coasts of the islands.

2. *Human Beings*: There are no data on the intentional introduction of lepidopterans to the Archipelago, although the importation of plants could play a significant role in the indirect introduction of insects (Miller 1994). Human settlements in Galápagos are relatively recent. The first inhabitants settled on Floreana and San Cristóbal during the last century, bringing many plants, mainly fruits and vegetables, but also ornamental plants (Mauchamp 1997).

Asclepias curassavica L., the main milkweed host plant of *D. plexippus* in Galápagos, is an introduced plant and grows mainly in the agricultural zones of Floreana, Santa Cruz, and San Cristóbal (Lawesson *et al.* 1987). It was collected for the first time by the year-long expedition of the California Academy of Sciences in 1905-06 (Stewart 1911). However, the entomologist of that expedition, F. X. Williams, a very capable lepidopterist, neither collected nor observed the butterfly (Williams 1911). Based on this, it is possible to suggest that the species was not introduced before this date.

3. *Flying*: The long-distance dispersal abilities of many lepidopterans are well known (Guppy 1925, Beebe 1949, Ferguson *et al.* 1991, Smith 1992). *D. plexippus* is famous as a long-distance migrant, because it performs spectacular annual migrations in North and Central America and on occasions over the Pacific (Carlquist 1981). Zwaluwenberg (1942) verified repetitive colonization by the species on remote Canton Island, in the central Pacific, and at the same time detected the simultaneous establishment of the host plants. It is probable that Galápagos has had many such arrivals and failed attempts to colonize where there are no *A. curassavica* plants. Peck (1994) demonstrated that the winds in a strong El Niño year probably create favorable circumstances for the transport of insects between islands and from tropical America to Galápagos.

During the past two years (1995-96), I have collected *D. plexippus* on San Cristóbal, Santa Cruz, and Floreana. I have found eggs and early instar larvae on the plants *Asclepias curassavica* L. and *Sarcostemma angustissima* R.

W. Holm (Asclepiadaceae). The latter species is widespread throughout Galápagos. I have the impression that on islands where both milkweed plants occur, when the abundance of *A. curassavica* decreases as a result of herbivore pressure, the frequency of ovapositions on *S. angustissima* increases. Larval development, however, appears to be incomplete on this second milkweed species and may be why the monarch butterfly is only found on the islands where *A. curassavica* grows.

Based on the current distribution and well-established dispersal potential of this species, together with dates of discovery of butterflies and their host plant, it seems most reasonable to assume that *D. plexippus* arrived in the Archipelago between 1906 and 1923 through natural dispersal mechanisms, after humans had introduced the milkweed host plant.

ACKNOWLEDGMENTS

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ANTS (HYMENOPTERA, FORMICIDAE) OF FLOREANA: LOST PARADISE?

By: Boris Pezzatti, Trimurti Irzan, and Daniel Cherix

INTRODUCTION

Ecological impacts of introduced mammals and plants on the endemic fauna and flora of Galápagos is an important problem that has been relatively well documented (e.g., Hoeck 1984, Hamann 1991, 1994). However, little is known about the impact of introduced arthropods (Baert 1994, Meier 1994). Especially among ants, so-called "tramp" species have been readily transported by humans. Due to their biological characteristics, these "tramp" species become rapidly established and can spread out easily. Although small in size, ants are among the most widespread and destructive invading species. Introduced into a new area, they become real pests and can either displace or eliminate native ant species or other arthropods, like the imported fire ants *Solenopsis invicta* Buren in the United States (see, e.g., Vinson 1994). One of the most recent introductions, with far-reaching consequences for the Galápagos ecosystem, is the little red fire ant, *Wasmannia auropunctata* (Roger) (Lubin 1984).

In the late 19th and early 20th centuries, several papers on ants were published based on material collected during early expeditions to the Galápagos Islands (Smith 1877, Emery 1893, Wheeler, 1919, 1924, 1933, Stitz 1932). No further studies on ants were published until 1972, when problems caused by the introduction of *W. auropunctata* arose (Silberglied 1972). Although a number of studies have been conducted, particularly on *W. auropunctata* and its control (Clark *et al.* 1982, Lubin 1984, 1985, Meier 1994, Ulloa-Chacón and Cherix 1990, 1994), the resulting knowledge is still considered fragmentary (Brandão and Paiva 1994).

The aim of this study was to determine patterns of distribution of the ant fauna on the island of Floreana, with special attention to introduced ants. For this purpose, species richness, abundance, and frequency of the ant fauna were studied (Pezzatti, Irzan, and Cherix, in prep.). In addition, different collecting methods were compared as a first step in the development of standardized methods for further investigation of ants on the Galápagos Islands (Irzan and Pezzatti 1997).

Floreana Island was selected for this research because both old (Wheeler 1919, 1924, 1933) and more recent data (Lubin 1984) on ant fauna were available. Moreover, the history of Floreana and its present situation made it an interesting study site. The early colonization and introduction of plants and animals have had an important influence on the native fauna and flora, and we supposed that the ant fauna would have been similarly affected.

MATERIAL AND METHODS

Study Site

The vegetation zones, originally described by Wiggins and Porter (1971) are partly represented on Floreana. The littoral zone and the transition zone are very reduced on the lee side of the island, i.e., on the northern and western slope (Dr. Alan Tye [Head, Department of Plants and Invertebrates of the Charles Darwin Research Station (CDRS)], Iván Aldaz [Botanist, CDRS], pers. comm.; pers. obs.).

In the humid highlands of Floreana, two different "sub-zones" of the *Scalesia* zone can be distinguished: one area

which is more or less typical of *Scalesia* zones, with *Scalesia pedunculata* as the main element, and a second one, where *Scalesia pedunculata* is absent and the tree layer is dominated by *Zanthoxylum fagara*. However, pristine zones hardly exist on Floreana nowadays (Hamann 1981; pers. obs.). In the humid zone, it was virtually impossible to find natural areas without guava trees, citrus trees, or the shrub *Lantana camara* (pers. obs.).

To study the ant fauna of Floreana, eight representative sampling sites were chosen (Figure 1). In order to allow a comparison between inhabited and natural zones of the island, four sites were situated on human-impacted territories and four corresponding ones in the natural zone.

The transect of the human-impacted sampling sites (A1-A4) lay on the western side of Floreana, stretching from the village Puerto Velasco Ibarra (Black Beach) on the west coast of the island to the agricultural zone in the highlands. In selecting the exact sites along this transect, the vegetation structure (herb vs. shrub and/or tree) was considered to be important because of its influence on the ant fauna. In order to collect those ants that could easily expand from the impacted to the natural areas, the hu-

man-impacted sampling sites should have a vegetation structure similar to that of the corresponding natural sites. Pastures, which are dominated by *Pennisetum pupureum*, do not have a corresponding natural vegetation structure. For this reason, they were not sampled, although they cover a large part of the cultivated area.

The natural sites (N1-N4) all lay on the northern side of Floreana. Climatic conditions there are similar to those on the western side of the island, where the human-impacted transect lay. Furthermore, the northern slope of the island is much more accessible than the southern one. The sites were situated in areas representative of their respective vegetation zones so that most characteristic species were included. Those "natural sites" are all free of direct human impact; however, the indirect influence of humans through feral donkeys, goats, and plants, originally brought to the area by humans, could not be avoided.

In addition, three more sites on the coast that were not included in the transects were sampled. These sampling sites were situated in the littoral zone on the lee side of Floreana. The vegetation is patchy. In order to make the three sites comparable, they were all chosen with

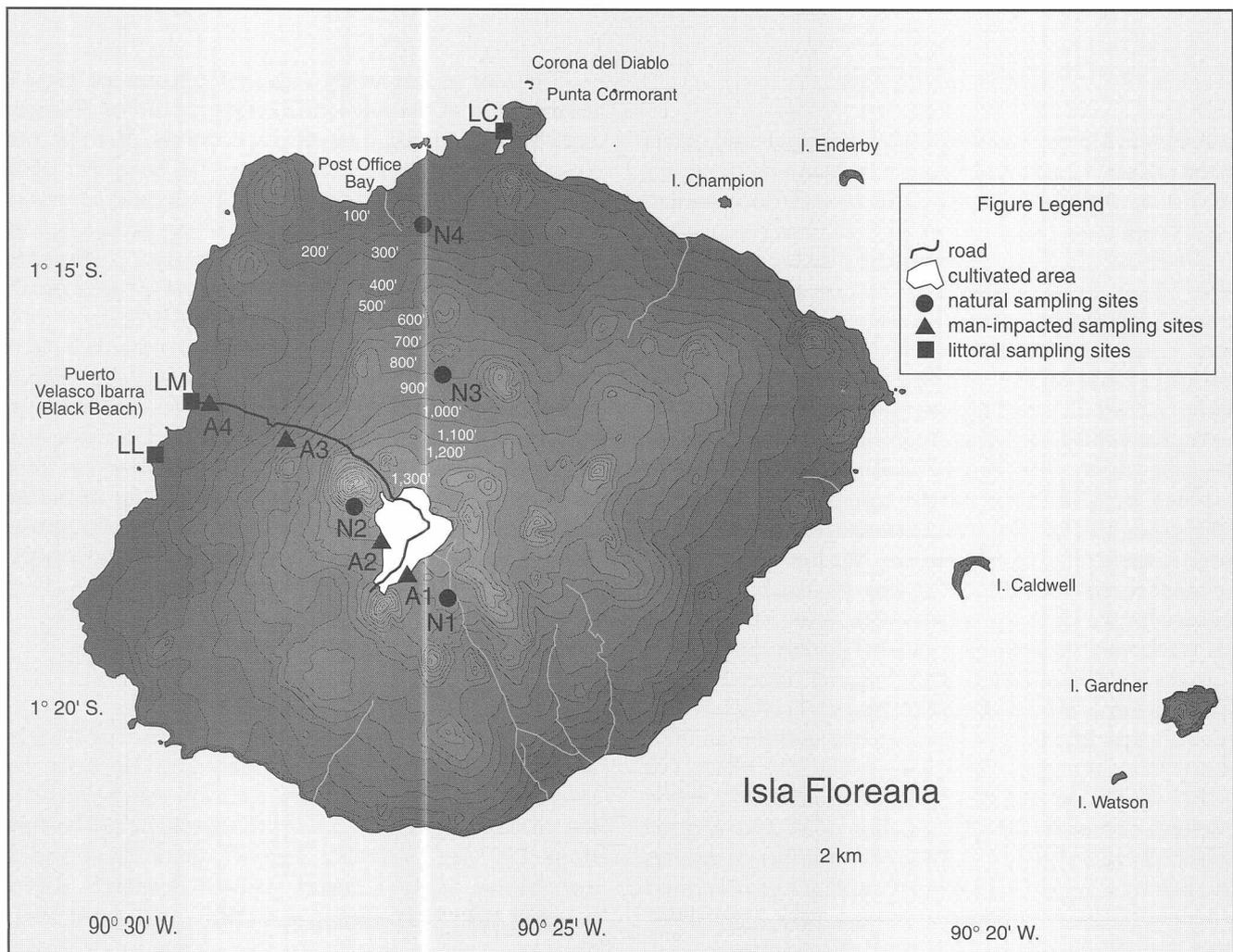


Figure 1. Map of Floreana with study sites indicated.

Cryptocarpus pyriformis as the dominant plant species in that area. One point lay in a natural zone (LL), two in human-impacted areas: one site was situated next to the dock of the village (LM) and the other (LC) lay in a tourist-impacted area (visitor site Punta Cormorant) in the north of the island (Figure 1 and Table 1).

To obtain a general picture of the ant fauna, sampling sites were chosen outside areas infested by *W. auropunctata*. According to several studies (Silberglieid 1972, Clark *et al.* 1982, Lubin 1984, 1985, Meier 1994), only a few ant species can coexist with *W. auropunctata*.

Ant Collection

Field work was carried out during 8 weeks from December 1996 to the beginning of February 1997. Both qualitative and quantitative data were gathered with various methods. In addition to a general visual search, pitfall traps and baits were used. Pitfall traps consisted of plastic cups (65 mm internal diameter, 90 mm long) filled with about 50 ml of ethyl glycol.

At each of the sites N1 to N4 and A1 to A4, three pitfall traps were placed in a triangle. The traps were left for 15

days. At sites LL, LM, and LC, pitfall traps were placed in the same way, but left for only 6 days.

We did not analyze quantitatively the number of ants collected with pitfall traps, since this can be influenced significantly by several factors and generally does not give a representative idea of abundance (see Seifert 1990).

As bait we used Eppendorf plastic vials half-filled either with a mixture of honey and water (bottled with a piece of cotton) or with tuna (in water and in oil). Both tuna in oil and tuna in water (without oil) were used, since oil can act as a repellent to some ant species.

Twenty-five numbered baiting points were laid systematically in a square of 8x8 m, each distant 2 m from one another. We sampled sites N1 to N4 and A1 to A4 twice with honey and twice with tuna to ensure reliable results. Baits were put in place between 2:00 pm and 4:00 pm and collected the following morning between 7:00 am and 9:00 am (17 h baiting time).

At sites LL, LM, and LC, the same baiting procedure was followed, but only once with carbohydrates and once with proteins.

The ants were counted for each baiting point separately.

Table 1. Description of the sampling sites, their altitude (meters above sea level), and main vegetation elements.

N: natural sampling sites A: man-impacted sampling sites L: littoral sampling sites

Code	Altitude m a.s.l.	Vegetation zone	Main vegetation elements	Comments
N1	300	humid	<i>Zanthoxylum fagara</i> , <i>Tournefortia rufosericea</i> , <i>Cordia leucophlyctis</i> , <i>Psidium guajava</i> , <i>Dichondria repens</i> , <i>Oxalis cornelli</i>	In the highlands, moist, soil well developed, herb layer existing, introduced plant species present
N2	330	humid	<i>Scaevola pedunculata</i> , <i>Croton scouleri</i> , <i>Cordia leucophlyctis</i> , <i>Capraria biflora</i>	Near main crater, moist, soil stony, seedlings of <i>S. pedunculata</i> , introduced plant species present
N3	215	upper arid	<i>Prosopis juliflora</i> , <i>Waltheria ovata</i> , <i>Clerodendrum molle</i>	Arid, soil sandy
N4	25	lower arid	<i>Prosopis juliflora</i> , <i>Parkinsonia aculeata</i> , <i>Castela galapageia</i> , <i>Cordia andersonii</i>	Arid, soil sandy with rocks
A1	335	humid	<i>Manihot esculenta</i> , weeds	Manioc cultivation, soil well developed
A2	315	humid	<i>Citrus sp.</i> , <i>Phyllanthus nodiflora</i> , <i>Paspalum conjugatum</i> , <i>Kalanchoe pinnata</i>	Pasture with orange trees, in cultivation zone
A3	160	upper arid	<i>Hibiscus rosa-sinensis</i> , <i>Spondias purpurea</i> , <i>Terminalia catappa</i>	Garden of a private house with ornamental plants, near a spring; sole inhabited plot, surrounded by Park land
A4	10	lower arid	<i>Laurus nobilis</i> , <i>Jatropha curcas</i> , <i>Spondias purpurea</i>	Garden of a private house in the village Puerto Velasco Ibarra with ornamental plants
LL	1	littoral	<i>Cryptocarpus pyriformis</i>	South of Puerto Velasco Ibarra, gravel soil
LM	2	littoral	<i>Cryptocarpus pyriformis</i>	Close to the dock of Puerto Velasco Ibarra, domestic animals straying at night, rocky soil
LC	1	littoral	<i>Cryptocarpus pyriformis</i>	Tourist visitor site, sandy

Identifications were based on available keys and species descriptions (references in Table 2, and in "Literature cited" with asterisk). Additionally specimens were compared with the reference collection of H. Kutter at the Museum of Zoology of Lausanne and the reference collection of A. Forel at the Museum of Natural History of Geneva, both in Switzerland.

RESULTS AND DISCUSSION

Diversity of Ants

We collected and identified 25,241 ants (1,539 in pitfall traps and 23,702 with bait). They belong to 24 species (13 genera): 3 species of Ponerinae, 16 species of Myrmicinae, 1 species of Dolichoderinae, and 4 species of Formicidae (Table 2).

Among the collected species, four are new records for the ant fauna of the Galápagos Islands: *Monomorium destructor*, *Quadristruma emmae*, *Tetramorium caldarium*, and *T. lanuginosum*. *T. caldarium* is probably not new, but has been previously misidentified as *T. simillimum*, because of the close resemblance of these two species. The other species may represent recent introductions.

Additionally, in comparison with data from M. Coulter and M. Alvarez, as well as data from Y. Lubin and M. Alvarez (unpublished), four species are recorded for the first time on Floreana: *Strumigenys louisianae*, *Pheidole* spp. A and B, and one *Hypoponera* sp.

Paratrechina guatemalensis ssp. *itinerans* (Forel), *Cylindromyrmex striatus* Mayr, and *Monomorium pharaonis* (Linnaeus) were found on Floreana in previous works (respectively, Wheeler 1919, Stitz 1932, M. Coulter and M. Alvarez 1982, unpublished), but have not been encountered in this study.

The determination of species origin in Galápagos is an often discussed problem. Especially for small organisms such as ants, it is virtually impossible to decide whether or not a species arrived by natural means. We propose here a classification, considering the origin, in the case of tramp species, or the distribution for the other species.

Therefore we defined the following categories (see Table 2):

- Endemic (E);
- Native (N);
- Possibly Native (N/I): species which could have reached the Galápagos by natural means (originated from the Americas or distributed in the Americas);
- Old Introductions (OI): other species, which were already recorded for Galápagos by early collectors;
- Recent Introductions (RI): remaining species, which were only recorded in recent papers (Clark *et al.* 1982, Lubin 1984), and the present study.

The origins of most tramp species, as indicated in the literature, are only presumed. As already mentioned by Brandão and Paiva (1994), more detailed information

about the tramp ant species, in particular about their true origin, is needed to be able to classify them correctly.

Considering this characterization, the ant fauna of Floreana is mainly composed of introduced species. Among the 24 ant species encountered on Floreana, only two are endemic (*Camponotus macilentus* and *C. planus*) and only one is definitely native (*Solenopsis globularia* subsp. *pacifica* is native at the subspecies level). Most of the remaining are common tramp species, i.e., well-known pest ants which have been spread by commerce throughout the world (Hölldobler and Wilson 1990). Due to their sometimes extremely small size and their privileged relationship with the human environment (Passera 1994), these species are very easily transported unnoticed, and some of them probably arrived in Galápagos on ships of buccaneers, whalers, and early settlers. Some important characteristics allow tramp species to establish and disperse (Brandão and Paiva 1994, Hölldobler and Wilson 1990, Passera 1994):

- polygyny and high capacity to produce and rear new queens;
- unicoloniality and related low levels, or absence, of intraspecific aggression;
- generalism in feeding (omnivorous) and nest site preferences;
- tendency to move, permitting establishment in very unstable, human-made habitats, such as villages or cultivated areas;
- absence of nuptial flight for most of the time;
- interspecific aggression in some of the species, e.g., *W. auropunctata*;
- small size.

Patterns of Distribution and Displacement

The first important result of this study is the evidence showing that, on Floreana, introduced species (especially the earliest introductions) are by no means restricted to human-impacted zones, but have spread over the whole island into natural areas (Table 3). We found 16 species in the natural sampling sites (N1-N4), and 17 in the human-impacted ones (A1-A4). Adding the sampling sites in the littoral zone and the species found outside sampling sites, we collected a total of 17 species in the natural zone. The human-impacted zone seems to have a somewhat higher species richness, since we found 23 species there.

On the one hand, the biological characteristics of tramp species make them successful competitors of native ant species. On the other hand, the probable existence of empty niches may also facilitate the progression of these species into natural zones. Indeed, the extremely poor native ant fauna (three to seven species) leads to the hypothesis that the ant community was far from being saturated and several potential niches were not yet occupied by any ant species. This has certainly facilitated the colonization and establishment of introduced ants on the islands.

Table 2. Ant species found on Floreana during this study.

- A Species recorded on Floreana by early collectors. Based on works of Smith (1883), Emery (1893), Wheeler (1919, 1924, 1933), and Stitz (1932).
 B Species recorded on Floreana in recent works. Based on unpublished data of M. Coulter and M. Alvarez (1982) and Y. Lubin and M. Alvarez (1983), which were kindly made available from Y. Lubin.
 C New for Galápagos (this study)
 D Status in Galápagos. E = Endemic; N = Native; N/I = Possibly native; OI = Old introduction; RI = Recent introduction.
 E Cosmopolitan tramp species. Some authors give a different distribution (cosmopolitan vs. pantropical) for these tramp species.
 F Pantropical tramp species
 G Mean body length of workers. Size classes: I < 2.5 mm; II 2.5-4 mm; III > 4 mm.

Ant species	A	B	C	D	E	F	Probable origin (only for tramp species)	G
<i>Hypoponera</i> sp. A ¹		(x)		?				II
<i>Hypoponera</i> sp. B				?				II
<i>Odontomachus bauri</i> Emery ²	x	x		N/I				III
<i>Cardiocondyla emeryi</i> Forel		x		RI		•*	Africa (Wilson and Taylor 1967)	I
<i>Cardiocondyla nuda</i> (Mayr)		x		RI		•*	Africa (Wilson and Taylor 1967)	I
<i>Monomorium destructor</i> (Jerdon)			•	RI		•*	India (Bolton 1987) Africa (Wilson and Taylor 1967)	II
<i>Monomorium floricola</i> (Jerdon)	x	x		OI		•*	Tropical Asia (Emeryi 1921 in Wilson and Taylor 1967)	I
<i>Pheidole</i> sp. A ³				?				II
<i>Pheidole</i> sp. B				?				I
<i>Quadristruma emmae</i> (Emery)			•	RI		•	Afrotropical region (Bolton 1983)	I
<i>Solenopsis geminata</i> (Fabricius)	x	x		N/I	•**		North to South America (Trager 1991)	II
<i>Solenopsis globularia</i> (F. Smith) subsp. <i>pacifica</i> W. M. Wheeler		x		N				I
<i>Solenopsis</i> sp. ⁴		(x)		?				I
<i>Strumigenys louisianae</i> Roger ⁵				N/I				I
<i>Tetramorium bicarinatum</i> (Nylander)		x		OI	•		South East Asia (Bolton 1979)	II
<i>Tetramorium caldarium</i> (Roger)			• ⁶	OI	•		Africa (Bolton 1979)	I
<i>Tetramorium lanuginosum</i> Mayr			•	RI	•		Asia (Bolton 1976)	II
<i>Tetramorium simillimum</i> (F. Smith)	x	x		OI	•		Africa (Bolton 1979)	I
<i>Wasmannia auropunctata</i> (Roger)		x		RI	•*		American Tropics (Ulloa-Chacón and Cherix 1990)	I
<i>Tapinoma melanocephalum</i> (Fabricius)		x		OI		•*	Unknown (Wilson and Taylor 1967) African or Oriental origin (Smith 1965)	I
<i>Camponotus macilentus</i> F. Smith	x	x		E				III
<i>Camponotus planus</i> F. Smith	x	x		E				III
<i>Paratrechina longicornis</i> (Latreille)	x	x		OI		•*	Old World Tropics (Wilson and Taylor 1967)	II
<i>Paratrechina</i> sp. ⁷		(x)		?				II

* Tramp species in strict sense, showing all typical characteristics (Passera 1994)

** Cited in Passera, with special mention

¹ Possibly *Hypoponera opaciceps* (Mayr)² Widespread in Central and tropical South America (Brown 1976)³ Possibly *Pheidole williamsi* Wheeler⁴ Belongs to the subgenus *Diplorhoptrum*⁵ Widespread in the Americas (Brown 1962)⁶ Cited in Brandão and Paiva (1994), with reference to Clark *et al.* (1982), who did not publish these results⁷ Possibly *Paratrechina vaga* (Forel)

The second important result of this study is that the immigration of new ant species still continues. This could be due to the extraordinary increase in commercial exchanges and the dramatic development of tourism. In this study, four new ant species for the Archipelago have been detected, of which three, *M. destructor*, *Q. emmae*,

and *T. lanuginosum*, are believed to be very recent introductions.

The present distribution of ants on Floreana cannot be described as a static state, but rather as a state of transition, meaning the current situation will probably continue to change in the following years. This means, in addition

Table 3. Distribution of ants on Floreana Island.

• found at bait ◊ found in pitfalls Δ only by visual search (never in traps)

Species	Sampling sites								ΣN	ΣA	LL	LM	LC	ΣL	Σ
	N1	N2	N3	N4	A1	A2	A3	A4							
<i>Hypoponera</i> sp. A	◊	◊			•◊	◊			◊	•◊					•◊
<i>Hypoponera</i> sp. B															Δ ¹
<i>Odontomachus bauri</i>	◊	•◊	•◊			◊	•	Δ	•◊	•◊	◊			◊	•◊
<i>Cardiocondyla emeryi</i>			•◊	•◊			•◊	•◊	•◊	•◊			•◊	•◊	•◊
<i>Cardiocondyla nuda</i>		◊			•		•◊		◊	•◊					•◊
<i>Monomorium destructor</i>								•◊		•◊					•◊
<i>Monomorium floricola</i>		•◊	•	•◊		•◊	•	◊	•◊	•◊	•◊		•◊	•◊	•◊
<i>Pheidole</i> sp. A											◊			◊	◊
<i>Pheidole</i> sp. B													Δ	Δ	Δ
<i>Quadristruma emmae</i>		◊							◊						◊
<i>Solenopsis geminata</i>	•◊	•◊			•◊	•	•	•◊	•◊	•◊			•◊	•◊	•◊
<i>Solenopsis globularia</i> subsp. <i>pacifica</i>			•◊	•◊				•◊	•◊	•◊	•	•◊	•◊	•◊	•◊
<i>Solenopsis</i> sp.	Δ	◊			•	•◊			◊	•◊	◊	•◊		•◊	•◊
<i>Strumigenys louisianae</i>						◊					◊				◊
<i>Tetramorium bicarinatum</i>						•◊					•◊	◊	•◊	•◊	•◊
<i>Tetramorium caldarium</i>		•◊	•◊				•◊	•◊	•◊	•◊	•			•	•◊
<i>Tetramorium lanuginosum</i>											◊			◊	◊
<i>Tetramorium simillimum</i>	•◊	•◊	•	•	•	•◊	•◊		•◊	•◊	•◊			•◊	•◊
<i>Wasmannia auropunctata</i>															Δ
<i>Tapinoma melanocephalum</i>			•◊	•◊	•	•	•	•	•◊	•	•◊	•◊	•◊	•◊	•◊
<i>Camponotus macilentus</i>			•◊	•◊			◊	•◊	•◊	•◊	•◊	•◊	◊	•◊	•◊
<i>Camponotus planus</i>				•◊					•◊				◊	◊	•◊
<i>Paratrechina longicornis</i>		•◊						•◊	•◊	•◊	•	•◊	•◊	•◊	•◊
<i>Paratrechina</i> sp.		•				•◊			•	•◊	•			•	•◊
Species found at bait	2	7	8	7	6	7	8	8	12	16	8	6	7	12	17
Species found in pitfalls	4	10	6	6	2	8	5	8	15	16	6	7	9	14	21
Species found only visual	1							1	1	1			1	1	3
Total of species	5	11	8	7	6	10	9	10	16	17	10	8	10	17	24

¹ Found by visual search outside the sampling sites, in a sugar cane field

² Found by visual search outside the sampling sites, in the highlands

to distribution in space, we must consider distribution in time, and thus the possible dynamics of the introduced species.

Several aspects play a fundamental role in the interpretation of the distribution of introduced species: supposed introduction time and sites, different dispersal ways, and environmental pressure.

Supposed Introduction Time

Knowing the introduction time of a species could reveal if it had the possibility to express its ecological potential.

All tramp species collected on Floreana in early expeditions (see Tables 2 and 3), namely *Monomorium floricola*, *T. simillimum*, and *Paratrechina longicornis*, are now distributed all over the island. *Odontomachus bauri* and *Solenopsis geminata* show the same patterns (*S. geminata* is only absent in the natural arid zone).

Restricted distribution of some species may indicate a recent introduction (e.g., *M. destructor*, see below).

Supposed Introduction Sites

The presence of a species exclusively at a possible introduction site could be an indicator for a recent introduction, which has still not had the time for colonizing other areas.

This is the case of *M. destructor*, *T. lanuginosum*, and *Pheidole* sp. A, which were found only in or near the village Puerto Velasco Ibarra, where ships regularly bring all supplies. *Pheidole* sp. B was only found at Punta Cormorant, which is a highly visited tourist site.

Moreover, since many goods arriving by ship are transported directly to the highlands, it is necessary to consider this area as an additional introduction site for new species. This way of introducing new species may play a major role for those species which would not have been able to survive and establish themselves in the littoral or arid zones. Possible examples of such introductions are *S. louisianae*, *Q. emmae*, and *W. auropunctata*, which were collected in the humid zone only.

Tetramorium bicarinatum is a particularly good example for demonstrating the importance of introduction sites. It was found only at human-impacted littoral sites and in the highland cultivated zone. This is probably not dependent on environmental conditions, since it is recorded in the arid zone of other islands (Clark *et al.* 1982).

Dispersal

Once species have established themselves on the island, the question is whether or not these species will spread into adjacent areas. There are three different ways for ants to reach and colonize new areas: nuptial flight, budding, and passive transport.

By way of nuptial flight, alate sexuals normally leave the nest and mate. Afterwards mated queens can found

new colonies several meters or even kilometers away, especially with the help of wind. We observed this type of dispersal by *C. macilentus* and *O. bauri*.

By budding, workers and mated queens leave the nest on foot and establish themselves few meters away. This form of spreading is slower and does not allow colonization of distant areas, but it is more thorough (Passera 1994). As indicated, several tramp species do not have a nuptial flight and disperse solely by budding (Passera 1994). Workers together with dealate females of *T. simillimum* and *Cardiocondyla emeryi* were collected with pitfall traps (*T. simillimum* with bait as well). This perhaps indicates the presence of budding behavior.

Peck (1994a, 1994b) studied aerial dispersal and sea surface transport of insects between islands in the archipelago. He collected 6 or more species belonging to the genera *Paratrechina*, *Cardiocondyla*, *Monomorium*, *Pheidole*, *Hypoponera* and *Camponotus*, either using aerial dispersal or sea-surface transport. These two modes of colonization could be of great importance for ants, especially if female sexuals (i.e., mated queens) reach a new island. A comparison of ant diversity between inhabited, visited and unvisited, and uninhabited islands will be decisive to adjust the importance of these types of colonization.

The last means of dispersal in Galápagos is passive, due to humans. Passive transport represents the only way for long-range dispersal. Humans are responsible for dispersing tramp species within Floreana, e.g., from littoral sites to humid cultivated areas in the highlands (transport of goods between these areas is quite frequent) or within a single zone, which could be the case with *W. auropunctata*. In comparison with Lubin (1985), we found another population of *W. auropunctata* in the cultivated area, probably displaced by humans (the previous population is located around the most important fresh water source of the island and transports to and from this site are frequent).

Environmental Pressure

We suppose that the extreme conditions prevailing in the arid zone (aridity and high temperatures) may be a limiting factor for some introduced species, or at least a factor which prevents them from dominating. Our observations and measurements at the sampling sites of the natural area show that the situation there is quite close to an "original natural picture," with *C. macilentus*, *C. planus*, and *S. globularia* subsp. *pacifica* as dominant species. Since their arrival to the Archipelago a long time ago, these species have had time to adapt to the harsh conditions prevailing in the arid zone.

S. geminata and *C. nuda*, which did not occur in the natural arid zone, were found in the corresponding human-impacted area, where humidity was present (e.g., sprinkling, water sources).

The lability of man-made environments could be a possible explanation for the observation that these habi-

tats were often not dominated by a single species, as in natural zones, but that several species were quite abundant. Disturbance could therefore partially be interpreted as a factor which "resets" conditions to their starting point each time, thereby preventing the best-adapted species from dominating.

Finally, fluctuating weather patterns might also be of great importance. Wet years may increase dispersal, as already shown by Lubin (1985).

Assessment of Collecting Methods

From our results, it can be seen that pitfall traps represent a valid collecting method for deriving an index of diversity, in this case species richness (but see Seifert 1990). Indeed, among the 24 ant species collected on Floreana, 21 were collected with pitfall traps. The exposure time of two weeks should not be shortened, as sometimes only a few ants were collected, with some species represented by a single specimen.

The aim of the study is to obtain a more detailed picture of the area (i.e., information on distribution, activity, and dominance of a single species), so baiting methods must be used in combination with pitfall traps. The applied methods permitted us, with a relatively small effort, to learn what is happening among ants on Floreana.

The best bait was honey, which, in spite of being less attractive than tuna in oil to most of the species, recorded the larger number of ant species. Also, time expenditure was smaller for honey, both in preparing the bait and in analyzing the collected ants.

A shorter exposure time than we used (17 hours) is recommended for future investigations. In fact, confirmed by controls, a shorter exposure time of 6 to 8 hours would still allow ants to colonize the bait, but would avoid the bait being emptied.

A division of the baiting procedure into diurnal and nocturnal parts would be worthwhile, especially in the arid zone, where dominant ant species vary from day to night. Baiting in the daytime should end at dusk, whereas bait for the nocturnal trapping should be collected well before sunrise.

The sample sites were relatively small in size, but may be representative due to a certain uniformity of the chosen natural zones. This is not necessarily true for the man-impacted sites, where the heterogeneity of the habitats was considerable. The sites were nonetheless useful for obtaining an idea of how human-made environments can influence the ant fauna.

CONCLUSION

Our investigation shows that most of the introduced ant species occupy natural zones of Floreana.

In comparison, the case of the Hawaiian Islands is a dramatic example. The ant fauna, composed entirely of alien ants, has had a devastating effect on the native ter-

restrial fauna (Reimer 1994) (directly or indirectly, by symbiotic relationship with Homoptera). *W. auropunctata* is already an example of an aggressive tramp species that was recently introduced to Galápagos and has had a big impact on the native arthropod fauna (Lubin 1984). The absence of the endemic *Camponotus planus* in Puerto Velasco Ibarra is probably the consequence of the aggressive nature of *M. destructor*, whose future development should be closely investigated.

The methods applied in this study resulted in both qualitative and quantitative data, allowing us, with relatively little effort, to obtain a reasonable picture of the processes on one island. Until now, only a few studies using comparable methods have been conducted on the insect fauna of Galápagos, and our study may be a first step in the development of standardized methods for further investigation of ants in the Galápagos Islands.

It will now be necessary to follow future developments in the ant fauna on Floreana (e.g., *M. destructor*, *T. lanuginosum*, and *Q. emmae*).

The next step should definitively compare other islands, inhabited as well as uninhabited ones, in order to obtain data which allow a prediction of ant population dynamics. Recent groups of arthropods may act as good indicators for predicting medium-term consequences and possible further developments of an ecosystem, since they react rapidly to small disturbances.

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SCAVENGING BEHAVIOR OF THE WAVED ALBATROSS IN GALÁPAGOS: A POTENTIAL PROBLEM WITH INCREASING LONGLINING?

By: **Godfrey Merlen (reprinted from Pacific Seabirds¹)**

In 1994, the population of waved albatross (*Diomedea irrorata*) was estimated at 15,000 breeding pairs (Anderson 1995a). Well over 99% of their breeding activity is confined to Española Island in the Galápagos Archipelago. By attaching satellite transmitters to breeding birds during the incubation period, Anderson (1995b) was able to show that his sample (n=5) foraged over the continental shelf off Peru. However, the present report of a census carried out later in the same year shows that scavenging near the Galápagos Archipelago may also be an important part of waved albatross feeding. The proposed introduction of new fishing techniques (longlining and squid fishing) near the islands could result in a new conservation problem in an already beleaguered archipelago.

An unpublished report by the author on the occurrence and feeding activities of the waved albatross suggested that the birds are, to a greater or lesser extent, scavengers when in the waters near the archipelago during the breeding season. An excellent opportunity to further these observations on the distribution and scavenging behavior of waved albatross came when the author was asked by David Parer and Elizabeth Parer-Cook, of the Australian Broadcasting Corporation, to accompany them on a reconnaissance trip to the western part of the archipelago, aboard the motor yacht *Samba* between 1 and 14 September 1995. We maintained a dawn-to-dusk survey on nine full days. On the other days, the *Samba* was anchored or made short journeys. Observations were made on these short trips also. The survey was carried out mainly by two observers (G. Merlen and David Day), using 8x binoculars, but additional help was provided by the crew of the *Samba*, Naturalist Guide Mauricio Garcia, and by D. Parer and E. Parer-Cook. There was an excel-

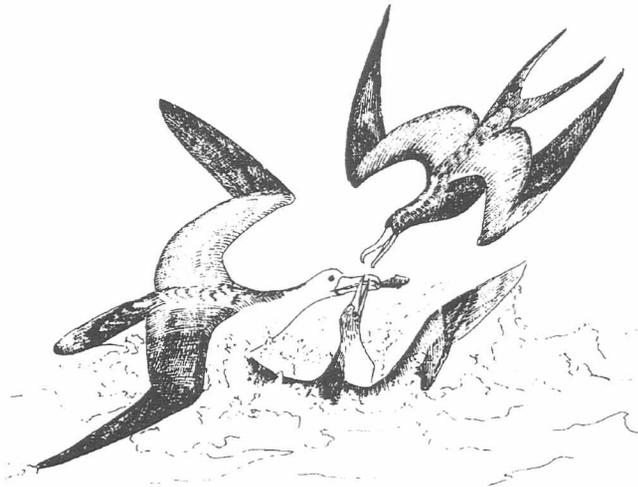
lent observation platform in the form of the flying bridge 3.5 m above sea level.

During the mostly calm weather, the distinctive white heads and necks of the waved albatross facilitated observation on the sea. Higher winds caused the birds to soar above the horizon, which aided the count in more adverse conditions. We avoided counting birds twice by only searching ahead of the boat. Whenever the boat stopped, circled, or made other maneuvers, the census was ended.

Where large concentrations of albatross were encountered, several counts were made by independent observers. After leaving such an area, no counts were made for half an hour. The average speed of travel was 8 knots and all positions were plotted by GPS.

Albatross in flight were usually alone, although a few to many were often in the same area. On the water small groups (1-3) were common.

By far the greatest concentrations were found where blue-footed boobies (*Sula nebouxii*) were or had recently been feeding. On one occasion, 389 albatross were closely associated with several other species in a feeding frenzy. Such activities were frequent offshore in deep water, when magnificent frigatebirds (*Fregata magnificens*), common dolphins (*Delphinus delphis*), blue-footed boobies, masked boobies (*Sula dactylatra*), waved albatross, white-vented storm petrels (*Oceanites gracilis*), wedge-rumped storm petrels (*Oceanodroma tethys*), and Galápagos sea lions (*Zalophus californianus*) were present. Inshore (in shallower water or between the central islands) bottle-nose dolphins (*Tursiops truncatus*) may replace common dolphins. Feeding frenzies are associated with concentrations of fish, which include tunas, sardines, jacks and sharks (pers obs.).



The development of a feeding frenzy seemed a fixed pattern. Dolphins found the food and blue-footed boo-

bies followed overhead. Once the food was accessible to the birds, they began to dive on it. Frigatebirds, which had kept up, often at considerable height, then descended to mob the boobies, causing them to disgorge their recently gathered fish; if this occurred, the fish was eaten by the frigatebirds. Albatross, which were present in these associations, also tried to take advantage of the melee by moving in and grabbing at the disgorged food. This was observed on dozens of occasions. We saw up to four albatross around one "downed" booby. Albatross did not seem to mob the boobies initially, but appeared to depend on the aggression and flying ability of the frigatebirds. Storm petrels picked up whatever morsels were left over.

These feeding activities were highly dynamic and moved over the ocean at speeds of up to 3-4 knots. Some lasted for hours, but many broke up after 20 minutes or so. Prediction of such events is extremely difficult, as the productivity of the region is controlled by upwellings and

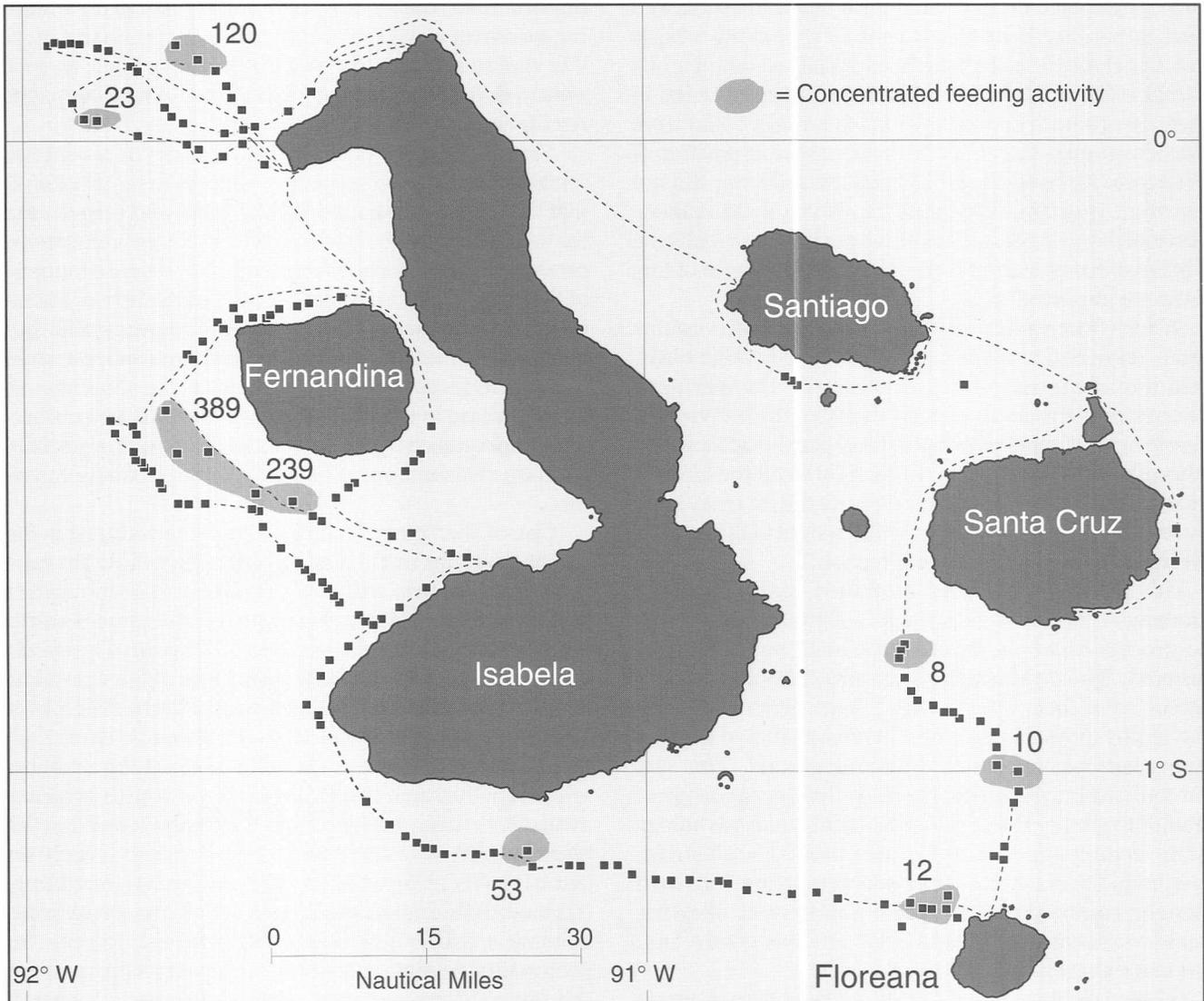


Figure 1. Survey route of the yacht *Samba* in the western part of the Galápagos Archipelago 1-14 September 1995. Locations of observations of waved albatross and of feeding concentrations are shown on survey route track.

fronts between water masses, which are unpredictable and unstable in themselves. On two consecutive days we found boobies and albatross in the same area to the south of Cape Hammond (southwest Fernandina). However, the great concentration along the equator was ephemeral and not repeated over three further days of observation. Perhaps it was due to changes in oceanic conditions or perhaps it was because on the first day (7th September) we witnessed an attack (0°09.4'N 91°44.0'W) by 7 orcas (*Orcinus orca*) on the feeding common dolphins. They killed at least one dolphin, and the small pieces that remained were scavenged by storm petrels, frigatebirds and albatross. Albatross also scavenged a large dead squid (0°19.9'S 91°43.4'W), later identified as *Angistrocheirus lesevri*. Large concentrations of albatross were always associated with feeding frenzies.

During the 24 days of observations (the cumulative time of the two reports), not a single albatross was seen feeding on live prey. Harris (1973) reported that the main food of breeding waved albatross was fish and squid. Since blue-footed boobies do not eat squid, the albatross must gather this themselves or gather it from other birds that frigatebirds attack such as swallow-tailed gulls (*Creagrus furcatus*). Some of the fish (Clupeids) found in albatross stomach contents in Harris's study could have been scavenged. Harris (1973) observed the interaction of albatross with boobies and felt that this behavior did not contribute greatly to their diet. However, the frequency with which we observed this albatross behavior leads me to believe that at least at times, or at certain stages of life, it may be important.

When concentrated feeding by boobies and dolphins began, it seemed to act as a signal, sucking in other birds, including albatross, from a great distance. The spacing of the birds over the ocean seemed such that the individuals were in sight of their neighbors at any particular moment, although not necessarily in direct sight of all the birds in the area. The movement of those nearer the fray may have caused others, further away and not in sight of the feeding activity, to move in the same direction.

This process sometimes continued until very large numbers of boobies were present (> 1000), although often the process broke up before such large accumulations gathered. Thus, although many solitary boobies and albatross were seen, spaced over a huge area of ocean, it was highly probable that they were capable of quickly joining various concentrated feeding groups. This system could be important, as it would allow a population of boobies to survey the ocean and quickly take advantage of any feeding opportunity that occurred. The albatross, clued in to the reaction of the boobies or using their own eyesight, could take advantage of this system, allowing them to scavenge more efficiently in areas where food was more abundant.

Masked boobies (*Sula dactylatra*), the other common diving sea bird near the islands, were not a major feature of the feeding activity and they never represented more

than 5% of the boobies feeding. The figure was often as low as 2%.

It is not easy to ascertain the exact relationship of the organisms involved in feeding frenzies, because, in the Galápagos, common dolphins are very nervous of the close approach of vessels. This may be due to the presence of purse seine tuna boats, which often set their nets on the dolphins, because tunas associate with them. Or perhaps any strange noise alarms them since their predator, the orca, is present year round.

It seems that the waved albatross is, at least at some times, a scavenger. From the duration of the observations and their limitation to daylight, it is not possible to say how important this method of feeding is, nor is it possible to state the importance of feeding frenzies, even though this feeding technique is extremely common. Should it be important, then the availability of food to scavenge has to be maintained. This, in turn, means that the structure of feeding frenzies and the well being of all their components (fish, dolphins, boobies, frigatebirds) may be of importance to the feeding, and, ultimately, to the breeding success of waved albatross. In this uncertain situation, it is vital to maintain the viability of this pelagic trophic system that is found in the western part of the Galápagos Archipelago.

One of the reasons that the marine environment has remained relatively untouched until the last few years is that the fishing fleet has been slow, local, and primitive in the techniques used. At present (1996), there is enormous pressure to allow local fishermen to increase the tonnage of their fleet. This is in part because of the lure of anticipated riches in the ocean in the form of migratory fish, but also because the conservation of coastal marine resources requires reduced fishing pressure near the shoreline. A large increase in the fleet could have serious and unforeseen consequences for the marine environment, especially if strong measures are not taken to control fishing activities.

One of the "new" techniques to be introduced is the use of longlines to harvest the valuable yellow fin tuna (*Thunnus albacares*) and other pelagic fish in the waters surrounding the Archipelago. As it is, longliners are already arriving from the mainland of Ecuador. The effects of longlining on albatross in other parts of the world has been catastrophic (e.g., de la Mare and Kerry 1994, Gales 1993.). Albatross scavenge from the baited hooks as they enter the water. It is not known whether waved albatross will adopt the same habit once this food source becomes available to them. However, with the knowledge that the birds are not only scavengers, but also feed largely on squid (Harris 1973), which is a popular bait for longlining, it is inadvisable to ignore the effects that may result from opening a fishery without further studies. In order to protect the assemblage of animals that may help to ensure the future of the endemic waved albatross, an overall protection should be given to the waters within the Marine Reserve (15 nautical miles seaward from the perimeter

of the Archipelago) by prohibiting potentially dangerous fishing techniques within this area. This is not only for the protection of single species, but for the well being of the ecosystem.

I would like to thank David Parer and Elizabeth Parer-Cook for giving me the opportunity to travel with them. Also to the crew of the *Samba* for the use of their keen eyes and especially to David Day.

My appreciation is also extended to Dr. Mike Harris and Dr. Sarah Wanless for their help in preparing this manuscript.

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Godfrey Merlen, Puerto Ayora, Galápagos.

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GALÁPAGOS PLUMOLOGY

By: Karen Harpp and Dennis Geist

INTRODUCTION

Although the Galápagos Islands are best known as one of the world's greatest natural laboratories for biological studies, they have also lent considerable insight into the dynamics of the earth's interior. Modern accounts of the geologic origin of the Galápagos Islands, including popular descriptions (e.g., Boyce 1994, Jackson 1990), attribute their formation to a "hotspot" or "mantle plume." The term "hotspot" refers to localities where volcanoes occur in the middle of one of the earth's great tectonic plates; hotspots are unusual, because over 90% of the world's volcanic activity occurs at plate boundaries. It is thought that hotspots result from "mantle plumes," conduits of hot, plastic (but not molten) rocks that ascend from deep within the earth's mantle (Figure 1). As these plumes of hot rock rise to depths of about 100 km from earth's surface, they begin to melt. When the melted fraction of the rock reaches several percent, it segregates from the rock (like water being squeezed from a damp sponge), eventually erupting to form volcanoes. No one knows the depth to the roots of mantle plumes, but most geologists believe they come from a layer in the earth's mantle either at 650 km or from the bottom of the mantle at 2700 km depth. Recent work on Galápagos lavas has identified some problems with the simple mantle-plume theory, but has taught us much about the origin, composition, and behavior of hotspots.

THE GALAPAGOS HOTSPOT

Although the Galápagos were proposed as resulting from a mantle plume early in the development of the theory (Morgan 1972), there are two problems with the simple plume model when it is applied to Galápagos. First, at more conventional hotspots such as Hawaii and Yellowstone, only one to four volcanoes at the young "upstream" (in terms of plate motion) end of the chain are active. In contrast, nearly all of the Galápagos islands have erupted in the recent geologic past, regardless whether they sit at the easternmost, or oldest, end of the chain, or at the westernmost, or youngest, end of the archipelago.

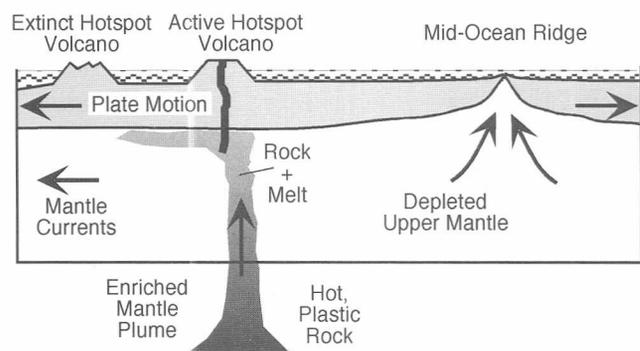


Figure 1. Cartoon of a simple plume rising from the lower mantle. The plume is a plastic solid which begins to melt as it nears the bottom of the overlying plate.

Second, the compositions of Galápagos magmas are unusual for hotspots. Generally, basalts erupted from hotspot volcanoes are compositionally distinct from those erupted in other tectonic environments, and each volcano evolves in a compositionally similar way. Galápagos lavas exhibit a wider range of chemical compositions than is usual, and compositional differences are more related to the volcanoes' location than to their stage of development.

Some of these complexities may arise from the fact that the Galápagos hotspot lies only about 100 km from the Galápagos Spreading Center, an active mid-ocean ridge. Great volumes of magma are produced beneath mid-ocean ridges, and in the islands these appear to contaminate the hotspot magmas produced by the Galápagos plume. Furthermore, the plates are strongly fractured, thin, and weak near mid-ocean ridges, which may permit magmas to ascend through the plate and erupt in places where they would not normally reach the surface.

This contribution describes recent studies using isotopic ratios of the elements lead, strontium, and neodymium, which have shed some light on the structure of the Galápagos hotspot and the dynamics of mantle plumes.

GEOCHEMISTRY OF PLUMES

Before considering the details of the isotopic ratios of Galápagos lavas, we shall describe how they are used as a diagnostic tool in studies of volcanic systems. Some naturally-occurring elements are radioactive, which means that their nuclei decay spontaneously into nuclei of other elements. The isotopes we focus on have half-lives (the time for half of the nuclei to decay) of billions of years. The original radioactive element is called the "parent" isotope, and the element resulting from the decay transformation is referred to as the "daughter," or "radiogenic," isotope. For example, naturally-occurring rubidium of atomic mass 87 (^{87}Rb) is radioactive and decays to produce strontium of atomic mass 87 (^{87}Sr) with a half-life of 50 billion years.

Isotopes such as ^{87}Sr and ^{87}Rb are useful in the study of young magmas such as those of the Galápagos hotspot because of processes that have taken place over the course of geologic time. This concept is best illustrated by tracking the behavior of a typical parent-daughter isotope pair through the early part of earth history. The elements Rb and Sr, for example, were partly segregated from each other when the continental crust formed from magma made by partial melting of the earth's mantle billions of years ago. When rock begins to melt, larger ions migrate preferentially into the liquid fraction, with the smaller ions remaining behind in the residual solid. Because Rb^+ is a larger ion than Sr^{2+} , more Rb^+ partitions into the melt than Sr^{2+} (Figure 2A). It is simplest to consider the variations of the Rb/Sr ratio during melting; the melt that goes on to form the crust will have higher Rb/Sr relative to the source material, and the rock left behind in the mantle will have relatively lower Rb/Sr (Figure 2B).

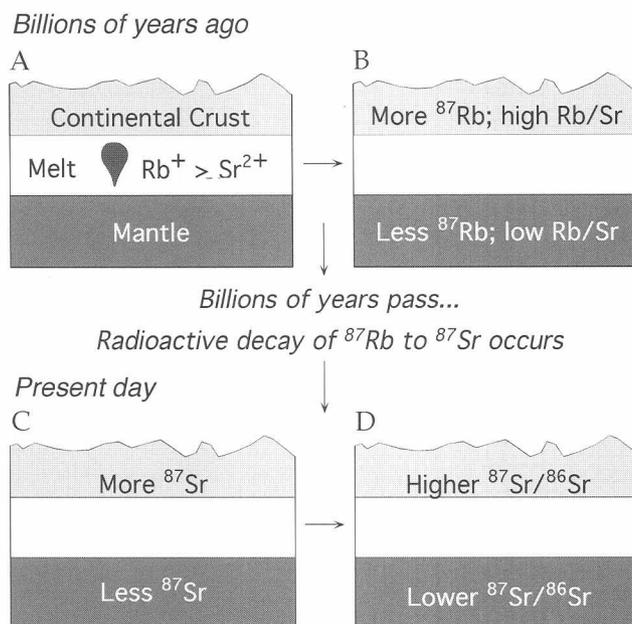


Figure 2. Schematic diagram showing how the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of the crust and the depleted mantle have evolved and changed with time.

The continental crust began to form about 4 billion years ago, and, as time passed, some of the radioactive ^{87}Rb isotope decayed, producing increasing amounts of ^{87}Sr . Meanwhile, in the part of the mantle depleted of melt, where there was less ^{87}Rb , less ^{87}Sr was produced during the same time (Figure 2C). When abundances of isotopes are determined, the concentration of the daughter isotope (^{87}Sr) is measured with respect to another isotope of the same element whose abundance in the earth has not been affected by radioactivity (e.g., ^{86}Sr). Thus, as a result of the melting process and the passage of billions of years, the old continental crust has a distinctly higher $^{87}\text{Sr}/^{86}\text{Sr}$ ratio than does the depleted mantle (Figure 2D).

A very important aspect of such isotopic systems is that present-day geologic processes, such as weathering, melting, and solidification, are incapable of changing the ratios of isotopes of the same element (for example, $^{87}\text{Sr}/^{86}\text{Sr}$). This is because natural chemical and physical processes do not differentiate between isotopes of these heavy elements. Moreover, in young magmatic systems, the time for decay of the radioactive parent isotopes is very long relative to the ages of the erupted material. In other words, although a partial melt has a higher $^{87}\text{Rb}/^{86}\text{Sr}$ ratio than the rock it leaves behind, the melt and rock have identical $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, until many millions of years have passed.

Because oceanic basalts derive directly from the earth's mantle, the isotopic ratios of the basalts faithfully record the isotopic ratios of the mantle, thus serving as a "fingerprint" of their mantle sources. Several other isotopic systems are similar to the Rb-Sr system, including the samarium-neodymium (Sm-Nd) and uranium-thorium-

lead (U-Th-Pb) systems; for these we measure present day values of $^{143}\text{Nd}/^{144}\text{Nd}$, $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$.

Lavas erupted from mid-ocean ridges such as the Galápagos Spreading Center have isotopic fingerprints identical to the melt-depleted mantle. The source of mid-ocean ridge lavas is known to be shallow, thus the upper mantle is the isotopically-depleted material left over from formation of the continental crust. Ocean island lavas have distinctly higher Sr and Pb ratios than depleted mantle values, and lower Nd ratios (^{147}Sm , the parent isotope, is smaller than its daughter isotope ^{143}Nd ; this size relationship is opposite to that in the Rb-Sr system described above). It follows, then, that ocean islands are "enriched" relative to the depleted mantle and cannot have been derived from it; they must come from mantle that was not depleted by melting early in earth's history, or from depleted mantle that was re-enriched at least a billion years ago. Other evidence suggests that ocean island lavas come from the lower mantle, which must therefore be isotopically enriched.

Not all magmas come from a single source. Some magmas originate from parts of the earth where two sources have mixed prior to melting, and some magmas form by mixing melts from two separate sources. If two materials with different isotopic ratios are mixed, the hybrid will exhibit an intermediate isotopic ratio that is the weighted average of the two components. In other words, in a geologically young system where time does not alter the isotopic ratios significantly, such as the Galápagos, we can use isotope ratios to determine the sources of the magmas. We have taken this approach in the Galápagos.

THE TOROIDAL AND BENT PLUME MODELS

Early work on the compositions of Galápagos lavas indicated that they are unusual for a hotspot (McBirney and Williams 1969, Baitis and Swanson 1974). In particular, it was shown that some Galápagos lavas have compositions essentially identical to those of mid-ocean ridge lavas, whereas others have more typical hotspot compositions. White and Hofmann (1979) made the key observation that lavas from Santiago, Santa Cruz, and San Cristóbal in the central part of the archipelago have isotopic compositions that suggest the magmas were derived from the shallow depleted mantle, the same source as mid-ocean ridge magmas, with little hotspot contribution. Most lavas from the west, north, and south, in contrast, have more typical hotspot-like isotopic signatures, with higher Sr and Pb isotopic ratios, and lower Nd ratios.

Geist *et al.* (1988) subsequently obtained more detailed isotope data from the archipelago. They added to White and Hofmann's observations by backtracking older volcanoes to their location at the time of eruption, to account for the drift of the volcanoes by plate tectonics. For ex-

ample, lavas from Santa Fe are nearly 3 million years old. Because the plate on which the Galápagos Islands lie is moving about 5 cm/yr to the east, then at the time that Santa Fe was active, it was located about 150 km to the west of where it is now, approximately where Fernandina is currently. When the isotopic data were corrected for plate motion, a horseshoe-shaped pattern emerged, with the hotspot-like component increasingly concentrated to the north, south, and west, and the shallow-mantle component focused along the central axis of the archipelago.

This observation presented a substantial problem. One could easily imagine a rising plume being polluted by the surrounding mantle as it ascends, but with the contamination occurring mostly around the margins of the mantle plume, just as smoke is progressively diluted with air around the margins of a plume of smoke. Unfortunately, this model would yield exactly the opposite pattern to what is observed in the Galápagos. A breakthrough came from a group of fluid dynamics modellers (Griffiths 1988), who showed that instead of mantle plumes being like a column of smoke above a chimney, they might be more like rising drips or bubbles. The importance of this is that rising drips entrain their surroundings not through their sides, but up through their bottoms, like a smoke ring. This makes a doughnut-shaped torus, with pristine plume material around the margins and entrained shallow mantle in the center (Geist *et al.* 1988).

It was then shown that the toroidal-plume model is unlikely to work in the Galápagos. This is mostly because the fluid dynamicists believe that under the conditions of the earth's mantle, plumes are likely to resemble continuous chimneys; only at their initiation would plumes act like large, ascending drips (Richards and Griffiths 1989). The Galápagos hotspot has been active for at least 20 million years, and maybe as long as 90 million years, so there could be no appeal to the Galápagos plume being in the initiation phase.

With yet more detailed isotopic and age data, White *et al.* (1993) have developed a consistent dynamic plume model. If a continuous, chimney-like plume is bent, like a smoke column in the wind, it can entrain the surrounding material in a horseshoe-shaped pattern (Richards and Griffiths 1989). According to this hypothesis, the Galápagos plume rises beneath Fernandina and is bent to the east by currents in the plastic mantle. As it is dragged along by the overlying plate, the plume's central part is progressively contaminated, or diluted, by the surrounding shallow mantle material.

THE CURRENT MODEL FOR THE GALAPAGOS PLUME

In 1990, a group of researchers carried out a research cruise in the Galápagos to collect submarine lavas erupted onto the Galápagos platform. The fundamental idea behind the project was to determine whether the isotopic pattern throughout the archipelago was consistent with

either the bent plume or the toroidal plume model by collecting samples from submarine volcanoes. If the bent plume model held, then the isotopic pattern should remain a horseshoe, whereas if the toroidal model was more appropriate, the horseshoe should close to a circular pattern with the acquisition of more data to the east of the islands. Remarkably, every newly-acquired lava fit into the existing east-facing horseshoe pattern observed previously (Figure 3), suggesting that the bent plume model was more appropriate for the Galápagos than the toroidal plume model.

The new data also made it clear that Galápagos magmas cannot result from mixing between just two mantle reservoirs, the depleted mantle and the plume source (Harpp, 1995). On a plot of $^{208}\text{Pb}/^{204}\text{Pb}$ versus $^{206}\text{Pb}/^{204}\text{Pb}$, the endmember compositions of a typical mantle and plume are shown (Figure 4A); any mixture of these endmembers must fall along a straight line between the two extreme compositions. Similarly, on a plot of isotopic ratios of two different elements, e.g., $^{87}\text{Sr}/^{86}\text{Sr}$ versus $^{143}\text{Nd}/^{144}\text{Nd}$, the mixing array is hyperbolic, but the hybrids must plot along a single hyperbola (Figure 4B).

The Galápagos data clearly do not fall along simple mixing curves (Figure 4). Principal component statistical analysis indicates that at least four separate, distinct isotopic reservoirs are required to explain the variation in the geochemical data. Four plausible compositions for these sources, when mixed in varying proportions, can produce all of the Galápagos lavas (Figure 5). The four reservoirs have the following characteristics:

- 1) PLUME has an isotopic signature characteristic of ocean island lavas from some other archipelagos, with intermediate Sr, Nd, and Pb ratios;
- 2) DGM (Depleted Galápagos Mantle) has a composition typical of ocean ridge lavas from the shallow mantle throughout the Pacific basin, including the Galápagos

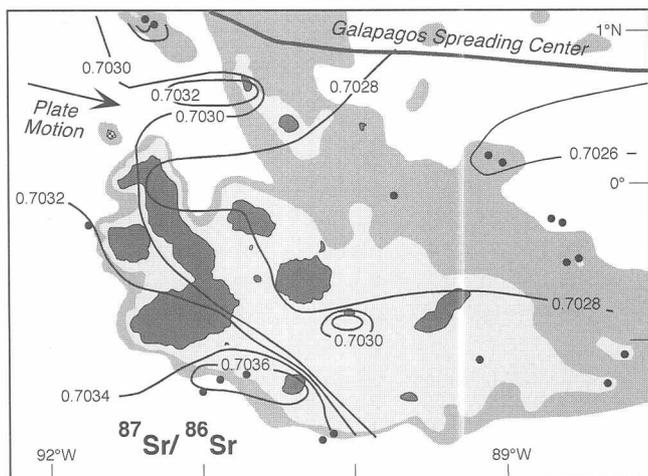


Figure 3. Geographic variation patterns of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in basalts from the islands and seamounts. Samples have been corrected for the distance they have travelled since eruption due to plate motion. Data from Harpp (1995) and White *et al.* (1993).

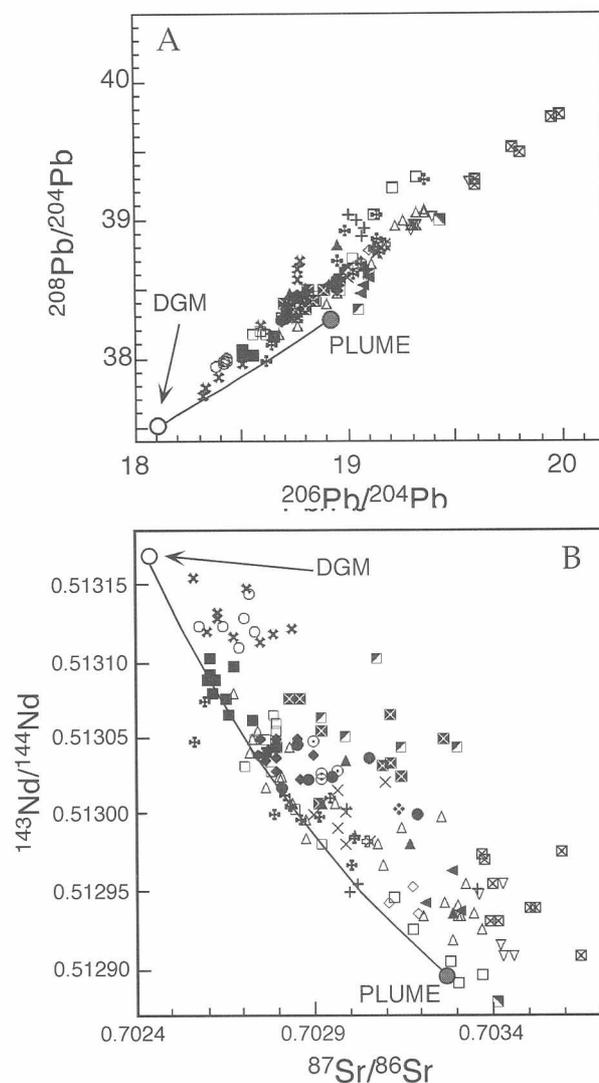


Figure 4. Covariation plots of Pb isotopes (top) and Sr and Nd isotopes (bottom). The typical endmember compositions for a plume (PLUME) and the depleted mantle (DGM) are indicated by the large circles. The line connecting the two endmember compositions is a two-component mixing curve. Symbols for the Galápagos data correspond to different regions of the archipelago; the legend is included with Figure 5.

Spreading Center, with low Sr and Pb isotope ratios, but high Nd;

3) FLO (short for Floreana, where lavas most closely resemble this composition) has elevated Sr and Pb isotope ratios, low Nd, and high concentrations of many trace elements. FLO appears to have been enriched in trace elements within the past 2 billion years and may be a piece of recycled oceanic crust that was subducted and later captured by the upwelling plume;

4) WD has a unique combination of Pb isotopic ratios and appears in lavas from Wolf and Darwin islands and seamounts in the northwestern quadrant of the archipelago. Such signatures are rare in the Pacific basin, and this is clearly the most mysterious of the various sources

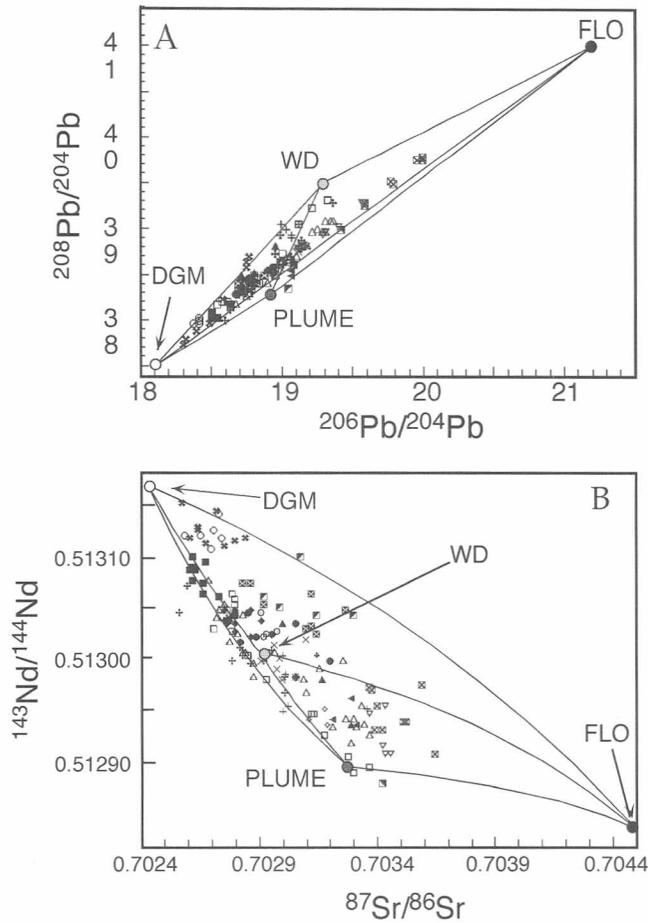


Figure 5. Covariation plots of Pb isotopes (top) and Sr and Nd isotopes (bottom). The compositions for the four component mixing model are shown as the large circles: PLUME, the depleted mantle (DGM), a recycled, enriched composition (FLO), and an anomalous composition observed only on Wolf and Darwin Islands and northeastern seamount areas (WD). Mixing lines are shown connecting the four components. The Galápagos lava data are superimposed on the mixing curves. From Harpp (1995).

of Galápagos magmas. In some ways, WD resembles material collected from the Indian Ocean ridge system thought to be the dregs of the subcontinental mantle. It is, however, a minor component of most Galápagos magmas.

The proportions of the mantle reservoirs that contribute to each volcano are mapped in Figure 6. The major contribution from the PLUME component arises, as expected, in the western part of the archipelago, where the volcanoes are most active. Correspondingly, the contribution from DGM, the depleted mantle, increases continuously eastward and northward, consistent with dilution of the plume away from its center by mantle mixing. The enriched endmember, FLO, is localized in the southwest near Floreana. FLO may be a peripheral part of the plume that was incorporated from a small, highly altered part of the upper mantle. Regardless of its

origin, the pocket of FLO seems to be affected by the same mantle dynamics as the plume, with increasing dilution eastward and northward from its center.

The distributions of both PLUME and FLO illustrate the two primary forces at work in the mantle beneath the Galápagos. First, downstream flow related to currents in the mantle decreases the contributions of PLUME and FLO in the direction of plate motion (approximately east). Second, there is a deep, strong lateral flow of mantle to-

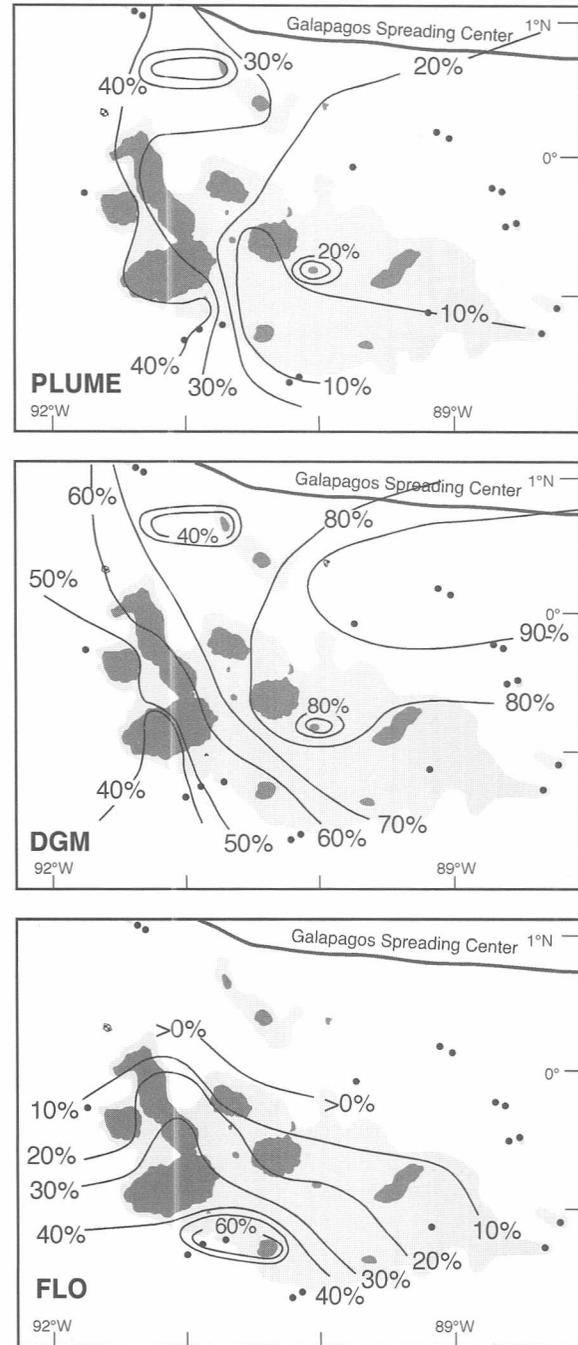


Figure 6. Contours of maximum contributions to Galápagos lavas from three of the proposed endmembers, the plume (PLUME), the depleted mantle (DGM), and the Floreana-like composition (FLO). The 1000 m bathymetric limit is shown.

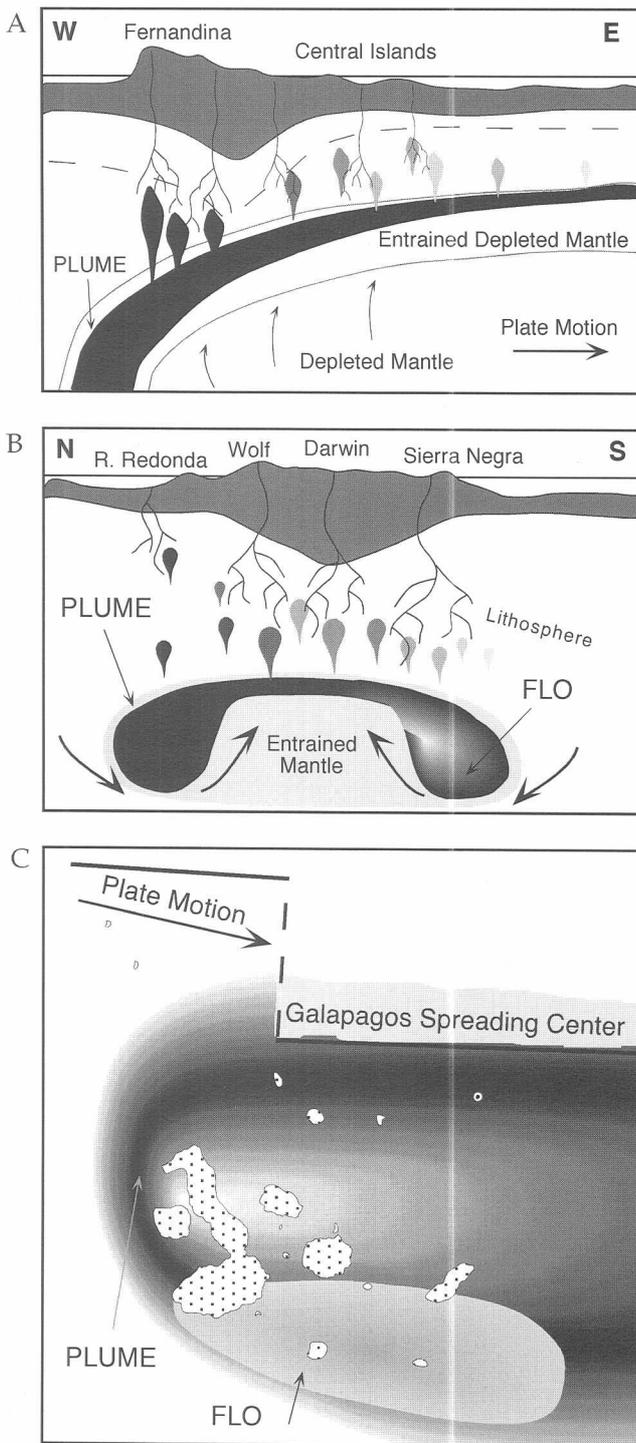


Figure 7. Schematic views of the present model for the Galápagos plume. These are for illustrative purposes, and are not drawn to scale. Black represents pure PLUME; white represents pure depleted mantle (DGM); gradations of grey represent mixing among the components. Arrows trace entrainment of depleted mantle into the plume conduit. A. West-east cross-section of the plume; note the progressive eastward dilution of the bent plume as it entrains depleted mantle; FLO is not shown in this view. B. North-south cross-section in the bent part of the plume (i.e. the main conduit is farther west in this figure). Note that depleted mantle is being entrained into the center of the plume, and FLO is localized in the south. C. Top view of the Galápagos plume, at shallow mantle levels. Flow of plume is eastward, in the

ward the adjacent spreading ridge, feeding mantle which is upwelling beneath the ridge system.

If the hot plume conduit is being bent to the east by mantle flow and plate motion, a pattern consistent with the observed geochemical variations might result. Depleted mantle is drawn into the center of the plume because the plume heats up its surroundings, which become warmer, less dense, and begin to rise into the interior of the bent plume (Figure 7); such effects have been reproduced in laboratory-scale tank experiments. As the plume is progressively diluted with depleted mantle material "downstream," less melting occurs, and the volume of erupted material decreases, accounting for waning volcanic activity to the east within the archipelago (Figure 7).

The decrease in PLUME and FLO contributions to the north may result from interaction of the plume with the adjacent Galápagos Spreading Center. It is clear that Galápagos plume material is being incorporated into the mantle beneath the Galápagos Spreading Center, based on plume-like signatures in lavas erupted along the ridge. The upwelling currents feeding the ridge may be responsible for transporting some of the plume material northward, on an archipelago-wide scale.

More than five million years ago, the Galápagos plume was located directly on top of the spreading center; the ramifications this has for the early history of the Galápagos are not clear at this point, although it is possible that magmatic production was enhanced by this coincidence. Thus, there may have been more, larger volcanoes in the Galápagos island chain than there are now. By studying drowned islands and seamounts "downstream" of the Galápagos, we may be able to shed some light on the extent of land present in the Galápagos prior to 5 million years ago (Christie *et al.* 1992).

CONCLUSIONS

The Galápagos hotspot is more complex than originally believed, due to dynamic processes in the earth's upper mantle. Our heightened understanding of these processes leads to new insights into how mantle plumes work. Unlike strong plumes such as Hawaii, the Galápagos plume is relatively weak and interacts strongly with surrounding mantle as it is tilted by prevailing mantle currents. As it is bent, the plume thermally entrains surrounding upper mantle. This results in the horseshoe-shaped distribution of depleted mantle and enriched hotspot material. Currently, our research group is trying to decipher the intricacies of the Galápagos plume via more detailed sampling of individual volcanoes to

direction of plate motion. Note the distribution of concentration (i.e. darkest) plume in a horseshoe-like pattern, with depleted (i.e. lighter) material at the center. FLO is indicated in the south-west corner, and mixes eastward in the direction of plate motion. Views A and B modified from White *et al.* (1993).

examine how compositional evolution of single volcanoes can be used to constrain plume models.

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NATURALIST GUIDES ASSIST IN MONITORING FLAMINGOS

By: Christine Breuker and Hernán Vargas

INTRODUCTION

The population of the Caribbean flamingo (*Phoenicopterus ruber ruber*) in the Galápagos Islands is a small one and has been for at least 30 years. The total number of adult birds is almost certainly less than 500. Given this small size, it is necessary to evaluate the status of the population, so the Charles Darwin Research Station (CDRS) and the Galápagos National Park Service (GNPS) monitor the flamingos by three methods:

- The annual census, conducted since 1967, usually in January, of the birds in most of the lagoons in the Archipelago where flamingos occur.
- The monthly census of the flamingo populations found in lagoons in southern Isabela Island, where the main breeding sites for these birds are located.
- The counts conducted by naturalist guides for the lagoons located near the visitor sites Punta Cormorant (Floreana), Cerro Dragón and Bachas (Santa Cruz), Punta Moreno (Isabela), Rábida, as well as "sail-by" counts of the lagoon on one of the Bainbridge Rocks.

The purpose of this paper is to analyze and summarize the flamingo data submitted to the CDRS by naturalist guides, primarily from the lagoon at Punta Cormorant on Floreana, but also from other lagoons near visitor sites.

The lagoon at Punta Cormorant is a place of great interest for both tourists and biologists. Located at the northern tip of Floreana, the brackish, shallow water is home to a number of wading birds and surrounded by interesting dry-zone vegetation. The water level varies seasonally and yearly. Both a greenish beach (of olivine crystal origin) and a white beach (of coral origin) are nearby. The area is a popular site and is visited by a more or less steady flow of tourists, accompanied by their naturalist guides. The prospect of seeing flamingos on the lagoon is an attraction. The trail taken by tourists overlooks the large lagoon from its northern and eastern shorelines. However, a review of the carrying capacity of the site in 1995-96 showed heavy overuse and resulted in recommendations for reducing use by tourists (Amador *et al.* 1996, Cayot *et al.* 1996).

METHODS

Naturalist guides were given a report form on which to record information about flamingos. Although for many years guides have submitted their observations, including information on flamingos, this new report form was designed by René Godard, who came to the Station in 1993 as a visiting scientist and recognized that naturalist guides would be an excellent source of data about flamingo numbers and activity at the visitor sites. In addition to recording the date, hour, number of birds, number of chicks, and distance of the flock from the observer, the guides were asked to record information about the kinds of behaviors the birds were exhibiting. They collected the data as they visited the lagoons with their tourist groups, except for the lagoon on Bainbridge Rock, for which flamingos were counted as the boat passed by. These reports from guides have been submitted steadily to the CDRS since November of 1994.

RESULTS

Approximately 300 reports have been submitted to the CDRS from naturalist guides since counting birds at the lagoons near visitor sites began in November of 1994. Of these reports, 73.4% were for the lagoon at Punta Cormorant, 11.3% from Cerro Dragón (Santa Cruz), 5.5% from Rábida, 4.1% from Las Bachas (Santa Cruz), 2.3% from Punta Moreno (Isabela), 1.7% from Bainbridge Rock, and 1.7% from Playa Espumilla (Santiago) (Table 1). The number of reports submitted per month varied from 1 to 15. The majority of the reports indicate that the birds were seen 20-200 m from the observer between 0700 and 1500.

Most of the flamingos were found at the lagoon on Punta Cormorant, where the average was 21.7 ($n=215$, range 0-172), and the fewest were found on Rábida, where the average was 1.9 ($n=16$, range 0-9). Based on only 5 reports, the lagoon on Bainbridge Rock had the second highest average (Table 1).

Table 1. Results of flamingo counts at visitor sites near flamingo lagoons carried out by naturalist guides from November 1994 to March 1997.

Site	Number of reports	Average number of birds	Min. number	Max. number
Punta Cormorant	215	21.7	0	172
Bainbridge Rock	5	9.6	4	15
Punta Moreno	7	4.7	1	7
Playa Espumilla	5	4.2	1	11
Las Bachas	12	2.5	0	5
Cerro Dragón	33	2.5	0	8
Rábida	16	1.9	0	9

At Punta Cormorant, the average number of birds per sighting varied from a high of 109.3 in February of 1995 to a low of 0.7 in September of 1996 (Table 2). The average number of birds per sighting was higher in the first four months of the report period (November 1994-February 1995) than it has been at any time since. The averages were 84.0, 81.2, 104.0, and 109.3 birds for each of the four months, respectively, all of which are more than double the sighting average in any month since that time.

Table 2. Results of flamingo counts at the Punta Cormorant lagoon carried out by naturalist guides from November 1994 to March 1997.

Year	Month	Number of reports	Average number of birds	Min. no. of birds	Max. no. of birds
1994	November	1	84	84	84
	December	9	81.2	30	172
1995	January	12	104	60	153
	February	4	109.3	80	131
	March	5	40.4	27	56
	April	6	19.8	14	33
	May	4	4.8	4	5
	June	3	5	4	7
	July	13	7.1	1	18
	August	12	8.9	4	11
	September	15	12.2	0	23
	October	8	12.5	0	18
	November	9	9.3	4	18
	December	3	3.3	0	6
1996	January	14	10.7	0	32
	February	11	15	1	29
	March	12	34.1	18	65
	April	7	10.3	0	24
	May	11	4.3	0	11
	June	12	5	1	9
	July	15	1.9	0	4
	August	2	9	8	10
	September	6	0.7	0	3
	October	3	4.3	2	7
	November	3	2.7	0	5
	December	4	10	2	19
1997	January	6	8.7	4	13
	February	2	15	2	25
	March	3	42	22	60

There was a tendency for the number of flamingos to change in abundance monthly. The range in the average number of birds per report went from a low of 4.3 birds in July to a high of 48.8 birds in December (Table 3). The average number of birds per sighting was lowest in the dry, cool months of May, June, and July, with sighting averages of 4.4, 5.0, 4.3 birds, respectively, and highest in the wet, hot months of December, January, February, and March, with averages of 48.8, 45.3, 37.2 and 36.8 birds, respectively.

During the report period, from November of 1994 to March of 1997, there were three annual censuses of flamingos, conducted in January. The results of the counts from these censuses at Punta Cormorant were as follows: 146 in 1995, 25 in 1996, and 4 in 1997. Naturalist guide report averages for January of these years were as follows: 104 in 1995, 10.7 in 1996, and 8.7 in 1997 (Table 2). No juveniles were reported in the annual census for these years.

DISCUSSION

Reports from guides have been collected for nearly two and a half years, November of 1994 through March of 1997. The number of reports submitted is understandably related to the vagaries of the tourist business in Galapagos. Nevertheless, a substantial number of reports (nearly 300) has been submitted. There is a published policy with regard to the number of groups allowed daily at the visitor sites (Amador *et al.* 1996, Cayot *et al.* 1996). Cerro Dragón and Rábida have visitor sites in the Intensive category and presumably are able to sustain a large number of visits by tourist groups. The Punta Cormorant site was included in the Intensive category until the carrying capacity study in 1995-96. Average use at that time was 15 groups per day, while the carrying capacity was calculated at 2 groups per day. The decision was made to put Punta Cormorant into the Extensive category and reduce the number of groups per day.

The lagoon at Punta Cormorant, which has had an average of 21.7 birds over the report period, has generated 73.4% of the reports submitted by guides. This visitor site has been heavily used. The lagoon at Cerro Dragón, which has had an average of 2.5 birds per report, is also heavily used, but has generated only 11.3% of the reports. It is possible that guides are less likely to submit reports from visits in which no flamingos have been observed. This may also be the case for sites such as the lagoon on Rábida, which historically has had large numbers of flamingos, but in recent years has not. Oral communication from people recently visiting Rábida indicates a possible return of the flamingos there, although no written reports by guides have been submitted for this site since March of 1996. Recent information about the Bainbridge Rock lagoon is encouraging as well.

Because of the large number of reports, data regarding flamingo flock size at Punta Cormorant on Floreana were

Table 3. Monthly average of flamingos per report at the Punta Cormorant lagoon, based on two or three years of data, as available.

Month	Number of reports	Average number of birds per report	Min. no. of birds	Max. no. of birds
January	32	45.3	0	153
February	17	37.2	1	131
March	20	36.9	18	65
April	13	14.7	0	33
May	15	4.4	0	11
June	15	5	1	9
July	28	4.3	0	18
August	14	8.9	4	11
September	22	9.6	0	25
October	11	10.3	0	18
November	13	13.5	0	84
December	16	48.8	0	172

analyzed more thoroughly. At the point of maximum population size in the report period (January and February of 1995), there were individual guide sightings of up to 142 birds at Punta Cormorant. Reports of fewer birds are far more common, however. Of particular interest is the fact that the counts of birds in the early reports of the guides (late 1994 and early 1995) have never been equaled or even approached since that time. It may be of significance that there has been no individual report of a sighting of more than 100 birds at any point since February of 1995. The official census done in January of 1995 supports the findings of the guides, with a count of 146 birds, the highest January count at Punta Cormorant of any year in which the annual census has been done.

Reasons for the abnormally large flamingo count at Punta Cormorant during the period from November 1994-February 1995 are unclear, since no information is available for the months immediately prior to that time. The annual census done in January of 1994 indicates no unusually large number of flamingos at the site. Breeding success in 1994 would not account for the dramatic increase in the number of adult birds at the site by November. A more likely explanation is the immigration of birds from other lagoons in the archipelago. Though that is a matter of speculation, inter-island migration of the Galapagos flamingo has been documented (Gordillo 1973). Favorable conditions with respect to water level and food supply are likely to be part of the explanation as well (Tindle and Tindle 1978).

It is possible that the best conditions for flamingos at Punta Cormorant occur in March, as shown by an average count of at least 30 birds in each of the three months of March in the report period (Table 2). If this is the case, March would be the month in which tourists could most reliably expect to see flamingos there.

With a range in monthly report averages from 4.3 to 48.8 birds, the flock size at Punta Cormorant is clearly not what would be thought of as large at any time of year. Nevertheless, a seasonal pattern is apparent, with flock size being lowest in the dry, cool months of May, June, and July and highest in the wet, hot months of December, January, February, and March. Though the time of breeding in flamingos is variable and susceptible to interruption, the Galapagos flamingo tends to have a breeding season from June to November (Godard and Stevens 1993). The drop in the water level with the onset of the dry season produces the muddy conditions necessary for nest construction. There is, in fact, evidence of breeding activity at Punta Cormorant, though very little from the naturalist guide reports. This is understandable, considering the large size of the lagoon and distance from any observer on the trail (at the northeast corner) to the likely nesting sites on the western edge and small islets of the lagoon (Vargas 1989). Nevertheless, 7 nests were reported by a guide in April of 1996, and a sighting of 38 old nests (some with abandoned or destroyed eggs) was reported after a field trip by CDRS personnel in May of 1996 (CDRS files).

Guides also reported sighting chicks at various times in early 1995.

The decrease in the flock size at the lagoon on Floreana at the onset of the dry season suggests, however, that other lagoons may be more important breeding locations. The lagoons of southern Isabela are likely candidates. Of these, the flock at the lagoon at Quinta Playa seems to be the largest. Because there is no visitor site at Quinta Playa, no guide reports are available for that location, so it is of some interest to look at the bird counts from the lagoons at Punta Cormorant and Quinta Playa generated by the last three January censuses. At Quinta Playa the flock size increased from 97 (1995) to 226 (1996) to 245 (1997). At Punta Cormorant, the flock size decreased from 146 (1995) to 25 (1996) to 4 (1997). This decline at Punta Cormorant is corroborated by the counts reported by naturalist guides for January of these three years, which go from 104 (1995) to 10.7 (1996) to 8.7 (1997).

While to suggest that flock sizes between these two lagoons alternate in this way is certainly premature, it is also important to keep in mind the possible impact of heavy tourism at the lagoon on Floreana. In a one-week period in April of 1997, for example, 64 tour boats were scheduled to visit the site, and as many as 13 tour boats (both large and small) in one day (GNPS records). Quinta Playa, on the other hand, has no tourist site. Much more information is needed before any meaningful conclusion can be drawn with regard to the impact of tourism on flock size at Punta Cormorant.



Photo by Robert Tindle

RECOMMENDATIONS

The staff at the CDRS encourages additional naturalist guides to become involved in reporting information about flamingos at any location in the archipelago, in order to obtain as much information as possible.

Because reports of visits in which no flamingos are sighted (negative data) are just as important as the ones from visits in which the birds are observed (positive data), the CDRS staff would encourage the guides to submit both kinds of data to this on-going monitoring of flamingos.

Because little is known about the reproductive behavior of flamingos, information on courtship behavior, nests, chicks, and juveniles is particularly appreciated.

The GNPS should reduce the number of groups per day visiting Punta Cormorant so that it coincides with the numbers established in the study of carrying capacity.

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INSIDIOUS INVADERS

By: J. P. Lundh

Those involved in the work of conservation in the Galápagos Islands have given first priority to the control of introduced mammals. This is amply justified by the enormous destruction these animals have caused to the flora and fauna of the islands where they have been introduced. But there are other invaders that are far less obvious due to their size, which usually also makes us unaware of their presence until they have become more or less established and thus nearly impossible to eradicate.

Dr. Chantal M. Blanton, Director of the Charles Darwin Research Station (CDRS) from May 1992 to September 1996, has expressed concern about the introduction of these small animals, recommending stricter control. This has

become most urgent, considering the greatly increased traffic between the islands and the mainland in the last two or three decades. The likelihood of introducing such animals has increased enormously compared to previous years. This is not to say that the problem is recent or that its importance has not been realized before.

Fortunately, it is far from easy for accidentally introduced living organisms to become established. A cargo with half a dozen geckos scattered throughout it is not necessarily an opportunity for these to become established on an island. There is the possibility of the animals not going ashore with the cargo or being eaten by a predator upon arrival. A gravid female must arrive, or a female

and a male must meet and breed. For many such small animals, the Galápagos lowlands may become the ultimate barrier, given how inhospitable the dry region is for most of the year. Had it been easier to become established, Galápagos could have had a more varied insect fauna and a greater number of gecko species – if there had been enough food for all. We must remember that ships have brought cargo to Galápagos since 1832 – split bamboo, lumber, cases with various contents, and other potential hiding places.

But such introductions are not impossible. Wheeler (1919) reports eighteen ant species collected in the Galápagos. Of these, six are mentioned as “relatively recent introductions.” Hebard (1920) reports nine cockroach species for the Galápagos, only one of them endemic (*Anisopygia snodgrassii*). Hebard believes the eight non-endemic species to have been introduced from the mainland in cargo brought to the Islands. One species, the German cockroach (*Blattella germanica*), he reports only from Española Island. This species became very common in the inhabited parts of Santa Cruz Island during the 1940s, and the settlers believed it had come from Panama via the military base on Baltra Island.

The little red fire ant (*Wasmannia auropunctata*), which is now so abundant on Santa Cruz, was introduced from there to some of the other islands. It was first discovered on Santa Cruz about 1934, in some shrubbery near the Puerto Ayora landing. In 1935, there was an area at the beginning of the inland trail where this ant had become established in large numbers. It later spread with the help of people, especially during El Niño years, when the trail became overgrown, making it possible for the ants to be brushed off in large numbers on people’s clothes and on the loads carried by donkeys. This was because the ants climb onto the leaves and branches to get away from the rain-soaked ground.

It is possible that *Wasmannia* was brought to Santa Cruz from Cocos Island. Several scientific expeditions visited the Galápagos in the early 1930s that stopped at Puerto Ayora after having visited Cocos Island on their way to Galápagos. The ant is extremely numerous on Cocos and has been so for many years. Snodgrass and Heller (1902) found it abundant on Cocos in 1899.

Before the turn of the century, Dr. George Baur collected four geckos on San Cristóbal Island which belonged to a then-unknown species. It was described by Garman in 1892 and given the name of *Gonatodes collaris* (Van Denburgh, 1912). Later expeditions were unable to find this species. The California Academy of Sciences Expedition of 1905-06 made extensive collections of geckos from San Cristóbal – 148 specimens of *Phyllodactylus leei*, an endemic species, and 21 of *P. tuberculatus*, a common mainland species that had become established on the island. No *Gonatodes* was found (Van Denburgh, 1912).

It was discovered much later that *G. collaris* is a mainland species. It is, of course, possible that the Baur specimens had been collected in Guayaquil and became

mixed up with his collections from San Cristóbal. However, there is another possibility – Baur had collected a newly introduced gecko, either catching the lot or taking so many that they could not become established.

The next collection of *Gonatodes* that I know of consisted consisted of three specimens I caught in the general area of the landing at Puerto Baquerizo Moreno, San Cristóbal, in 1961 or 1962. These I gave to Dr. André Brosset, then Director of the CDRS. Unfortunately, Dr. Brosset left the Islands before he received information about their identity. Later, I saw several geckos that appeared to belong to the same species, or a closely related one, in the same area. Dr. Marinus S. Hoogmoed believes my specimens could be *Gonatodes caudiscutatus* (Hoogmoed, pers. comm., 1991). This particular species has been reported from both the towns of Puerto Baquerizo Moreno and El Progreso.

Another gecko (*Lepidodactylus lugubris*), of pantropical distribution, has been reported from Santa Cruz (Hoogmoed, 1989). However, Dr. Hoogmoed did not meet with this species while he was doing a preliminary study of another gecko (*Phyllodactylus reissi*), also a recent introduction, which had been observed for the first time in 1975, near the Puerto Ayora landing. This last species gives good reason to fear for the survival of the gecko native to the island (*P. galapagensis*), since the latter disappears from areas invaded by its larger relative, the introduced *P. reissi* (Hoogmoed, 1989).

There is still much to learn about these small invaders and how they affect the island species with which they must compete. Unfortunately, their small size is their greatest advantage. It makes it easy for them to hide in cargo from the mainland and to remain unnoticed for a long time. Once successfully established, they may turn out to be impossible to eradicate. The little red fire ant is an example familiar to every Galápagos resident and can serve to raise local awareness of the insidious invaders.

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A SANTA CRUZ PIONEER HAS DIED

On February 19, 1997, Mrs. Elfriede Horneman passed away in the home of her daughter, Mrs. Friedel Vonka, near Kirkenes, in the north of Norway, where she had been living for a number of years. She would have been ninety years old in October.

Born in Frankfort as Elfriede Engelmann, she learned to speak several languages and worked as a secretary, until she met Jacob Hersleb Horneman, a Norwegian mining engineer, in England in 1938. The two married and went to Galápagos, where Horneman had owned property in the Santa Cruz highlands since 1927.

The slender city girl soon became a tough, hard-working Galápagos pioneer, adapting to the primitive conditions and making the best of what the island had to offer. One of her first actions was to change the name of the Horneman property from "Progreso" to the more realistic "Vilnis," Norwegian for "wilderness," then laboring hard to keep the place from living up to its new name.

Though she began suffering from back problems, which caused her considerable pain, Mrs. Horneman continued working, even learning to lay bricks and wield

the machete. However, she always kept a bright smile and a brave optimism, no matter how bad things could seem. Thus, she raised two children, a daughter and a son, and kept things going.

As if this were not enough, she also offered hearty hospitality to every visitor, and many well known people found a welcome in her home: Thor Heyerdahl, Robert Bowman, Eric Shipton, Sven Gilsäter of Swedish TV, E. Yale Dawson, and many others. However, her hospitality was offered with equal generosity to the poor and unknown visitor or to fellow settlers who happened to come to the Horneman home. As the years went by, she gradually became known as "Mutti" to many of these friends.

Mrs. Horneman finished translating Dr. Stein Hoff's excellent history on the Norwegian settlers in the Galápagos, *Drømmen om Galápagos* (The Dream about Galápagos), from the Norwegian original to English. Unfortunately, she died before seeing this work in print.

Those of us who were fortunate enough to know her feel her death as a great personal loss.

J. P. Lundh.

GERARD CORLEY SMITH

*Gerard Corley Smith,
CMG, former Ambassador to Ecuador,
died on October 7 aged 88. He was born on
July 30, 1909.*

Although he had a long and distinguished career in the diplomatic service, Gerard Corley Smith will be particularly remembered for his close involvement with the cause of conservation in the Galapagos Islands. His association with the islands began in 1962, when as Ambassador to Ecuador he attended the official opening of the Charles Darwin Research Station, and gained an insight into the unique wonders of that archipelago and the strenuous efforts being made to safeguard them for the future. It was a cause that he was to espouse for the rest of his life.

Gerard Thomas Corley Smith was educated at Bolton School and Emmanuel College, Cambridge. In 1931 he entered the General Consular Service, and over the next 15 years he served in Paris, Oran, Detroit, La Paz, Milan, St Louis and Brussels. He first came to international at-

tention in 1949 when, as the British representative on the UN Economic and Social Council in New York, he was chosen to present the case against the Soviet forced labour camps, or gulags, the existence of which was only then beginning to be revealed to the world. It was a task that predictably earned him the anger and disapproval of the Eastern bloc delegations and their press.

Corley Smith returned to Europe in 1952, and in the same year was appointed CMG. His next posting was to Paris, where he served for two years as press counsellor at the British Embassy. From there he went to Madrid to take up the appointment as labour counsellor at the British Embassy, 1954-59.

With his wide experience, Corley Smith became Ambassador to Haiti in 1960. It was not an easy posting, nor could it have been under the harrowing and deeply oppressive regime of François ("Papa Doc") Duvalier. Years later, Corley Smith would recall his affection for the ordinary Haitian people, who greeted him with their friendly "Bonjour Blanc!" (a Creole expression for "Hello, stranger!") as he took himself bird-watching in the hills.

But the misrule there, the mistrust he saw, and the "atmosphere of brooding terror" became increasingly hard to bear.

Once again, Corley Smith was chosen as spokesman, this time for a delegation of ambassadors protesting against the extortion being practised on foreigners by the Tontons Macoute, Duvalier's infamous bogeymen and secret police. When he was asked by the Haitian Minister for Foreign Affairs who was doing the extortion, Corley Smith replied "the Tontons Macoute." "Who are they? I never heard of them," objected the Minister, himself a Macoute. When Corley Smith said he need only ask the first person he met on the street, he was given 48 hours to leave the country, on Duvalier's order. The beleaguered regime added: "The Haitian Government has made it known to this famous ambassador . . . that his impertinence and haughtiness as a British colonialist would not be tolerated."

Corley Smith's next appointment was to Ecuador in 1962. In Quito he found an altogether more congenial atmosphere, and unlimited scope in the country around him to pursue his interest in ornithology. Staff at the embassy soon took it as a matter of course that his official duties would be interspersed with bird-watching trips to the Andes.

An interest in high-altitude hummingbirds brought him into contact with Professor Jean Dorst of the French National Museum of Natural History in Paris, an authority on these birds who was also President of the Charles Darwin Foundation for the Galapagos Islands.

A second journey to Galapagos followed in 1964, when Corley Smith joined the Duke of Edinburgh during his first visit to the archipelago on the Royal Yacht *Britannia*. It was a visit that had repercussions for both men. The Duke would later become patron of the Charles Darwin Foundation; the ambassador "became hooked on Galapagos."

Throughout his remaining time in Ecuador, Corley Smith took a discreet but influential part in Galapagos affairs, embracing the idea that wildlife-orientated tourism could be the key to economic stability for the islands, and helping to engineer the Grimwood-Snow Mission

and Report, which gave recommendations for the administration for the future national park.

Corley Smith left Ecuador in 1967, and the following year the new National Parks Service of Ecuador came into existence. The newly retired ambassador was lured to join the executive council of the Charles Darwin Foundation. The first meeting he attended was in England, at Down House, Darwin's former home, where members saw in the tall, silver-haired and distinguished-looking former diplomat a remarkable likeness to the portrait there of T. H. Huxley. In 1972, when Sir Thomas Barlow stepped down, Corley Smith took on the role of secretary-general of the foundation. It was a great coup for the ever-persuasive Dorst.

Over the next ten years Corley Smith served the foundation diligently and wholeheartedly. Those who worked with him during that period cherish the memory of his quiet skill in handling complex problems, his sage advice, and the bravado with which he ran the show "from an attic bedroom, with one typist paid (and badly) by the hour." In addition, he edited, published and distributed 24 "well-nourished" issues of the foundation's bulletin *Noticias de Galápagos*.

It was a buoyant period in Galapagos affairs. With his natural optimism and his gratitude to successive Ecuadorean administrations for their commitment to international science, Corley Smith helped to forge the remarkable alliance that grew between the national Government and this voluntary organisation. "Most crucially," as Dorst later wrote, "he perceived and understood the way the foundation had to meet and adapt to changing conditions in Ecuador."

On his retirement from the post of secretary-general, Corley Smith was awarded the Order "Al Mérito" by the Government of Ecuador for his services to science and conservation in the Galapagos Islands.

Corley Smith married Joan Haggard in 1937. She predeceased him, but he is survived by a son and three daughters.

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