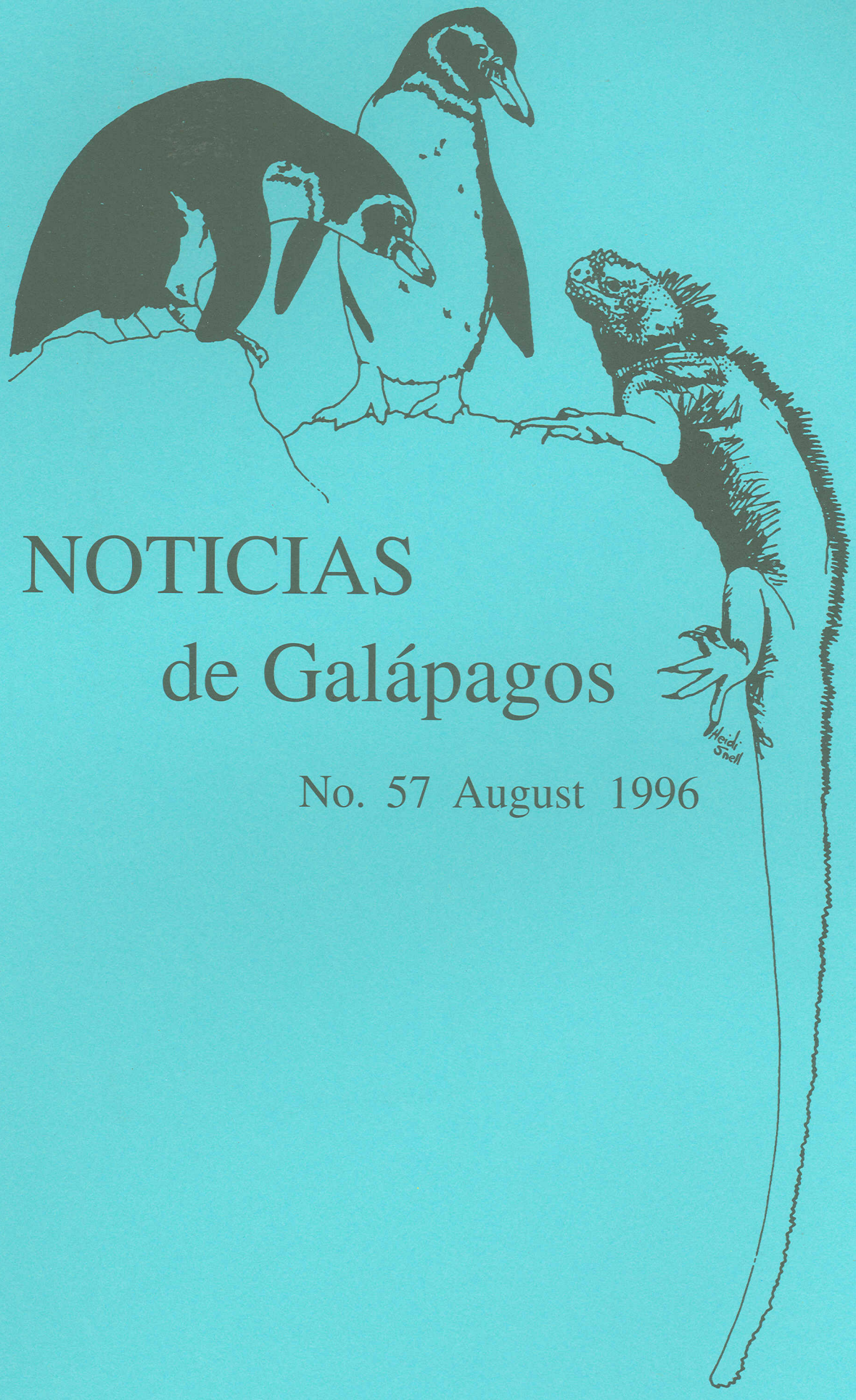


# NOTICIAS de Galápagos

No. 57 August 1996

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While emphasizing that the continuing success of conservation in the Galápagos is directly dependent on the receipt of future contributions, we wish once again to state our deep gratitude to all those supporters whose generosity has made it possible to achieve so much since the establishment of the Charles Darwin Research Station and the Servicio Parque Nacional Galápagos.

Regular donors at the US $25 level become "Friends of the Galápagos" and will receive annual subscriptions of ***Noticias de Galápagos*** and the ***Galápagos Bulletin***, both published twice per year.

**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. 57 August 1996

*Contents*



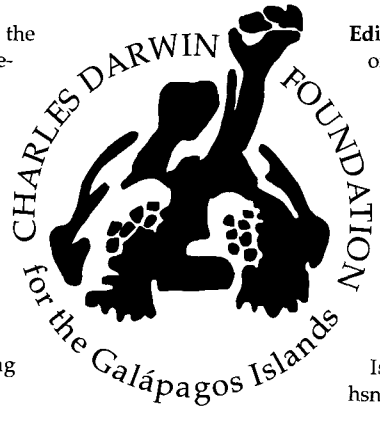
**Information for Subscribers:** *Noticias de Galápagos* is provided twice per year to current "Friends of the Galápagos." Institutional and lifetime subscriptions, as well as back issues, are available. Please contact the Charles Darwin Foundation, Inc. (see inside front cover) with any questions about subscriptions. *Noticias de Galápagos 55* includes a complete Table of Contents for all issues through 1995.

**Information for Authors:** *Noticias de Galápagos* is the official publication of the Charles Darwin Foundation for the Galápagos Islands. We publish material that contributes knowledge about the diversity of the Galápagos. Any manuscript dealing with natural history, ecological or evolutionary processes, conservation biology, geology, geography, comtemporary or historic human activity, or the preservation of biological diversity, in relation to the Galápagos will be accepted for review. Manuscripts are most welcomed in an electronic format (Microsoft Word preferred, Word Perfect acceptable). Submission can be via files attached to INTERNET messages, or on 3.5" diskettes, or by hard copy. Electronically submitted manuscripts are routinely published 6 months to a year quicker than others. It is the author's responsibility to write clearly and correctly in English. The publication of manuscripts requiring translation or great amounts of editorial correcting will often be significantly delayed. Use *Noticias de Galápagos 56* as a guide for style, and contact either the editors or the editorial assistant by electronic mail or telephone for more details.

Published by The Charles Darwin Foundation for the Galápagos Islands, an International Organization created under the auspices of the Government of Ecuador, UNESCO, and the International Union for the Conservation of Nature & Natural Resources.

Published with partial financial support of the Charles Darwin Foundation, Inc.; the Tinker Foundation, Inc.; and the Museum of Southwestern Biology of the Department of Biology, University of New Mexico.

Printed by the University of New Mexico Printing Services, Albuquerque, New Mexico, USA.




**Editor:** Howard L. Snell, Biology Department, University of New Mexico, Albuquerque, New Mexico 87131, USA; snell@mail.unm.edu; (505) 277-3411, (505) 266-3818

**Associate Editor:** Thomas H. Fritts, Noticias de Galápagos, National Museum of Natural History, Washington, DC 20560, USA; 72370.1207@compuserve.com; (202) 357-1930

**Editorial Assistant:** Heidi M. Snell, *R/V Prima*, c/o Estación Científica Charles Darwin, Puerto Ayora, Isla Santa Cruz, Galápagos, Ecuador; hsnell@fcdarwin.org.ec; (5) 526-147

# NEWS FROM ACADEMY BAY

## IT IS *SCALESIA ATRACTYLOIDES*!

If you are in good physical condition a brisk two and a half hour hike from a landing on a beach called "Las Campeonas" will bring you to the unstable rim of a small, unnamed volcanic pit-crater on Isla Santiago. On a conservation and management trip by Galápagos National Park Service (GNPS) personnel in late 1995, wardens made a very fortunate discovery at this site.

Five mature individuals of a plant thought to be extinct in the wild, *Scalesia atractyloides*, were found clinging to the steep crater walls. One warden managed to secure a few leaves for positive identification. Upon return to Santa Cruz, the presentation of the leaves was nearly ceremonial when the entire group of Park wardens brought the leaves over to the Charles Darwin Research Station (CDRS) Botany Department for a confirmation of the identification. Iván Aldáz keyed out the leaves and the conclusion was positive, *Scalesia atractyloides* still lives a precarious life on a cliff inside a pit-crater!

It was a wonderful discovery, yet in retrospect, it seemed strange that these men, most whom are not botanists, were so happy. It is just a plant after all. There is nothing special about this plant. Its discovery did not mean a cure for cancer or even personal gain, in fact it was risky just to collect a few leaves. So why the big smiles? Why the camaraderie exhibited and the swagger in the steps of those involved in the discovery? Why was everyone remotely near that entire building grinning like kids in a candy shop?

Perhaps because they, or rather we; are all involved in what seems to be an overwhelming battle against the odds. These wardens and others like them go out year after year, trying to eliminate the plagues which threaten the wildlife and well being of Galápagos. Then, almost as if by accident, they find something which was thought to be gone, already a lost battle. So they returned triumphant, not with tangible treasures of gold or jewels, but something more important, something to elevate them in the esteem of their peers. And truly, it is priceless to find something once thought to be gone forever from the face of the Earth. Something far more important than a piece of gold or an elegant gem.

Five living, respiring plants which only exist on one island in one tiny pit crater on the face of this Earth.

***Heidi M. Snell***

## THE MARINE BIOLOGY LABORATORY RENAISSANCE

Over the past years the crisis affecting the world's marine resources has touched Galápagos. In an effort to respond to the need for marine research in Galápagos a team headed by Dr. Rodrigo Bustamante was hired in mid-1994. They were presented with the challenge of revitalizing marine biological research at the CDRS, in order to provide the government of Ecuador with sound advice on marine biology and conservation in the Galápagos Marine Resources Reserve (GMRR). The net result is a new Marine Biology Laboratory infrastructure, enthusiasm, and a buzz of activity in the CDRS. Staff research has already played a major role in decision making on topics of fisheries management and tourism. Currently the Marine Biology Laboratory (BioMar) team members are:

**Rodrigo Bustamante**, Ph.D., who hails from Chile where he earned a degree in marine technology and biology, he then received his Ph.D. from the University of Cape Town, South Africa He specializes in marine biological diversity , fisheries biology and benthic ecology.

The husband and wife team of **Priscilla Martínez** and **Fernando Rivera**. Both were Ecuadorian Fulbright scholars who obtained their M.S. degrees in Guam. Priscilla is a specialist in the reproductive biology and general ecology of sea cucumbers while Fernando's research is on the biology of corals, specifically repatriation and recovery of damaged coral reefs. He is also a talented videographer, both underwater and on land. He has produced a video which is available on the underwater marine life in Galápagos, and was the cameraman and producer of the Alcedo Campaign video. Priscilla and Fernando have worked in Galápagos since they were students in the early 1980's.

**Jorge Gomez Jurado** is a Bachelors-level research technician who during 1995 created the new marine-organism rearing facility at the Station. He is also active in the field research of the laboratory. He maintains all the marine lab equipment, which includes everything from outboard motors to dive equipment, pumps, aquaria and the entire saltwater circulation system.

**Adelaida Herrera** has worked at the Station on intertidal research since 1993. She is now responsible for the research project on the endemic Galápagos giant chitons, organization and maintenance of the marine section of the CDRS museum collections, and the general operation of BioMar.

BioMar also has been training several Ecuadorian thesis students. **Graciela Monsalve** is researching the use of the marine area by tourists and tour boats, and monitoring their effects. **Veronica Toral** is analyzing the reproduction and behavior of sea cucumbers in Academy Bay.

Three more students complete the remainder of this active group. Two are Galapagueños: **Jimmy Peñaherrera** is a high school graduate working on a system for anchoring boats near dive spots, to protect the few sites of

Galápagos corals. **Natalia Vidal** is studying chitons for her high school senior project.

**Victoria Turner**, from Great Britain, was the lab's international volunteer. She just recently completed her time in Galápagos. She helped in all aspects of cataloging, organizing and curating the specimens presently in the Museum collection of the Station. This will form the basis for further research of biological diversity in the Marine Reserve. She in an enthusiastic diver who participated in a wide variety of research dive trips.

Just about everyone on the BioMar team would rather spend their time underwater than on dry land. The lab is now in full swing and the compressor gets a weekly workout keeping all of the tanks full. Day or night these eager divers are studying and monitoring many species and locations.

From almost nothing the Marine Laboratory has quickly grown to become the strongest department at the Darwin Station. With many threats to the Galápagos Marine Resources Reserve before them, their tasks are challenging. Their studies and projects provide the Ecuadorian Government with information to make decisions about the marine ecosystems. Fortunately this dynamic group has a strong love of the sea and professional dedication to studying its organisms. They will rise to meet the many challenges before them.

***Chantal Blanton and Heidi M. Snell***

## THE CDRS RESEARCH VESSEL *BEAGLE*

The Station's *Beagle* has now been running nearly continuously for almost a year. At the end of May 1995 she began anew life with a new captain and crew after more than two years of inactivity. Prior to that voyage, *Beagle* had been in dry-dock to resolve a gearbox problem that had plagued her since the beginning. After changing the original setup, *Beagle* was made shipshape and immediately launched into service.

The *Beagle* is a modest vessel. She was constructed in Norway in 1979 as a fishing boat and arrived in Ecuador in early 1989 with several sister ships to be used in the coastal fishing industry. A few years ago, Godfrey Merlen was asked to search for a national vessel for the CDRS. He traveled to the coastal city of Manta where he found a vessel which would fill the needs of the research station. Godfrey found two sister ships for sale. The owner wanted to sell both of the ships as a package deal and under those circumstances Godfrey decided to realize his dream of having a vessel to pursue his studies of cetaceans around the islands.

He determined the ships were hearty vessels as both had been fishing 10 years in the North Atlantic before arriving in Ecuador. They were reasonably priced and would stand up to the Galápagos seafaring life. He personally purchased what became his vessel *Ratty* and negotiated on behalf of the Station for the vessel which in 1991 became the Darwin Station's *Beagle*, (she was know as the *Molly* in the North Atlantic and then the *Maria Cristina* in Manta).

*Beagle's* beginning was shaky when her inexperienced captain at the time did not understand the intricacies of her foreign design. The gearbox was more complicated than that usually found on small vessels in Ecuador and proved impossible to repair locally. *Beagle* then sat until such time as interest, need and generous funding from Frankfurt Zoological Society - Help for Threatened Wildlife, allowed for a proper refit to be made.

Thus after a long series of changes and upgrades, *Beagle* has been set to the task of scientific research around the islands. Her captain is a Galápagos native, born of a seafaring Galápagos family. He knows the islands as well as any man alive and many of you may have traveled with he and his brother Fermin aboard the *San Juan*. Bernardo Gutierrez signed on as captain in May 1995 and has remained with *Beagle* ever since. Additional crew are Luis Cadena and Vladimir Barzola. The dry-land "crew member" is Edwin Yánez, head of logistics for the CDRS.

*Beagle* is 12.8 meters (42 feet) in length and accommodates 6 passengers and 3 crew. She operates with a Volvo Penta 160 hp diesel engine and moves along nicely at 8 knots. She recently had a brand new diesel generator installed in the engine compartment, which is a definite improvement to the noisy generator she once carried on her roof.

As is the tradition with all boats, there is always something which needs repair or improvement, but *Beagle* keeps pace with the often demanding job of keeping science afloat and on the move in the islands. A good example of this was her schedule from May 1995 through March 1996, when *Beagle* completed 46 trips navigating a total of 138 days.

The Darwin Station's *Beagle* carries forth today with the tradition of her namesake the *H.M.S. Beagle* of Charles Darwin's famous voyage, and the pursuit of scientific knowledge is still the main goal even after all these years.

***Heidi M. Snell***

## ALCEDO UPDATE

In March 1996, Brian Bell, of Wildlife Management International, Ltd., New Zealand, visited the Galápagos as a consultant to help us with the problem of feral goats on northern Isla Isabela. Brian is an expert in island restoration and eradication of introduced animals. During his visit, Brian worked with GNPS and CDRS personnel. Following a flight over northern Isabela and Santiago, they made a 3-day trip to Alcedo to see the situation up close. The current estimate of goats on Alcedo is 75,000 to 100,000 animals. The habitat of the tortoises and other fauna on Volcán Alcedo is deteriorating but it is still recoverable if immediate action is taken. Without any control, the population of goats is likely to reach its peak

during the next 12 months, at which time it will outstrip the vegetation and the ecological damage will be devastating. Unfortunately, the ecosystem on Alcedo appears much more fragile and vulnerable to destruction by goats than most of the other islands in the archipelago.

Brian presented a plan to the GNPS and the CDF which consists of 3 phases:

1. A holding operation primarily by a GNPS hunting team, aimed at reducing the number of goats so that the habitat, particularly on Volcán Alcedo, does not deteriorate further (this will occur during the rest of 1996).
2. An eradication project (6 months in 1997), centered on a shooting team operating from a New Zealand helicopter and a permanent GNPS hunting team operating on the ground.
3. A period of intensive monitoring over the next four years (1997-2001).

The estimated cost of this project, including restoration work for the flora and fauna, is 5 million dollars. A major fund-raising campaign is underway under the coordination of the Charles Darwin Foundation, Inc. which is providing major support during this first stage of the campaign. Brian Bell's visit was funded by the Galápagos Conservation Trust of Great Britain.

In May of 1996, the first shipment of bullets (30,000) finally arrived after a complex set of difficulties which delayed them, and the first major hunting trip was undertaken. We hope to have good news of the advances in the next issue of *Noticias de Galápagos*.

***Linda J. Cayot***

## BENEFIT ART SHOW HELD ON SANTA CRUZ

A group of artists based in Galápagos joined together to provide one of the first local fundraising efforts to support conservation projects in the islands. An exhibition, "Artists for Alcedo" was held in the main lobby of Hotel Galápagos, from 16 through 25 February. The exhibition was run by the artists themselves. Twelve artists featured their work and the wide variety of artistic expression and mediums created an appealing show for everyone.

A large crowd of Galapagueños attended the opening evening. The Alcedo video, produced by the CDRS and GNPS was presented and sales that night were astounding. The show was professionally executed and all were surprised at the quality and wide variety of styles displayed. The members of the Galápagos community of artists had kept themselves isolated from one another and the show brought many of them together for the first time.

The show raised over $1,000 from a percentage of the art sales and direct contributions for the Alcedo Campaign. Since nearly all of the funds to support conservation work in Galápagos depend on the generosity of visitors and donors, it was heart-warming to see a group of people from Galápagos take action and create an art show to directly benefit the preservation of these unique islands.

***Heidi M. Snell***

## NEW CONSTRUCTION

After twenty years of breeding and rearing land iguanas in captivity, the GNPS/CDRS breeding center will finally have its own laboratory and office. The construction of this building was planned several times during the past twenty years, but the funding always went to conservation efforts of greater priority. Several problems with the iguana program during the past decade have caused a renewed effort aimed at increasing the entire population in captivity and thus the numbers of iguanas repatriated to their island of origin. A part of this is the construction of the new laboratory, to be inaugurated in May 1996. The construction was funded by the Dutch Friends of Galápagos.

***Linda J. Cayot***

## GEOLOGICAL ACTIVITY?

During the first week of April, the CDRS received an interesting report by Pancho Dousdebes a Naturalist Guide. In early April Pancho and a group of his passengers were treated to an unusual event on their morning panga ride in Tagus Cove, Isabela. They were observing a group of penguins along the northwest side of the cove about 20m (66') from shore. As a whole, the water is quite deep in the cove and that day the sea was very calm and clear. The panga motor was turned off and as they floated quietly, they noticed bubbles coming up through the water all around them in a large area about 30 x 60 meters (98 x 197'). They remained in that location for around 15 minutes and the bubbling did not let up. Finally they continued on with their panga tour.

The bubbling remains a curiosity to Pancho who deeply regretted being unable to SCUBA dive and check out the source of the bubbles. His impression was perhaps some underwater fumarole activity. He describes the bubbling rate and bubble type as exactly the same as the underwater "vent" at Roca Redonda, the tiny isolated islet 35 nautical miles to the NNW of Tagus Cove. The bottom contour of Tagus Cove where the bubbles apparently originated ranges from 2 to 22m deep, (7 - 72'), actually an underwater cliff much like the rest of the cove, however the only mapped irregularity in the huge cove is in this same location.

Little mysteries like this spice up any trip around the islands, and I wish we could tell you exactly what it was that Pancho reported. He has twice been back to Tagus Cove since then and each time he has seen no more bubbling and the water has been murky. However, crew of a tour ship reported a slight smoke or dust plume over the

far (Cabo Hamond) side of Fernandina (on April 14th). And just today Pancho informed me of a very large mushroom shaped cloud rising from the Alcedo fumarole area on the evening of April 19th which was viewed while anchored off Cerro Dragon on western Santa Cruz. It appears the islands are "restless" once again.
***Heidi M. Snell***

## HIGH TECHNOLOGY SCIENCE

Recently Galápagos received the last of several visits by scientists which have resulted in a relationship between 24 satellites and a dome on top of the Tomas Fisher Science Building at the CDRS.

Mark Smith, a representative for the Jet Propulsion Laboratory (JPL) of the United States National Atmospheric and Space Administration (NASA) completed the final installation and hookup of their technical equipment. This added Galápagos to the long list of Global Positioning System (GPS) receivers continuously collecting data in the pursuit of knowledge. Galápagos has become integrated into a tremendous database being generated worldwide from many important sites.

This program was principally begun by researchers whose main interest is to observe movements in the earth's crust, the study of plate tectonics. With this knowledge they continue to produce a velocity field precise to a few millimeters per year of the plates worldwide and formulate ideas on the behavior of the earth's crust.

The Earth has two types of crust, oceanic and continental. The continental crust is much older, more complex in composition and averages 6 times the thickness of the oceanic type. There are 15 lithosphere plates on the Earth's outer shell, of those, 7 are considered major. The boundaries of these plates and their related movements are manifested by the active volcanic and seismic zones of the earth.

Investigating the relative motions of plates and understanding seismic activity serves many purposes. One most easily identified is the long-term forecasting of probable earthquakes. Also by understanding the Earth's surface movements, we gain insight on the inner regions of our planet.

Another use for the data presently being collected is to determine at any given time and position on Earth, the amount of water vapor present in the atmosphere. This undoubtedly is of great interest to scientists who study weather. The data are also used to better understand the Earth's ionosphere which affects earth to earth and earth to space communications. This includes everything from radio and TV to communications with space probes. The GPS tracking network is also used to calculate orbits of the GPS satellites as well as orbits of other satellites that carry GPS receivers themselves.

The location of the Galápagos archipelago is a rare situation on Earth because it exists near a triple junction between two giant and one large plate. Galápagos is special because of this location simply because it is not easy to put receivers on an oceanic type of crust. It is ideally located not only for producing a better understanding of how the Earth's tectonic plates behave, but also to provide better coverage for ionospheric studies, atmospheric studies, and orbit determination since there are so few stations located in the oceans.

All of the GPS network stations are "receivers only" and do not communicate in any way with the orbiting satellites. Currently the Galápagos site has nothing to do with obtaining exact measurements of altitudes or "global positions" of other locations here in the islands. Hopefully that technology will eventually come to the islands so that scientists and conservation managers can use it as a tool to improve the knowledge about the islands and the locations of their natural treasures. In the meantime the Galápagos location and the Charles Darwin Research Station have become a part of the larger "global science" picture.
***Heidi M. Snell and Andrea Donnellan***

## MORE PINTA NEWS

The latest update on the problem of goats on Isla Pinta comes from a GNPS report of a trip made from 28 March to 4 April of this year. The National Park's boat, the *Guadalupe River*, carried 11 hunters to Pinta for five days of intensive hunting on as much of the island as they were able to traverse. On this trip hunting dogs were not used and this made the task of locating the goats in the dense brush a bit more difficult.

At the end of the five days seven goats had been killed. Four adult females, two adult males and a juvenile. The females contained a total of two male fetuses. Unfortunately 13 adult goats escaped, the majority of these were males. The latest estimate of animals remaining on Pinta by the hunters themselves was an additional 20 to 30 animals.

The Pinta vegetation has recovered sufficiently to form a dense thicket making the small groups of goats difficult to locate and follow. Once found, the goats take refuge in the large fields of rough lava and the wardens are unable to successfully follow them. The wardens themselves express hope that they will be able to complete the eradication by the end of the year.
***Heidi M. Snell***

## FIRST RECORD OF THE GREEN HERON (*BUTORIDES VIRISCENS*) IN THE GALÁPAGOS ISLANDS

On the 28th of March, 1996, while counting waterfowl at the freshwater lagoon known as the "Pozo de Claudio Cruz" in the highlands (400m) of Floreana, I saw a bird

which looked familiar but had a different coloration than I expected for a Galápagos resident. The bird looked very much like a striated heron, among the pintail ducks (*Anas bahamensis*) and common gallinules (*Gallinula chloropus*). The heron was perched on a log about 20 cm from the water's surface at the edge of the lagoon. A closer inspection revealed the rich chestnut color on the birds neck and chest. This led me to believe that the bird was not the striated heron (*Butorides striatus*) or the lava heron (*Butorides sundevalli*) which lack this color in their plumage and are resident in the Galápagos.

I photographed the heron to help with later identification. Back at the CDRS, I reviewed the literature and found that it was a green heron (*Butorides viriscens*). This occurs from North America to Central Panama and the West Indies; however northern birds winter as far south as northern Colombia and Venezuela. The closest source of the individual that I saw would be Cocos Island (off Costa Rica, and about 400 miles from the Galápagos), where migratory green herons have also been reported.

Note: The taxonomy of *Butorides* is complicated and still unresolved in Galápagos and America. It is possible that the different groups of this genus could hybridize or there may be a single very variable species.

***Hernán Vargas***

## *GALÁPAGOS EXPLORER* GOES AGROUND

Finally I am sitting down to write down something about my experience aboard the *Galápagos Explorer* when she grounded on San Cristóbal. At 5 PM on 29 December 1995, I boarded the *Galápagos Explorer* from Puerto Ayora for a week of guiding. I was on vacation from my job as the Public Relations person for the CDRS. This was going to be "the" cruise of the year for me. I was very excited about returning to guide on this ship that I loved so much. I initially learned to guide aboard her and once again I felt she would welcome me as she had so many times in the past. I was especially looking forward to celebrating New Years with all my old shipmates and other guides.

The portion of the trip as a guide should have ended on 6 January at around 2 in the afternoon. This was when the passengers would have departed the ship and boarded the plane to Guayaquil. On this same day I would have continued to travel to Guayaquil without tourists on a 72 hour trip with my 3 year old daughter, the guides ,the crew and some of their families . We were schedule to sail through "La Portuaria" the seaward entrance to the city of Guayaquil, a beautiful view. The ship was then to go into dry-dock for a week while many crew went on vacation.

Unfortunately none of those plans were realized. The cruise which had been perfect up until 6 January suddenly ended in an unexpected grounding on Playa Ochoa, San Cristóbal at 2:30 am, only 12 hours before the tourists were scheduled leave. The details of that moment I promise for another time. I could fill an entire book about my feelings on how it was, why it happened, how we felt, how we united as a group both passengers and crew to find courage, strength, calm, and then resignation. The feelings of the crash, the desperate struggle to free the ship, the power blackouts, the lifeboats, the captain, the passengers, the crew and the children, until at last we received the order to abandon ship.

I must admit that even now, I am seized with a deep sense of sadness by the loss. Why the *Galápagos Explorer*? Why when I was aboard with my little one? I was not the only mother aboard with her daughter, two other families of the crew were also traveling to Guayaquil with their children. There were 76 passengers and some 40 crew members including housekeeping personnel and guides. Only the crew of that ship and others who work on the sea and love boats can comprehend the sentiments I feel. What despair, what sorrow! When I think of it I want to cry. My captain, my favorite admiral Raúl Toledo with his white uniform, impeccable, serene, who stayed aboard on the bridge giving us the benediction when we departed in the lifeboats. It was like a movie...even now I get emotional just writing about that night.

This ship made us all happy, her salons and corridors contained so many smiles and pleasing memories, she doesn't deserve to die as a rusting skeleton on the rocks of Playa Ochoa. The ship deserves to be changed to a castle for corals and fishes of a thousand colors. Perhaps then people from all over the world could once again visit her, not to navigate the waters aboard but rather to dive along side her and she would surely inspire dreams again, this time under the waters of Galápagos.

***Alexandra Bahaumonde***

***Editorial Note:*** The *Galápagos Explorer* was the largest tour ship operating in the islands during 1995. She remains stranded on shore where she grounded on January 6, 1996. She grounded during the high tides of full moon which were unfortunately the highest tides for that time of year. At least three different salvage tugs have come to Galápagos to effect her removal, but none were successful. For now, the efforts to pull her off have been abandoned. Slowly the boat has been dismantled and what remains at present is the hull and superstructure. From a distance she appears to be a normal ship anchored quite close to the beach. Her stern is beginning to rust, the telltale sign of a neglected ship. The National Park has ordered her removal but what actually happens remains to be seen.

Contrary to what appeared in the international press at the time of the accident, the ship did not leak fuel or oil and there was very little contamination in the area except for her huge hulk upon a pristine beach. Nearly everything that could be salvaged has been removed from the ship. We anxiously await the day that what can be recycled is finally removed and the useless hull is dumped

at sea to create the undersea castle for Alex and the fishes of Galápagos.

## A FLIGHT OVER ISABELA'S NORTHERN VOLCANOES

On April 25 four lucky people were able to go aboard a special aircraft for a flight over the 3 northern volcanoes of Isabela. Chantal Blanton and Heidi Snell from the Darwin Station, and Galápagos National Park Service wardens Nestor Cadena and Nelson Ballesteros joined the pilot and his copilot at dawn to drove across Santa Cruz to Baltra and board the plane. The plane and crew are in Galápagos to do a documentary film "*Vivir una vida normal en un lugar fuera de lo común* (To live a normal life in an extraordinary place)."

The show will be a 52 minute documentary of a series called "*Dans La Nature*" with Stéphane Peyron. The airplane is a special dream of Canal +, a French television channel which will air the program. It is a one-of-a-kind craft named "*L'AVION.*" It is large but classified as an ultra-light, its gross weight is 8,000 lb. and empty weight is just 6,000 lb.. The length of the plane is almost 40' and its wing span is 67'. It has two 300 hp engines, one on each overhead wing. The unique plane was built in the United States and carries the Federal Aviation Administration #N376LC. It has a striking appearance, because it is large and bright yellow in color. The bottom half is formed as the hull of a boat and the airplane can touch down on water, snow, or land like a normal plane. Upon entering the plane items of note are several fuel tanks strapped to the floor and of course the anchor and line, life raft and paddles. It is full of windows, some which can be opened during flight, and has a large hatch in the floor which can be removed for filming. The low flying speed is quite an advantage for filming and the pilot/copilot team can make the plane perform well.

Upon takeoff we noted this was not an ordinary plane. Perhaps because of the strange shape and other differences, it has a different motion in the air. The view from the panoramic windows was spectacular. Once the plane was on course we were allowed to wander about to look out the windows having been duly warned to avoid the hole in the floor!

The flight first went over Santiago to give the two wardens on board an aerial view of that island. The vegetation in the highlands of Santiago consists of many trees which were leafed out (it was the end of the rainy season) and this made it difficult to see the thousands of goats we know are there. From Santiago we flew directly to the tallest of the Galápagos volcanoes, Volcán Wolf.

We flew clockwise around the rim two times and no one was able to spot a goat. We know they have recently been there because less than an year ago in August of 1995, a group of geologists saw 3 goats on the rim (D. Geist, pers. com.). We do not know our exact altitude above the rim but it did not seem to be over 200'. Chantal and the wardens felt the caldera was the most spectacular they had ever seen.

Heidi video taped the rim from the hatch in the floor while Chantal and the 2 park wardens looked out the windows for goats, however none were seen. We were able to glimpse what appeared to be trails near the cliffs of the caldera's interior rim on the western side. Land iguanas which inhabit the rim are the only animals large enough to create trails besides goats. To us the trails were goat-like because of where they went (near the edge) but it was hard to be certain because of the small field of view and the bouncing caused by air turbulence, in fact we never saw a land iguana either.

One advantage of using an airplane to spot goats is that they usually run, and the movement makes them visible from the air. Had they remained in one place we probably would not have seen them. The vegetation appeared to be quite thick in many spots giving them lots of cover.

The next volcano to the south was Volcán Darwin and we flew towards it at "rim" elevation but with a good view of the desolate lava flows which make up the landscape. Despite these vast lava fields, there are obviously enough vegetation patches to allow goats to make the northern crossing to Wolf more easily than the crossing of the Perry Isthmus that goats made to colonize Alcedo.

We flew the same pattern over the rim of Volcán Darwin. A few distinct trails were immediately visible and it was not long before a group of about 10 goats was spotted. As we made another circle we spotted 6 more groups of about 5-10 each. There were areas of dense green vegetation on the southern and western sides while the north and east sides had little vegetation and consisted of large areas of ash or scoria. In fact in a vast scoria plain on the east side there was a distinct, well-worn trail leading across the unvegetated area. We were depressed to see this much sign of goats. For several years we have been receiving anecdotal accounts of occasional numbers of goats around Tagus Cove and Beagle Crater on the western coast of Volcán Darwin. A couple of field parties have seen goats and their sign at lower elevations on the flanks of the same volcano but no one has been to the summit in many years and we were living in blissful ignorance of how bad the situation was at the top.

It appears to us that the goats are following the same pattern we have witnessed on Alcedo. The densest vegetation is on the south and western sides which is where the goats logically concentrate. However on Volcán Darwin the goats are obviously moving all over the rim from the trails we could see. The numbers of animals we observed were less than 1% of the numbers of goats on the rim of Alcedo. But our flight path was just around the rim and not along the vegetated portions of the flanks. Obviously the population of goats on Volcán Darwin is much greater than we thought, and will become a serious threat to the vegetative communities there quite quickly.

The last caldera was Volcán Alcedo. We reversed the flight pattern this time and flew counter-clockwise. I think the biggest surprise for us was the number of goats and herds of donkeys which were on the northwest side of the caldera. Since the vegetation along the south rim is so distinct and humid, that is where the greatest concentrations of goats and tortoises are. But goats were everywhere as we began the sweep towards the south side. Goats began running by the hundreds and then thousands. Clouds of dust and running goats were visible everywhere, even out across the barren sulfur fields and areas of fumarole activity. Once the goats began running it was hard to say if they belonged to a particular herd. Goats poured off the rim in all directions. The wardens and Chantal estimated up to 200 goats in the larger herds, and groups of 20 to 40 were common everywhere along the rim. That may not sound impressive but the numbers of these herds was great everywhere. Extensive goat and burro trails form gray, erosive braids on the steep slopes.

It was an extremely sad sight for us. We had heard of the destruction, we had seen the video and pictures, but to actually see it so clear and close from the plane, we were filled with a sense of panic for the ecology of Alcedo, so much has already been destroyed!

Accurate counts of the goats are impossible without an experienced person making the estimates. The terrain is rough and the plane flew low along the rim so the goats disappeared from view over the edge or under the plane and out of view. There are thousands. An image that came to mind was ants swarming out of a disturbed nest site. Our work is cut out for us.

It is sad to report these observations because they support the conclusion that the situation on Isabela Island is deteriorating rapidly and that our efforts at eradicating feral goats are going to have to be great and widespread to be successful. The Galápagos National Park Service and the Charles Darwin Foundation are eager to begin research and management programs aimed at eradicating these devastating feral organisms but we can not do it without your help.

***Heidi M. Snell and Chantal Blanton***

# THE ENDEMIC RODENTS OF ISLA FERNANDINA: POPULATION STATUS AND CONSERVATION ISSUES

## By: Robert C. Dowler and Darin S. Carroll

### INTRODUCTION

Knowledge of the endemic rodents of the Galápagos began with Charles Darwin's collection of rats from San Cristóbal in 1835 and the description of those specimens as a new species, *Mus galapagoensis*, four years later (Waterhouse 1839). Since then, six additional species of native rodents have been described from four other islands in the archipelago. All extant species are now recognized as belonging to one of two genera, *Oryzomys* and *Nesoryzomys* (Patton and Hafner 1983). In addition to these species, evidence for several extinct species of rodents and the extinct genus *Megaoryzomys* from several islands is available in the form of subfossil skeletal material collected from lava tubes (Steadman and Ray 1982). The distribution and status of the seven species known from the Galápagos during the last century and a half was recently summarized (Key and Muñoz 1994). Tragically, four of the seven species are now thought to be extinct, likely due to the introduction of *Rattus rattus* (Brosset 1963, Niethammer 1964). The three remaining species all occur on islands currently free of introduced rats. The Santa Fe rice rat, *Oryzomys bauri*, is very similar genetically to the mainland species, *O. xantheolus*, suggesting that their colonization of the Galápagos occurred very recently (Patton and Hafner 1983). In contrast, members of the second extant genus of endemic rodents in the archipelago, *Nesoryzomys*, are genetically distant both karyotypically and electrophoretically from any mainland form (Gardner and Patton 1976, Patton and Hafner 1983). The arrival of this genus in the Galápagos is estimated to have occurred more than 3 million years ago (Patton and Hafner 1983). The genus *Nesoryzomys* is likely represented now by extant populations only on the island of Fernandina.

On Fernandina two species have been described. The first was *Nesoryzomys narboroughi*, described by Heller in 1904. Patton and Hafner (1983) proposed that *N. narboroughi*, and *N. swarthi* on Santiago were not sufficiently distinct morphologically from *N. indefessus* on Santa Cruz to justify their recognition as distinct species and suggested that the three large species be synonymized under the name *Nesoryzomys indefessus*. Thus the large Galápagos rice rats from Isla Fernandina represent a race, *Nesoryzomys indefessus narboroughi*, not specifically distinct from the other large rice rats of Santiago and Santa Cruz. No genetic tests of this hypothesis have been conducted, because unfortunately no extant populations of either *N. swarthi* or *N. indefessus* have been found. With recent advances in molecular technology, tissue from existing specimens in museum collections may be analyzed to further clarify the relationships of the three forms.

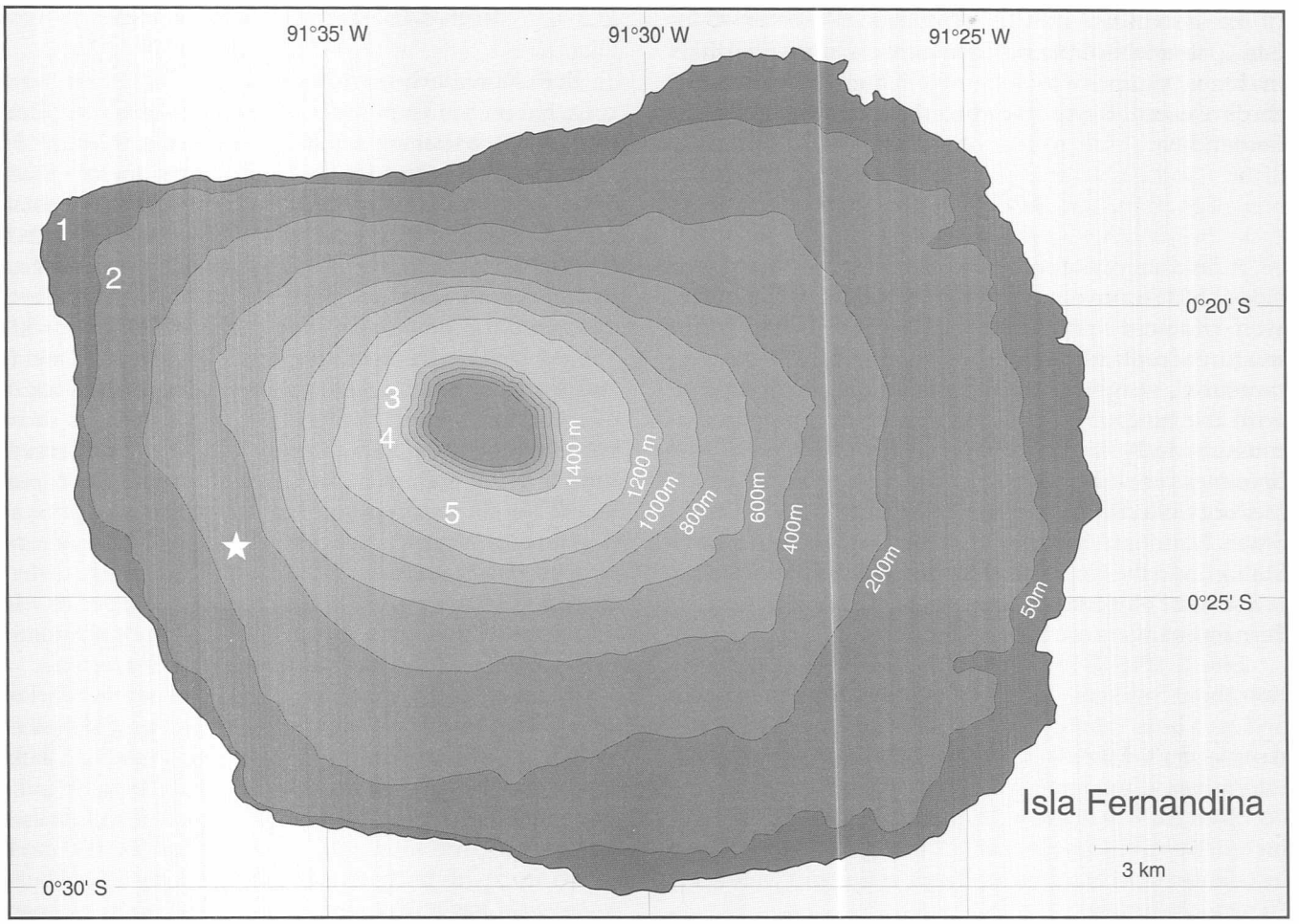



**Figure 1.** Map of Isla Fernandina. Numbers 1-5 designate the five collecting sites for *Nesoryzomys fernandinae* and *N. narboroughi*. The star represents the location where owl pellets containing the first reported skulls of *N. fernandinae* were collected (Hutterer and Hirsch, 1979).

The taxonomic arrangement treating *narboroughi* as a subspecies of *N. indefessus* has been adopted in major works on mammals (Nowak 1991, Musser and Carleton 1993), but many continue to use the species name N. *narboroughi* for the Fernandina form (e.g. Key and Muñoz 1994, Steadman and Zousmer 1988, Trillmich 1986). We also choose to use *N. narboroughi* in this paper simply to prevent confusion, the evidence for synonymy of the three large species notwithstanding. *Nesoryzomys narboroughi* has been considered common on Fernandina, based on field studies of mammals conducted there (Patton and Hafner 1983; Godfrey Merlen, pers. comm.) and from anecdotal accounts of rats causing problems in camps of researchers on the island.

A second smaller species, *Nesoryzomys fernandinae*, was described in 1979 by Hutterer and Hirsch based on cranial remains from owl pellets collected by Hirsch on the west side of Fernandina at an elevation of about 300 meters (Figure 1). The owl pellets were reported to be fresh and the field crew reported seeing small rodents at their campsites; however, no specimens were collected because the project lacked appropriate permits. Some researchers considered that the skeletal remains from the owl pellets could be of subfossil material and that the smaller living rodents seen were likely immature *N. narboroughi*. One sighting of a mouse-sized rodent on lava beds away from the coast at Cape Hammond in 1974 by Adserson and Adserson (1987) gave hope that *N. fernandinae* existed, and published accounts of the Galápagos fauna continue to list Fernandina's rodents as one or two species (e.g. Jackson, 1993). Because the populations there likely represent the only members of the genus *Nesoryzomys* remaining in the Galápagos, several authors have suggested that the conservation of the species on Fernandina is of the utmost importance. This concern has grown with the increasing risk of introduction of the commensal rodents, *Rattus rattus, R. norvegicus*, or *Mus musculus*, to Fernandina (Clark 1984, Key and Muñoz 1994, Trillmich 1986).

This paper reports the results of field work conducted on Isla Fernandina during August, 1995. The objectives of our research were to: 1) determine if an extant population

of the Fernandina mouse (*Nesoryzomys fernandinae*) exists; 2) to establish the status of the Galápagos rice rat (*N. narboroughi*); and 3) to determine if there is evidence for the invasion of any introduced species of rodents to Fernandina.

## METHODS

A field survey of rodents was conducted on the west side of Isla Fernandina from 1 to 14 August 1995. Rodents were captured using Sherman live traps baited with a mixture of peanut butter and rolled oats. Individuals were measured, weighed, and released at the site of capture, with the exception of voucher specimens prepared as museum study skins or fluid-preserved specimens. These specimens are to be deposited at the Angelo State Natural History Collection of Angelo State University, the United States National Museum, the Charles Darwin Research Station, and the Departamento de Ciencias Biológicas de la Escuela Politécnica Nacional, Quito. Five sites on Isla Fernandina were sampled (Figure 1) .

Site 1. 0°18'05" S, 91°39'08"W; Cape Douglas, elevation about 5 meters. This area bordered the sandy beach and lava beds inland from the landing area. The dominant vegetation here was saltbush (*Cryptocarpus pyriformis*) intermixed with some espino (*Scutia pauciflora*). Sampling occurred for five nights at this site (345 trap nights) and included establishment of a 7 x 7 trap grid for four nights in a dense stand of saltbush. Traps in the grid were set at 10 meter intervals.

Site 2. 0°19'22" S, 91°38'19"W, elevation about 80 meters. The second site was at an ash field about 3 km southeast of Cape Douglas. Vegetation here was very sparse with a few small shrubs and a species of *Tiquilia*. Some patches of palo santo trees (*Bursera graveolens*) were within 100 meters of the study area. Traps were set for two nights at this site (205 trap-nights).

Site 3. 0°21'38"S, 91°33'55"W; elevation about 1360 meters. This site was at the summit along the rim of the caldera. Vegetation here was among the densest we observed on the island and consisted of large *Scalasia microcephala*, *Darwiniothamnus tenuifolius*, another large composite, and several species of grasses. We sampled here for only one night (40 trap nights).

Site 4. 0°21'52"S, 91°34'01"W; elevation about 1330 meters. This location was near site 3, but had sparser vegetation and some shallow canyons or erosion channels in the ash, in which some traps were set. Sampling occurred here for two nights (52 trap nights).

Site 5. 0°23'26"S, 91°34'01"W, elevation about 1330 meters. This location was on the southwestern side of the caldera south of some active fumaroles. Vegetation here was rather sparse but with some large *Scalasia* present. The area was trapped only one night (20 trap nights).

## RESULTS AND CONCLUSIONS

Both *Nesoryzomys narboroughi* and *N. fernandinae* were collected on Isla Fernandina. This represents a verification of the existence of the Fernandina mouse, *N. fernandinae* and provides the first examination of the external features of this species. As predicted by the small skull size originally described by Hutterer and Hirsch (1979), *Nesoryzomys fernandinae* is distinctly smaller than *narboroughi* in body size. Weight of 21 *N. fernandinae* averaged 30 g compared with 77 g for *narboroughi* (n=80). Table 1 includes representative external measurements and weights for samples of both species. Total length measurements were not recorded for specimens to be released, due to the difficulty in taking the measurement from a living animal; however, measurements of total length for six specimens of *N. fernandinae* prepared as museum specimens averaged 207 mm and those of nine *N. narboroughi* averaged 278 mm. Details on size differences and cranial variation between the two species will be presented in another paper with a formal taxonomic re-description of the species *Nesoryzomys fernandinae*.

Pelage of *Nesoryzomys fernandinae* is somewhat darker brown than that of *N. narboroughi*. Further differences include a yellowish wash on the face of *fernandinae*, lacking in *narboroughi*, and a less distinctly bicolor tail , compared with that of *narboroughi*. One of the most useful features for identifying *fernandinae* is the dark appearance of both front and hind feet, whereas *narboroughi* has obvious white feet. The white appearance of the feet can be seen quite easily, even in subadult *N. narboroughi* (Figure 2).

The distribution of the two species at sites we sampled on Isla Fernandina was completely sympatric. Both species were collected in the same trap lines at all of the five localities studied, although patterns of relative frequency

**Table 1.** External lengths and total live mass of *Nesoryzomys* from Fernandina.

| | Total l. (mm) | Tail l. (mm) | Foot l. (mm) | Ear l. (mm) | Mass (g) |
|---|---|---|---|---|---|
| | | *N. fernandinae* | | | |
| mean | 206.7 | 87.2 | 24.4 | 16.5 | 32.3 |
| s. error | 5.2 | 1.15 | 0.29 | 0.28 | 2.21 |
| range | 190-221 | 77-100 | 21-27 | 15-19 | 21-63 |
| n | 6 | 27 | 27 | 27 | 27 |
| | | *N. narboroughi* | | | |
| mean | 275.2 | 119.5 | 31.28 | 19.3 | 77.5 |
| s. error | 5.96 | 1.55 | 0.27 | 0.26 | 3.10 |
| range | 243-297 | 80-137 | 24-35 | 14-24 | 26-146 |
| n | 10 | 86 | 86 | 86 | 86 |

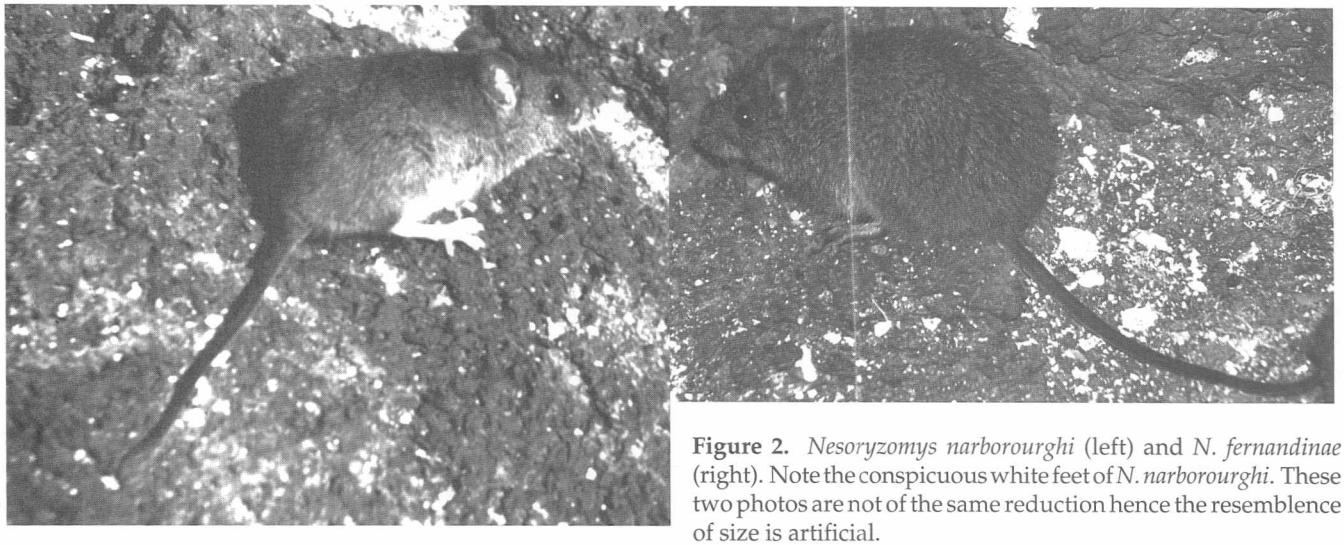


**Figure 2.** *Nesoryzomys narborourghi* (left) and *N. fernandinae* (right). Note the conspicuous white feet of *N. narborourghi*. These two photos are not of the same reduction hence the resemblence of size is artificial.

were different at most sites. On the coast at Cape Douglas, *Nesoryzomys narboroughi* was by far the most common species. Trap success, as measured by the percentage of animals captured per trapping effort, was high for *narboroughi* at site 1 (42%) compared with that of *fernandinae* (1%). At site 2, both species were rare with 2% and 0.05% trap success for *narboroughi* and *fernandinae*, respectively. At the sites along the crater rim (sites 3, 4, and 5), *N. fernandinae* was the more common species with an overall capture rate of 19% compared with 8% for *narboroughi*. The single highest capture rate for *N. fernandinae* was at site 3, where vegetation was the densest and trap success was 30% , compared with 7.5% for *narboroughi*. There appears to be a good correlation between available vegetative cover and population density, based on these preliminary data. No sampling was conducted at Punta Espinosa or other areas along the eastern coast of Isla Fernandina. It remains to be seen if the smaller species occurs in low densities at those locations on the island, and simply has been undetected in previous studies, or if it is restricted to western areas of Fernandina.

Preliminary analysis of data collected for four days on the trap grid at Cape Douglas reveals a minimum number of 36 *Nesoryzomys narboroughi* on the grid covering 3600 square meters. This represents a population density estimate of 100 *N. narboroughi* per hectare within areas of saltbush along the coast, a very high density compared to many other rodent species. However, this density can give a false impression of very large populations. Because few areas of continuous dense saltbush occur along this part of the coast, the actual population is potentially quite small.. In fact, the grid size chosen (60 x 60 m) was determined by the available vegetation and the edges of the grid met unvegetated barren lava. Thus, the available habitat for dense populations of *N. narboroughi* along the coast appears to be scattered patches of saltbush, either isolated from other such patches or connected by low density populations of the plants. The few captures of *N. fernandinae* on the grid suggest a density estimate of less than 6 per hectare at the same site.

No introduced species of rodents were collected, nor was there any other indication of an introduction of *Mus* or *Rattus* species, at any site on Isla Fernandina.

## DISCUSSION

This research documents that the Fernandina mouse, *Nesoryzomys fernandinae*, is an extant member of the Galápagos fauna. We further determined that healthy populations of both species of *Nesoryzomys* exist at sites from the coast at Cape Douglas to the caldera rim on the western side of Isla Fernandina. The two species are sympatric as suggested initially by the mix of skulls found in owl pellets by Hirsch (Hutterer and Hirsch, 1979); however, the fact that *N. fernandinae* occurs even along the coast was surprising. Collecting at Punta Espinosa and areas along the eastern coast should now be conducted to determine if only *N. narboroughi* occurs at those sites. Mangrove areas, a habitat not present near Cape Douglas, should be sampled to determine if only one or both species occur in that habitat. In any case, whenever populations are sampled, some specimens should be preserved as vouchers to verify the identity of the species collected. It is possible, though perhaps unlikely, that previous collecting efforts on Fernandina overlooked the smaller species, mistaking it for juvenile *N. narboroughi*. When collecting permits are limited, most researchers only take adult specimens, and this could have obscured the existence of the smaller *N. fernandinae* by the lack of specimens in museum collections. The other factor playing a role in the late discovery of this new species was that few, if any, specimens had been collected at high elevations on Fernandina, where the species is most common.

There is little doubt that the populations of the two endemic species of rodents on Isla Fernandina are vulnerable to extinction. The history of reduction and likely

extinction of the other species within the genus *Nesoryzomys*, with the concomitant increase and spread of introduced species of rodents, has been well documented (Brosset 1963, Clark 1984, Key and Muñoz 1994, Niethammer 1964, Patton et al. 1975). We envision three areas for action important for the long term conservation of the endemic rodents remaining in the Galápagos Islands: 1) gaining an increased understanding of the distribution and biology of the extant endemic species, 2) regular monitoring of known populations for the possible introduction of commensal rodents and the development of an emergency plan to deal with this potential event, and 3) initiating a captive breeding colony of known endemic species that can serve as a repatriation reservoir, should any of the species become extirpated in the wild.

First, an increased effort is needed to document the presence and status of populations of endemic rodents, both in other areas of Isla Fernandina and on other islands. Although highly unlikely, there is a remote possibility that extant populations of other species of *Nesoryzomys* still occur in other parts of the Galápagos. Though one would expect all of the islands to have been well surveyed, the reality is that collecting efforts aimed at rodents over the past 50 years have been very limited, and most have been conducted at coastal sites with relatively easy access. The fact that a new species of a mammal, undiscovered until recently, occurs and has healthy populations on Isla Fernandina, suggests that the presence of other endemic rodent populations in remote areas of other islands is not beyond the realm of possibility. As suggested by Key and Muñoz (1994), more research on the basic biology of the rodents is needed. Surprisingly little, if anything, is known of the ecology, behavior, physiology, genetics, and parasites of the endemic rodents in the Galápagos. This information may play a critical role in the long term conservation of these species.

Ideally, a regular monitoring program to detect the introduction of *Rattus* or *Mus* to Isla Fernandina should be initiated. This should be conducted twice a year if possible, but not less than annually. Areas with the highest risk of introductions, such as heavily used Punta Espinosa and coastal areas known to be illegally used by fishermen, should be targeted. The problems with attempting to monitor populations are immense, as the time and expense of maintaining such a schedule for several coastal areas of Fernandina are beyond the current means of the Galápagos National Park Service (GNPS) or the Charles Darwin Research Station (CDRS). This may represent a good opportunity for a collaborative project of monitoring. An important part of the monitoring program will be the development of an emergency plan to deal with the likely event of an introduction of commensal rodents. The plan should be formulated in advance by individuals at CDRS and GNP, in conjunction with scientists with expertise on rodent introductions, commensal rodent population ecology, effective control methods, and the biology of the endemic species at risk. It is essential that such a plan be finalized quickly, put in written form, and approved for use by the GNP, before the introduction occurs. In this way, action can be initiated immediately upon discovery of an introduction. Potential responses might include rapid determination of the extent of the introduction by immediate further sampling, intensive eradication efforts using trapping and poison, especially if the introduction is caught early and appears to be limited to a single locality on the island, and possibly the capture and removal of live endemic rodents for establishing a captive colony.

The last area concerning the long term conservation of endemic rodents in the Galápagos is the development and maintenance of captive colonies of the rodents, as first proposed by Trillmich (1986). Because of the lack of data on the basic biology of the endemic species, especially the two species of *Nesoryzomys* on Fernandina, establishing and managing such a colony potentially will be difficult. One or more zoos that have expertise with small rodent management should initially set up colonies to determine housing requirements, an acceptable diet, susceptibility to disease in captivity, and breeding protocols for maintaining the maximum genetic heterozygosity in the captive colonies of each species. This ideally should be a collaborative effort among zoo professionals at one or more Ecuadorian zoos and those at zoos in North America or Europe, which might have the funds, facilities, and expertise to establish such colonies. Although, as Trillmich (1986) noted, many may argue that to allow export and establishment of such rodent colonies outside the Galápagos or Ecuador is undesirable, the disadvantages are certainly outweighed by the benefit of ensuring the survival of these last remnants of an important part of the Galápagos fauna.

## ACKNOWLEDGMENTS

We wish to thank the Galápagos National Park and especially Eliecer Cruz for issuing the permits that allowed this research to be conducted. We gratefully acknowledge Chantal Blanton, Laura Chellis, and the staff of the Charles Darwin Research Station for assistance in planning and carrying out this project. Further logistic support was provided by Howard Snell, Heidi Snell, David Parer, David Day, and Bernardo Gutierrez. Finally, we thank our two field assistants, Diana Vinueza and Simon Villamar, without whose help we would have been unable to complete this study. Funding for this project was provided by a Research Enhancement Grant through Angelo State University. Tame Airlines of Ecuador provided transportation to and from the Galápagos at reduced rates.

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**Robert C. Dowler and Darin S. Carroll, Department of Biology, Angelo State University, San Angelo, Texas 76909 USA, robert.dowler@mailserv.angelo.edu.**

# VOLCANIC HAZARDS AT SIERRA NEGRA

## By: Robert W. Reynolds

### INTRODUCTION

Volcán Sierra Negra, located at the southern end of Isla Isabela, is an active shield volcano that hosts numerous native and endemic plant and animal species and an expanding human population, all of which are exposed to hazards associated with future volcanic eruptions. Further, it is the only historically active volcano in the Galápagos archipelago with a permanently populated by humans. Although the long-term eruptive history of the volcanoes of Isla Isabela remains largely undocumented, recent studies indicate that Sierra Negra is in a state of extremely active growth (Reynolds et al., 1995). In fact, the entire volcano has been resurfaced within the past 4500 years. Moreover, single eruptions are now known to affect large areas of the volcano. In consideration of the volcano's active status and the potential consequences to the native and endemicflora andfauna as well as the human populations, an appraisal of the volcanic hazards is warranted. The purpose of this article is to describe the various types of hazardous volcanic phenomena that have occurred in the recent geologic past at Sierra Negra and to summarize the risks to the variety of organisms that inhabit the flanks of the volcano. In addition, generalized hazard-zonation maps are provided to facilitate land-use planning and the development of emergency response plans. Information for this assessment was obtained from geologic mapping conducted during extended visits to Sierra Negra during 1991 and 1992. The data, interpretations and recommendations presented in this paper do not in any way suggest that the volcano is about to erupt or that human populations are in immediate danger.

### GEOLOGIC FEATURES OF VOLCÁN SIERRA NEGRA

The islands of the Galápagos archipelago are the result of oceanic hotspot volcanism, and the active western

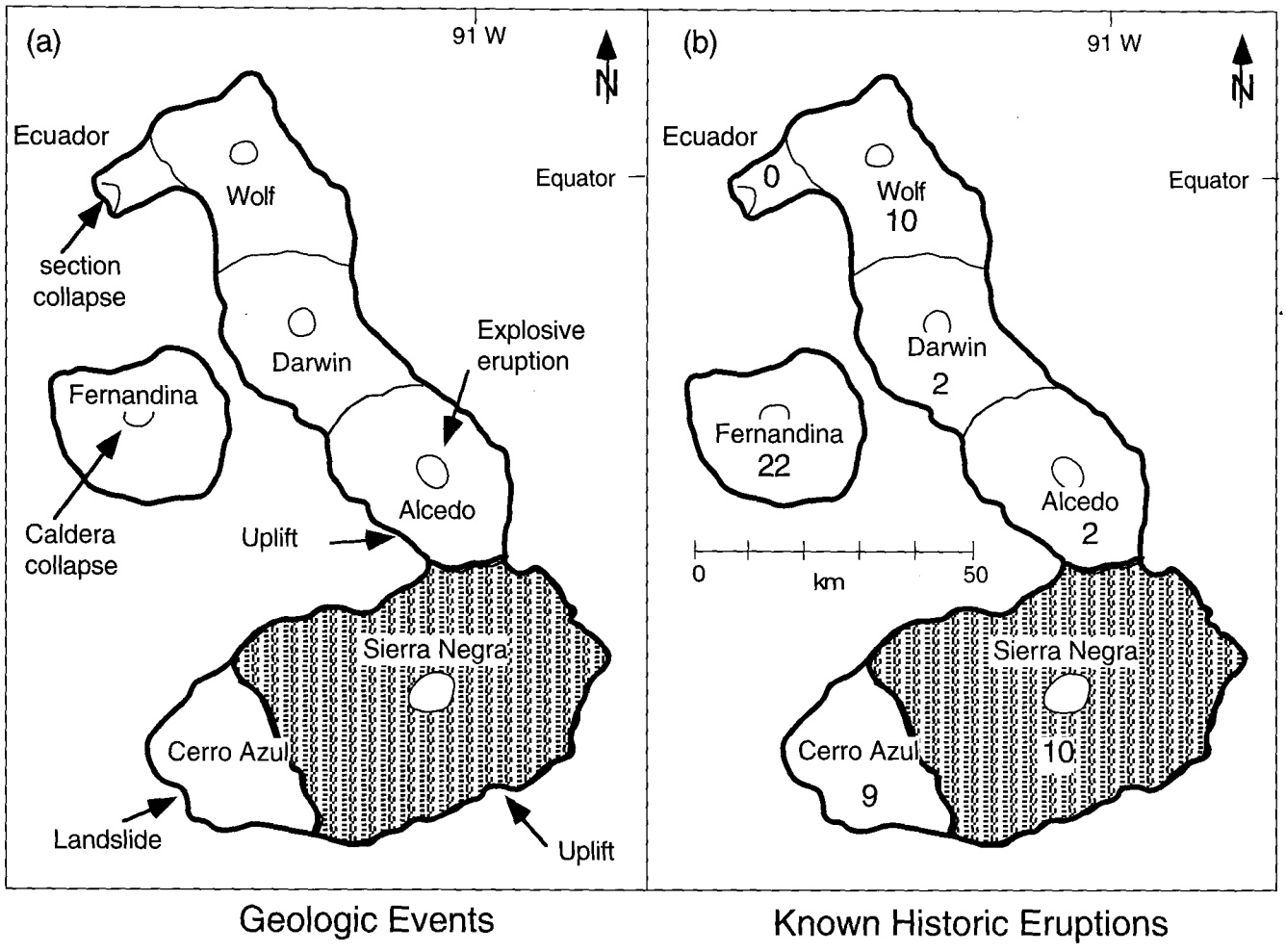


**Figure 1.** Western Galápagos volcanoes showing (a) geologic events and (b) number of historic eruptions associated with each volcano. Sierra Negra is the largest volcano in the group (stippled).

Galápagos volcanoes are coincident with the focus of the hot spot. Over fifty historic eruptions have been reported (Figure 1), and both the historic and geologic records are replete with evidence of caldera collapse, landslides, explosive eruptions and uplift (c.f. Simkin and Siebert 1994; McClelland et al. 1986; McBirney and Williams 1969).

Sierra Negra, in particular, is one of the most active and voluminous of the western Galapagos volcanoes. Ten historic eruptions have been reported at Sierra Negra (Simkin and Siebert, 1994; McClelland, et al., 1986). All eruptions prior to World War II were monitored exclusively from remote locations or passing ships and are severely lacking in detail. Some general trends however, are apparent. On average, an eruption has occurred every 15 years. The shortest interval between eruptions was 4 years and the longest 37 years. The shortest duration of an eruption was one week and the longest lasted about four months.

Sierra Negra is 60 km long, 40 km wide and rises 1100 m above sea level. It has steep upper flanks, broad gentle lower flanks and a flat summit entirely occupied by a large elliptical (7 x 10 km) caldera. Eruptive centers and associated lava fields are broadly distributed over five age groups (Figure 2). The majority of the eruptive products consist of aerially extensive lava flows that have erupted from a volcano wide system of ENE fissure system. Most fissures are surmounted by a chain of cinder cones and spatter ramparts. Many of the lava flows have traveled over 20 km from the fissures, ultimately terminating upon entering the sea. In general, the oldest fissures occur on the south and east flanks, intermediate-age fissures occur on the southwest and upper east flanks, and young fissures are found on the north flank.

Sierra Negra's summit caldera is large and structurally complex. Near vertical faults circumscribe the summit. The north section of the caldera consists of an east-trending, en-echelon sequence of faults that step down towards the central caldera floor. Displacements along the individual faults ranges from 3 to10 m. The eastern and southern caldera walls have talus aprons and landslide blocks at the base. The most significant structural component within the caldera is a complex set of faulted and uplifted blocks known as the "sinuous ridge". The sinuous ridge is composed of a 15 km-long compound set of

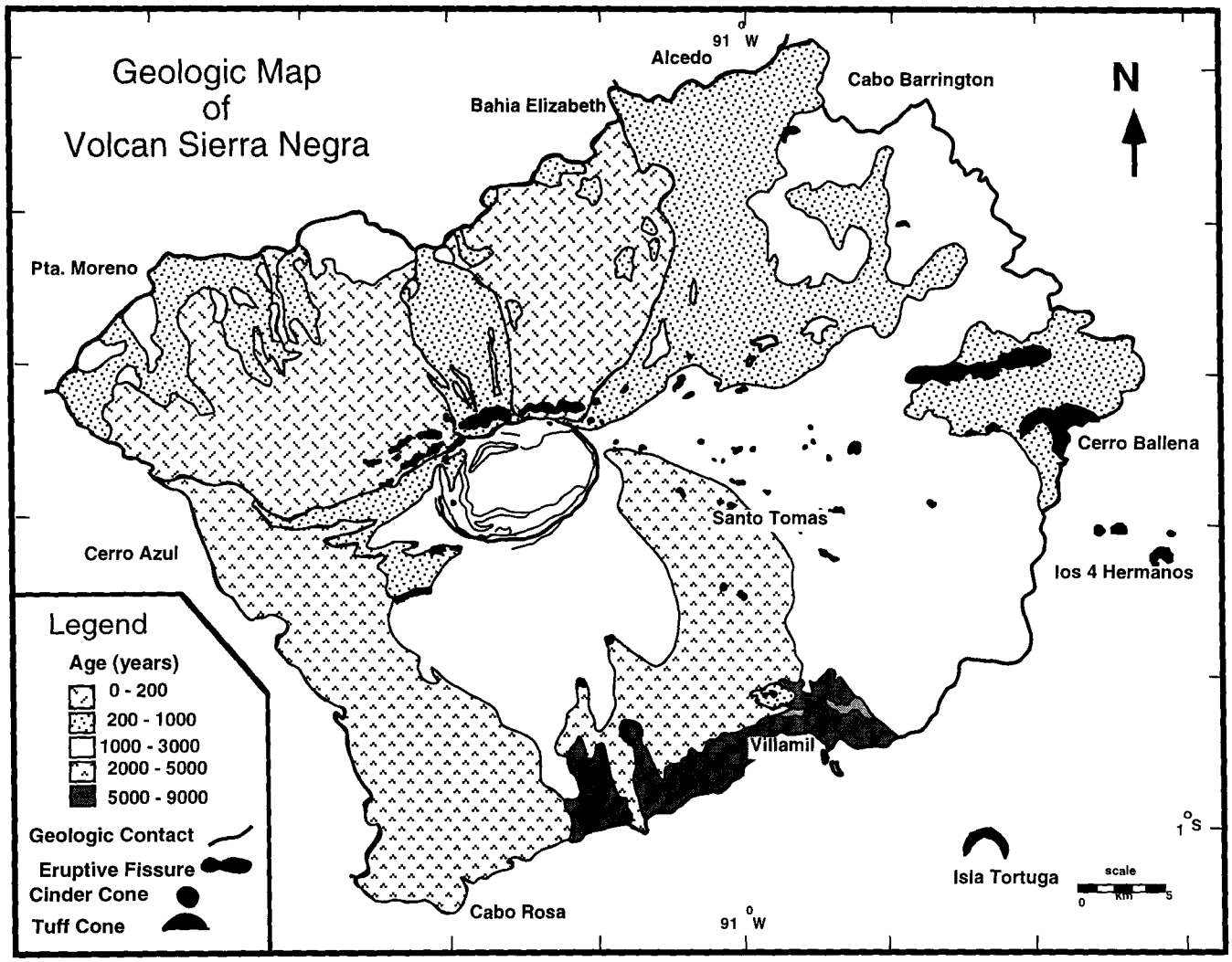


**Figure 2.** Geologic map of Sierra Negra showing the five ages of lavas and associated eruptive centers.

uplifted (1-100 m) and tilted (60-90o) blocks of caldera floor, the whole of which forms a C-shaped ridge that is open to the east. The compositions of volcanic gases emitted from the fault suggest that a shallow body of magma is currently degassing beneath the ridge (Goff et. al, 1995). Individual segments of the ridge overlap, split and combine to form curved benches. Field relations suggest that Sierra Negra's complex summit caldera may have developed in a piecemeal fashion as a result of episodes of magma intrusions (Reynolds et al., 1995). The sinuous ridge is thought to have been uplifted in a trapdoor fashion, possibly caused by the forceful intrusion of magma just below it.

The total average historic eruption output for the volcano is approximately 12 million m3/yr. Volumetric discharge rates for individual historic eruptions based on the combination of historic record and geologic mapping range from 44 to 248 m3/sec (Reynolds et al., 1995). In addition to the historical record, a variety of geologic age dating techniques have been used to constrain the age of the prehistoric lavas on Sierra Negra. Currently, eight absolute ages using 14C (Reynolds et al., 1995; Steadman et al., 1991) and cosmogenic 3He-exposure techniques (Reynolds et al, 1995) have been reported. Lava ages range from 400 to 6900 yr. These age determinations, together with geologic mapping, indicate a long term rate of lava production of about 1 million m3/yr. This estimate is an order of magnitude less than estimates based upon the historic record alone, and is interpreted to represent a minimum production rate for the volcano. In general, however, Sierra Negra has experienced rapid subaerial development in which over 90% of the volcano has been resurfaced in the past 4500 yr.

On the basis of eyewitness accounts and examination of the historic and prehistoric eruptive centers, thetypical behavior of Sierra Negra eruptions can be summarized. Most Sierra Negra eruptions are non-explosive (although some large explosions have occurred in the geologic past) and dominated by lava flows. Eruptions usually are preceded by shallow earthquake activity (M5 or less) followed shortly thereafter by eruption of a large cloud of tephra and gas (including sulfur dioxide and water vapor) which

rises as high as 5 to 8 km (McClelland et al., 1986). Fire fountaining (10-50 m height) ensues along the length of the active fissures, resulting in construction of a near vent rampart of cinder and spatter. With time, the eruption becomes focused at a few sites along the fissures. These sites construct cinder and spatter cones up to 20 m height. The cones typically breach on the down-flank side and focus lava into channels that lead directly away from the cones. Down flank from the eruptive center lavas spread laterally and overlap with earlier lobes from the same eruption. Close to the vent, the lava flows in channels at velocities up to 10 km/hr. The advancing front of lava travels only 1 to 5 km/day). During sustained eruptions, some of the lava channels roof over and become lava tubes; the formation of lava tubes is important, because they facilitate delivery of lava to the lower flanks and coast. As lava enters the ocean, explosive steam blasts can occur.

## AN OVERVIEW OF VOLCANIC HAZARDS AND RISKS

A volcanic hazard includes any aspect of an eruption that has the potential to harm biota or cause destruction of property (Tilling, 1989). "Direct" hazards are those volcanic phenomena intimately associated with an eruption and include all of the rock materials and fluids that reach the surface. Direct hazards that are known to occur during eruptions of Sierra Negra include lava flows, air fall tephra (ash and pumice), steam explosions, and emission of volcanic gases. Indirect hazards are secondary effects resulting from the subterranean movement of magma and volcano-generated earthquakes. With respect to Sierra Negra, these include ground deformation (which commonly result in landslides and earthquakes) and tsunamis (tidal waves). The risk associated with a specific hazard includes all of the expected consequences of that hazard together with an estimate of the relative severity (Tilling, 1989). For example, some risks associated with the hazard of lava flows include crushing of buildings and burning of cultivated land.

Once a hazard has been identified either from historic or geologic records, the distribution of the hazard can be portrayed on a hazard-zone map. Hazard zone maps outline areas in which the potential effects or risks are relatively higher or lower than adjacent areas. These zones are based upon the extrapolation that future volcanic activity will likely mimic that of the past. The hazard zones are designed to consider both the type of likely volcanic activity andthe distribution of humans, property, and endangered biota. Because risk severity usually changes gradually with distance from the source of the hazard, boundaries between adjacent risk zones are only approximate (Tilling, 1989).

Humans, property and a variety of rare plants and animals are directly exposed to the volcanic hazards posed by Sierra Negra. For example, several hundred people reside in the coastal village of Villamil. Most are involved in fishing or government -related activities and seldom travel widely overland.Fishermen, however travel the entire coast of Isabela, often in small boats and with no radio communication.] In addition, farms, ranches and plantations are dispersed around the village of Santo Tomas on the upper SE flank of the volcano where people are engaged in agricultural activities that requires considerable overland mobility. Tourists are routinely guided on day-long visits to the summit The most popular tourist sites are Volcán Chico, the site of the most recent eruption, and Azufre, the area of active sulfur fumaroles located inside the caldera. With the recent completion of a road to the summit, visits will likely increase. A variety of domestic animals are raised by the residents of the highlands. In addition, orange, avocado and banana plantations are cultivated on the SE flank of the volcano, near Santo Tomas. Moreover, populations of endemic animals are restricted to selected parts of Sierra Negra. The vulnerable flightless cormorant, for example, nests on the NW shores of Sierra Negra, giant land tortoises inhabit the southeastern and southwestern flanks of the volcano and sea turtles lay their eggs on the remote sandy beaches of the southern coast west of Villamil.

## THE NATURE OF VOLCANIC HAZARDS AT SIERRA NEGRA

### *Lava flows*

Lava flows are the greatest hazard posed by Sierra Negra. Future eruptions are most likely to originate from the historically active eruptive centers located on the upper north flank of the volcano. Because it is the focus of historical activity, the entire north flank of the volcano from the summit to the coast is an area of highest risk (Figure 3a). Although lava flows rarely threaten human life, they crush, bury and burn everything in their path. Lava flows can also ignite surrounding vegetation, causing wildfires a notorious problem on Sierra Negra as evidenced by human-initiated fires in 1985 and 1994. In addition to the high-risk zone on the north slope, a zone of moderate risk exists on the south flank, based upon the concentration of humans in proximity to a young, prehistoric eruptive center at Cerro Pelado. Several older prehistoric cinder cones and at least one steam-explosion have also occurred in this area.

### *Volcanic Gas Emissions*

Vigorous fumarolic degassing of the volcano has been noted for several decades at 2 locations, and there is evidence of several other extinct or inactive fumaroles (Banfield et al, 1956). Degassing is currentlly occurring along much of the north flank fissure system. Satellite-based remote sensing of the 1979 eruption recorded very high sulfur gas output (McClelland et al, 1986), and low level gas emissions have continued since the eruption.

Within the caldera, a large fumarole called Azufre occurs midway along a north-trending section of the sinuous ridge. It is probably the most active fumarolic area in the Galápagos. Rheomorphic flows of elemental sulfur and boiling sand pits are unique features of this fumarole. Near surface temperatures exceed 200 oC. Emissions include carbon dioxide (97 mol %), and sulfur dioxide (2.3 mol %) and trace amounts of hydrochloric acid, hydrogen sulfide, chlorine and fluorine (Goff et al., 1995).

The volcanic gases emitted from Sierra Negra are toxic to most plants and animals. Because the gases are heavier than air, the zone of highest risk includes those low lying areas immediately adjacent to the fumaroles, both within the western part of the caldera and along the north flank fissures (Figure 3b). The primary effects include poisoning, suffocation and acid burns. Populations potentially at risk include summit visitors such as scientists and tourists, as well as stray domestic animals.

### *Air Fall Tephra*

Air fall tephra constitutes volcanic solids deposited from the atmosphere during an eruption. These materials can range in size from fine ash to boulder sized ballistic projectiles. Particle size, exit velocity and wind direction and speed are the primary controls on tephra dispersal, hence the hazard posed by it. At Sierra Negra, basaltic pumice and ash usually precede and accompany the eruption of lava. Historic accounts indicate that the early stages of an eruption include fire fountaining and large clouds of ash that reach thousands of meters into the atmosphere. For example, during the 1979 eruption on the north flank, pumice and scoria accumulated to a thickness of 10-25 cm immediately south of the fissures, and ash was reported as far away as Villamil, 26 km south of the eruptive site (McClelland et al., 1986). The dispersal pattern was strongly influenced by high altitude NW winds. Large tephra blankets are dangerous because they can cause suffocation, roof collapse and fouling of machinery, such as automobiles and power generators. The zone of highest risk are those areas nearest the active vents and to the lee of the prevailing wind (Figs. 3c). Although thick tephra blankets are restricted to the near-summit region on Sierra Negra, nearby Alcedo volcano has a very large pumice blanket that is several meters thick and extends from the eruptive site at summit all the way to the to the east coast (Geist et al., 1994). Likewise, much of the northwest flank of Fernandina is covered with tephra from the 1968 eruption. Such an eruption from Sierra Negra could have serious consequences for its communities.

### *Ground Deformation*

The summit of the volcano is the most active area of ground deformation and thereby designated as highest risk (Figure 3d). The steep caldera walls are very unstable, and prehistoric landslides have occurred on both

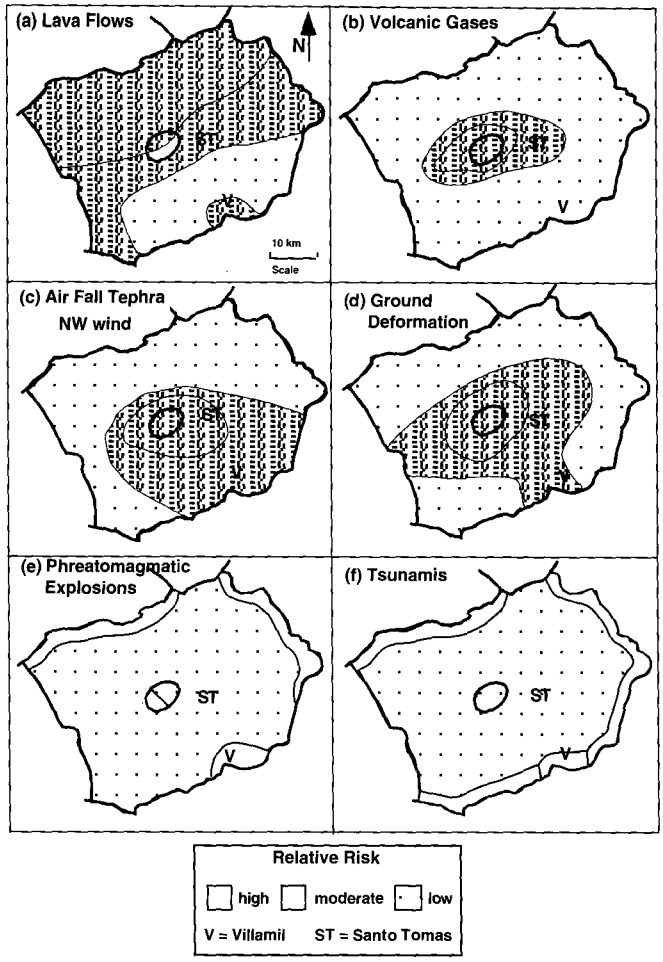


**Figure 3.** Hazard zone maps for volcanic hazards associated with Sierra Negra volcano. (a) Lavas flows (b) volcanic gases (c ) air fall tephra (d) ground deformation (e) phreatomagmatic explosions (f) tsunami. See text for explanations of each hazard.

the south and east walls. In addition, extensive faulting, probably accompanied by large earthquakes, has occurred within the caldera along the entire length of the sinuous ridge. Slopes have also failed in steep and hydrothermally weakened rock adjacent to fumaroles and eruptive vents. There is virtually no warning of such events. Visitors to the caldera and residents of the highlands are the only ones likely to be effected by such events.

Deformation of other parts of the volcano does not appear to be sudden or related to large earthquakes but may have serious consequences nonetheless. For example, the area around Villamil is slowly inflating, possibly due to the intrusion of magma beneath the town. Estimates based upon historic observations of the changing shore line range from 0.5 to 2 m for the past 30 yr., a rate of about 2 to 7 cm/yr (Reynolds et al, 1995). The geologic record suggests longer-term inflation in this area. Specifically, two elevated beach deposits are located at 5 to 14 m elevation at distances of 0.5 to 2 km inland. These ancient beach deposits, which underlie the airport currently being con-

structed on Isabela, are old (Reynolds et al, 1995). The combined age and elevation data result in a long term rate of uplift of 0.1 to 2 cm/yr.. In addition, the lagoon located in Villamil also results from uplift of the area.Gradual ground elevation may pose a long term hazard to Villamil because the uplift may change depth and shape of the harbor, crack building foundations and strain water pipes and other utilities.

### *Phreatomagmatic explosions*

When magma comes into contact with water, the heat from the magma (which is approximately 1150 oC) flashes the water to steam, producing an explosive expansion of hot gas known as a "phreatomagmatic" explosion. This can occur when an eruption begins beneath water (including ground water) or when lava flows laterally into water. Sierra Negra shows evidence of prehistoric phreatomagmatic eruptions (Figure 3e). The most dramatic example is located along the east coast at Cerro Ballena where a cluster of large tephra cones are located. These cones are the products of vigorous undersea eruptive activity. Other offshore examples include the islands of Tortuga and los Quatro Hermanos. Near Villamil, lavas have flowed into a lagoon or shallow ground water system causing extensive phreatomagmatic explosions, resulting in the formation of a subdued tephra cone. This cone is well exposed in part because it has been excavated and serves as the town water supply. Sierra Negra preserves evidence of prehistoric phreatomagmatic eruptions at the summit as well. The uppermost part of the western wall of the caldera is capped by a horizontal lens of phreatomagmatic ash (Reynolds et al., 1995).

The primary effect of phreatomagmatic explosions is the destruction caused by expanding hot gas and pulverized rock. The highest risk areas, although generally small, occur wherever magma is likely to come in contact with water. The north coast is a zone of highest risk because of the focus of recent eruptions there.

### *Tsunamis*

Volcano-generated earthquakes and giant submarine landslides can release energy into ocean which is transmitted as tsunamis or tidal waves. These large ocean waves travel very fast (100s km/hr) with heights as much as several tens of meters. Giant landslides have been documented on Isabela island at volcan Ecuador and Cerro Azul, and probably also occurred at Pinta and Santa Fe islands. Warning time from a locally generated tsunami is very brief (seconds to minutes). Distant tsunamis generated in other parts of the Pacific ocean, are a hazard as well, yet owing to their great distance allow hours of warning time. No tsunami deposits have been discovered along the coast of Sierra Negra, although local residents have reported instances of unusually high coastal wave activity that flooded the lagoon near Villamil. High risk zones include coastal coves and harbors, especially those that are inhabited (Figure 3f). The primary effects are flooding and crushing associated with the force of the incoming giant waves.

## EMERGENCY RESPONSE

In the absence of continuous seismic and deformation monitoring, little can be done to predict the timing of future eruptions on Sierra Negra. At present, the location and behavior of past eruptions provide the best clues to future volcanic activity. With this in mind, it is clear that the north flank of Sierra Negra has a high probability for an eruption every ten years or so. Moreover, the area likely to be affected by lava flows is considerable (5-15% of the volcano surface per eruption). Without active instrument monitoring, frequent visual inspections the summit and north flank by trained observers could be employed to record changes in fumarolic activity and recent ground deformation. In terms of instrumentation, a permanent seismic station would greatly assist in characterizing short term volcanic behavior at Sierra Negra and provide warning of the upward movement of magma. In addition, coastal tide gauges could be installed and a local radio station is needed for warning residents of the changing status of Sierra Negra and other Isabela volcanoes and to communicate Pacific tsunami warnings. All of these monitoring techniques are recommended for Sierra Negra.

In the event of an eruption or significant precursory activity, decisions ought to t be made concerning which emergency procedures to initiate and when they should be activated. For example, at some point during an eruption, the most appropriate emergency response may be evacuation. To help minimize the effects of a future eruption, an emergency response plan could be drafted that is specific to each of the hazards outlined above, including priorities for coordinating and implementing resources. This might best be facilitated by establishing a set of warning levels and associated procedures as part of the overall emergency response plan. Members involved in planning might include government officials, health care personal, local residents and scientists.

## SUMMARY

The historic and geologic record of Sierra Negra indicates that the volcano has experienced frequent, large eruptions. No monitoring of the volcano is currently in progress, yet extrapolation of its recent and long term eruptive behavior suggests that the volcano will continue to be highly active. Volcanic hazards at Sierra Negra are those common to large oceanic shield volcanoes for which assessments have been undertaken and emergency response plans have been successfully drafted and implemented (Millineaux et al., 1987). An active volcano monitoring program for Sierra Negra is recommended.

This should include a permanent seismic station, radio station, coastal tide gauge and frequent inspections of the summit. In addition, an emergency response team should be established to draft a plan for emergency response pertinent to each type of volcanic hazard and in consideration of risk to both humans and rare species of native and endemic organisms.

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**Robert Reynolds, Central Oregon Community College, Bend, Oregon, U.S.A.**

# GALAPAGOS REVISITED

## By: Mike P. Harris

Between 1965 and 1976 I was lucky enough to spend considerable time at the Charles Darwin Research Station (CDRS). During my first prolonged stay (1965-67) I spent a total of 10 months on Plaza Sur studying all the species of breeding seabirds, and one very wet, muddy and energetic 'garua' season following the Hawaiian or dark-rumped petrels (*Pterodroma phaeopygia*) at Media Luna. Subsequently (1970-71) my attention was focused mainly on the effects of increasing numbers of tourists on the waved albatrosses (*Diomedea irrorata*) at Punta Suarez, the flightless cormorants (*Nannopterum harrisi*) at Punta Espinosa and the frigates (*Fregata* spp.) on Tower. As a result I reckoned that I knew the islands and their seabirds fairly well but from the early 1970s my interests centered on the seabirds of higher latitudes.

In recent years several friends have been to the islands as tourists. All returned with enthusiastic and glowing reports of the islands. But I had been used to the Galápagos before any tourists or even controls on access. I had guided some of the first tours and had a say in the development of tourism and in the routing of the trails. How would I feel when confined by the necessary constraints or seeing possible damage to the fragile environment? Would I feel resentful or responsible? How would Puerto Ayora look? My interest in the islands was rekindled by the launch of the Galápagos Conservation Trust in London in April 1995. And so it was that I returned to the islands in January 1996 after a gap of 17 years.

This was meant to be a holiday and time was short, so Sarah and I took the advice of Luis Maldonado (Metropolitan Touring) and went on the south and west section of a M/V Santa Cruz cruise which visited Dragon Hill (Santa Cruz), Tagus Cove and Punta Espinosa (Bolivar Channel), Puerto Ayora, Punta Cormorant (Floreana), and Gardner Bay and Punta Suarez (Española). We left the ship at Baltra and spent a week at Puerto Ayora staying with Rolf Sievers, and visiting old friends and the CDRS. We managed a day with Hernan Vargas and David Day at and to the east of Media Luna and visited Plaza Sur on M/S Cachalote with Martin and other Schreyers. A fair sample of Galápagos revisited.

I was pleasantly surprised by how well the tourist parts of Galapagos we saw had stood up to the increase in visitor numbers. Obviously there were vastly more boats and the trails showed signs of wear but if the markers were removed these would be no worse than the donkey

and goat trails which once crisscrossed the same areas. It was harder to assess whether or not there had been changes in the numbers of animals as the non-annual breeding of some seabirds and the lack of site or even colony fidelity of others (e.g. flightless cormorants) makes the estimation of population size problematical. However one might have hoped for more than a single nest of cormorants at Punta Espinosa and a handful of marine iguanas (*Amblyrhynchus cristatus*) on the end of the rocky point. Still there appeared to be plenty of cormorants and marine iguanas in the general area.

The blue-footed and masked boobies (*Sula nebouxii* and *S. dactylatra*) at Punta Suarez were all ebullient and the usual oystercatcher (*Haematopus palliatus*) pair on the headland had at least one fledged chick. The blue-foots in particular were still amazingly tolerant of disturbance. Studies elsewhere have shown that some apparently tame birds are upset by humans, e.g. they have a markedly increased heart rate, but it is difficult to believe that these seabirds have suffered much from the almost continual procession of people. We did not expect to see any waved albatrosses, and indeed there were none at Suarez itself, but four were flying back and fro over the colony high up on the slopes inland of the cliffs. This date (28 January) is probably the latest these fine birds have been seen at Punta Suarez.

It was a delight to visit Plaza Sur again. One nesting Swallow-tailed gull (*Creagrus furcatus*) - ED 22221 - may well have remembered me as I had ringed it as a chick in February 1970! Undoubtedly this is the oldest known individual of the species. Although it was aged almost exactly 26 calendar years, one must remember that for these birds a breeding cycles lasts 9 rather than the normal 12 months, so that it had been alive about 35 cycles. Such longevity was not unexpected, as at least in the 1960s 97% of adults survived from one cycle to the next, but it was still exciting to find the bird. The Swallow-tailed gulls were at least as numerous as they were 30 years ago with as many pairs nesting on the cliff top in apparently suboptimal sites. And 4 pairs were breeding under the vegetation some 100 m west of the landing where none ever bred in the 1960s and 1970s. We found band-rumped storm petrel (*Oceanodroma castro*) chicks in burrows which were in use when I first searched out breeding birds in December 1965.

Plaza Sur had seen some rain, the bushes and trees were all green and the *Opuntia* were heavy with fruit. This might have obscured any subtle changes in the vegetation but a couple of passages through the western bush suggested little change, and certainly it was no easy task to traverse the area. *Opuntia* were different. Ever since my first visit these cacti have been falling over and in 1965 I wondered where this might stop. There are now markedly fewer cacti on the eastern half of the island and little regeneration. Presumably the still abundant, if slightly smaller, land iguanas (*Conolophus subcristatus*) are eating the bulk of the fruits and seedlings. One can see conflict here in the future, but otherwise Plaza Sur seemed well.

It once took a fit youth over 2 hours to walk from Pelican Bay to Media Luna. Now its a mere 20 minute drive and a 10 minute amble to get to the dark-rumped petrel nesting area. It was wonderful to stand above the dry stream and look across to Floreana and Santa Fe instead of being knee deep in water and pushing through garua-drenched vegetation. Nice to know too that the program of rat poisoning run by the Galápagos National Park Service (GNPS) has dramatically improved the nesting success of these fine birds.

However, all is not well, In 1965 there were a few guava bushes in the area, in 1970 a few handfuls of *Chinchona* could be seen and *Miconia* held sway. The view now is depressing - an awe-inspiring spread (or better put a relentless march) of *Chinchona* across the landscape and expanses of extremely sick looking *Miconia*. The vegetation on Media Luna itself is in better shape. There may well be a hope of keeping Media Luna as an example of the *Miconia* zone by sustained destruction of introduced plants but unless a specific and very efficient herbicide can be developed against *Chinchona*, I see no hope of defeating this plant and retaining the highlands of Santa Cruz in any semblance of its former state. As an ornithologist I hope that the petrels and the endemic rail (*Laterallus spilonotus*) will be able to cope with these changes. I am glad that I am not a botanist.

I realize fully the terrible problems facing Galapagos, goats on Alcedo, fishermen camped on Fernandina pillaging the seas, the inevitable trouble coming from increasing human immigration but I was heartened how well the islands had coped with the last 17 years. But it will take the continued vigilance of the world's scientists and conservationists to ensure that this happy situation continues.

**Michael P. Harris, Institute of Terrestrial Ecology, Banchory Research Station, Kincardineshire, AB3 4BY, Scotland.**

# THE COLONIA DE SANTA CRUZ OF 1926

## By: J. P. Lundh

Galápagos had been the subject of much interest in Norway long before any Norwegians came to the islands. There had been the Compañía Colonizadora Suizo–Escandinava, which in the 1800s recruited a number of Norwegian settlers, but never got beyond the planning stage. Much later, the Norwegian bark *Alexandra*, which had been drifting helplessly for about three months, was abandoned on May 8, 1907, within sight of Floreana. This and the six-month ordeal on Santa Cruz of her master, Captain Emil Petersen, and half of his crew, kept the Norwegian press busy for some time.

In 1914, August F. Christensen returned from several years in Chile and the South Shetlands, where he had been supervising his family's whaling operations. He began writing a series of articles, mostly about the Galápagos, where he had obtained a concession to set up a whaling station on Floreana. Christensen continued promoting the islands as an ideal location for a Norwegian settlement well into the 1920s.

In the meantime, three young Norwegian journalists visited the Galápagos in 1922—Jens Aschehoug, Per Bang and Finn Støren. This also resulted in a series of articles extolling Galápagos. Støren later joined Christensen, Bang and Harry Randall in writing a book, which came out in 1926. Randall also organized a group of settlers, who arrived in San Cristóbal the same year.

Christensen had by then organized a company that set up a whaling station at Post Office Bay on August 10, 1925. The little stone-bordered paths, the concrete posts, and the slab that supported the steam-driven generator are the sad remains of this colony, which broke up the following year.

Captain Olaf Eilertsen had been involved with the Floreana project from the beginning, but had to stay in Norway because of illness. He had collected every bit of information he could get about the islands since the bark *Alexandra* had been abandoned. Early in 1926, he went ahead and formed his own group of settlers and decided to start a cannery on Santa Cruz. The Colonia de Santa Cruz arrived to uninhabited Academy Bay on August 7 on the three-masted schooner *Ulva*.

The Norwegians blasted a channel into the lagoon, where they built a stone landing that is still in use. About forty meters inland from it, they built the cannery, seven dwellings (scattered around the area), a pipeline to the water hole in Pelican Bay, and a brick oven for baking. All this was done in the first few months, besides making ready the first shipment of canned lobster, mullet and turtle meat.

Two of the forty-five people from the *Ulva* were women, one of them Borghild Rorud, who was sent by the University of Oslo for collecting plants. *Acacia rorudiana* Christop. is named after her. The Floreana group had also a naturalist along, the zoologist Alf Wollebaek.

The *Ulva*, too large and expensive to maintain for the needs of the group, was sold to the Ecuadorian Navy, which renamed her *Patria*. Unfortunately, this also left the group at the mercy of the irregular and unreliable communications that then existed. This, the difficulty of getting spare parts for their two motor boats and the cannery, the gradual depletion of nearby resources, and increasing dissent within the group led to the collapse of the venture. In December 1927, very few people remained on the island. In the highlands, Elías Sánchez (who had lived there since 1917), Jacob and Anna Horneman (who had arrived that year), and Sigvart Tuset (from the *Alatga* group, which broke up in Panama); in Academy Bay, Kristian Stampa, Gordon Wold and Gunnar Larsen (the last another *Alatga* man).

It was not until the 1930s that a more stable and lasting Norwegian colony formed, mostly with the arrival of new people. A number of other Europeans also arrived, but the Ecuadorians were few at the beginning. The Norwegians remained in majority until 1938, when larger numbers of Ecuadorians began arriving.

**SOURCES:**

Aside from my own reminiscences, mostly from conversations with old settlers, the following have been consulted:

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**J. P. Lundh, Oslo, Norway**

# A KUDZU ALERT IN GALÁPAGOS: THE URGENT NEED FOR QUARANTINE

**By: André Mauchamp and María Luisa Muñoz**

To some people, it sounded strange, impossible, we were probably wrong, or it was a joke. We must admit that we made an error in asking for information about kudzu on the first of April! People thought it was a joke, and a bad one: "What do you know of this species? Is it a potential problem? We have the impression that it could possibly be a future pest." Future?!

Well, we have never lived in the USA and we are not specialists on invasions. We had never heard of kudzu, *Pueraria sp.* to botanists. And when we began to talk of it, people who knew the plant jumped out of their chairs as if they were sitting on a fire ants' nest. The issue was serious.

A few examples of their reactions: "The scourge of the south" (D. Simberloff, University of Florida, Tallahassee). "The state of Florida officially lists kudzu (*P. montana* = *P. lobata*) as a Category I Invasive Species" (S. Herman, Tall Timbers Research Station, Tallahassee, Florida). "There is nothing more important now than the complete destruction of this plant" (H. Snell, University of New Mexico, Albuquerque). Kudzu is known as the worst pest plant of the southeastern United States. It builds up dense, impenetrable thickets, climbs on trees and makes them fall, and is extremely expensive to control.

But, why was it a problem for us in Galápagos? We had spent a morning in late March working in the agricultural zone, spraying blackberry (*Rubus niveus*, another pest) with gliphosate (Round-Up, donated by Monsanto for the control of pest plants), and we were discussing with the farmer who owned the land the new species he had planted for his cattle. We found a new location with *Leucaena leucocephala*, which should be cut one day, and another new species for the list of cultivated plants, a grass (*Brachiaria decumbens*). The farmer also showed us a small test plot of a legume recently sown as a nitrogen-rich cattle fodder in the middle of a pasture. This plant looked, to the eye of a plant ecologist, like a good aggressive creeping pest. The 5-pound seed bag from Agripac said "Kudzu, *Pueraria*", with no species name given.

A verification in "The Plant Book" (Mabberley 1993), our bible in the herbarium, confirmed the existence of that Asian genus, and indicated that *P. montana* is a fast-growing species. That was the first step in the search for information on "kudzu; newly arrived to Galápagos." On the continent, *P. phaseoloides* var. *javanica* is the only commercialized species. In the agronomy books we checked, this species is called tropical kudzu and is considered good for agriculture because of its high rate of nitrogen fixation. This improves the quality of the soils and provides good fodder for domestic livestock.

The problem species of kudzu in the southeastern United States is *P. lobata* (or *montana*). According to the description given by H. Van der Werff (Missouri Botanical Garden, pers. comm.), this was not what we had found. Dr. Suquilanda, a well known agronomist from Ecuador, confirmed the aggressive character of *P. phaseoloides* (pers. comm.). Agripac confirmed that the species they sell is *P. phaseoloides* which according to O. Hamann (University of Copenhagen, Denmark), is a bad weed in Panama and other tropical American countries. Van der Maesen (Revision of the genus *Pueraria*, with some notes on *Teyleria*, 1985, Agricultural University of Wageningen) drops the following note, "as for kudzu [*P. lobata*], care has to be taken not to overgraze the canopy"! This means a lot if you read between the words.

Regardless of the species, for us, there is no doubt that we cannot take the risk. It may not be aggressive on the continent, but it has close relatives which are very dangerous. The plot and the seeds of kudzu are scheduled to be destroyed. Fortunately, the owner of the property understood the "potential weed" argument and was rapidly convinced. This understanding is possibly due to the fact that, although well managed, his property is invaded by 'cascarilla', *Cinchona succirubra*, a tree introduced for quinine cultivation in Galapagos in the 1940s. He knows what a pest is!

This episode, which could have been a catastrophe for Galápagos, clearly demonstrates the importance of establishing, at long last, an effective quarantine program. A study was completed (Whelan 1994), the reports are in the files (ours, those of the Galapagos National Park Service, and the files of the Ministry of Agriculture). There are national and local committees for quarantine, and yet not even the most basic enforcement! The permanent surveys, which allowed us to find kudzu in time, are an important stage of the program, but certainly not the only one.

At present, seeds and plants are introduced to Galápagos almost freely by people. There is no control at the entrances to Galápagos, not even a sign, just a message given in Spanish and English by TAME Airlines 10 minutes before the plane lands at the Baltra airport, and heard by whoever is listening. The message reminds passengers that it is strictly forbidden to introduce any plant or animal to the Islands. This double lack of communication and control is the origin of such problems. An education and communication program for quarantine is

about to start at the CDRS, financed by the Fondo Ecuatoriano Canadiense para el Desarrollo (Ecuadorian-Canadian Development Fund). Concern is growing in the DPA (Dirección Provincial Agropecuaria / Provincial Land & Livestock Administration). For example, the Undersecretary of the Ministry of Agriculture recently prohibited the introduction of a new grass for the soccer stadium of Puerto Ayora. The beginning is very slow but it is all we have for the moment. Unfortunately, this is just like a drop of water in the ocean.

There is an urgent need for a broad-scale program and financial support for it. Too many international agencies are interested in "development" projects for Galapagos and quarantine must be fully supported by those agencies promoting it. If we can't work out a solution immediately, these agencies are directly responsible for the rapid acceleration in the destruction of the "natural Galápagos". Quarantine is a system of regulations that must move parallel to the development, and it must be supported.

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**André Mauchamp, Head of the Botany Department, Charles Darwin Research Station, Isla Santa Cruz, Galápagos, Eduador and María Luisa Muñoz, Agronomist, Dirección Provincial Agropecuaria, Puerto Ayora, Isla Santa Cruz, Galápagos, Eduador.**

# WHAT IS HAPPENING WITH THE AVIFAUNA OF SAN CRISTÓBAL?

## by: Hernán Vargas

The island of San Cristóbal has produced various endemic taxa of birds, perhaps due to geographic isolation and its relatively old age. The Chatham mockingbird (*Nesomimus melanotis*), is an endemic species and other birds like the vermilion flycatcher (*Pyrocephalus rubinus*), large-billed flycatcher (*Myarchus magnirostris*), woodpecker finch (*Camarhynchus pallidus*), small tree finch (*Camarhynchus parvulus*), cactus finch (*Geospiza scandens*), warbler finch (*Certhidea olivacea*) and the lava heron (*Butorides sundevalli*) have developed subspecific characteristics which appear distinct from the populations on other islands.

The first recorded observations of the birds of San Cristóbal were made by Charles Darwin in 1835. It was in 1832 when the Ecuadorian government initiated colonization of Galápagos, and humans began to influence the natural populations of the island. Horses, cattle, burros, goats, pigs, dogs, cats, chickens and plants such as coffee and sugarcane were part of the colonization process as were the accidental arrivals of rats and mice. In the years which followed the flow of exotic introductions increased and some species like guayaba, oranges, blackberry grew well and they soon became plagues.

During April of this year, I made a trip to observe the birds on San Cristóbal with the idea of determining their actual status. I spent eight days looking for birds in many places in the various upper and lower zones of the island. Unfortunately, some of the species, common in the past were not observed at all on this trip while other bird species are apparently less abundant than ever before. For example, I did not see the vermilion flycatcher (*P. rubinus*) , the large tree finch (*Camarhynchus psittacula*), the Galápagos rail (*Laterallus spilonotus*) or the Galápagos dove (*Zenaida galapagoensis*). Perhaps the situation is most critical for the vermilion flycatcher, whose presence was last noted 9 years ago during 1987 in the area of the highland lake, El Junco (J. Gordillo, pers. com.).

The Chatham mockingbird, Hawaiian petrel and the cactus finch are among the species whose populations apparently have suffered alarming reductions. I observed a few mockingbirds on various parts of the island but their numbers seemed greatly reduced in areas such as Puerto Baquerizo Moreno. The Hawaiian petrel (*Pterodroma phaeopygia*) still survives in low numbers (10 - 20 pairs have been found) but these nest in only in a few gullies of the humid zone. The cactus finch was found in only one place, an isolated forest of *Opuntia* cactus (*Opuntia megasperma*). This site consists of no more than 20 hectares of cactus on the south-west side of the island near another area called Veinte Varas (20 Staffs).

These observations and others, indicate the avifauna populations have apparently been greatly reduced and

some populations of birds may be on the verge of extinction. Given the grim nature of my findings, I will be delighted to receive reports of sightings of the birds which I did not record.

In the past 161 years, San Cristóbal has suffered the extinction of the Galápagos hawk (*Buteo galapagoensis*), the sharp-billed ground finch (*Geospiza difficilis*)and probably the large-billed ground finch (*Geospiza magnirostris*). At this point we are unable to list any others with certainty.

What are some of the causes of these faunal extinction's and declinations? In the case of the hawk, man is the direct cause. For the others, surely the introduced organisms are playing leading roles. The introduced black rat (*Rattus rattus*) can eat the eggs and chicks of ground nesting birds such as the Hawaiian petrel, Galápagos rail, Galápagos dove, and the storm petrels. Actually the band-rumped storm petrel (*Oceanodroma castro*) and the wedge-rumped storm petrel (*Oceanodroma tethys*) now nest safely on Isla Pitt (a half mile off of the northeast coast of San Cristóbal) where the rats were eradicated a few years ago by Galapagos National Park Service and Charles Darwin Reseach Station personnel. From what has been reported elsewhere, donkeys appear the principle cause in the reduction of the *Opuntia* cactus, possibly a vital ecological base of both the cactus and the large-billed ground finches.

The known diseases which arrived with introduced animals include Avian Pox and Crop Canker (*Trichomanes gallinae* )and these have been known to reduce populations of native and endemic birds. It is very possible that the domestic pigeon (*Columba libia*) and the chicken (*Gallus gallus*) were carriers of these diseases which affect the endemic dove and other terrestrial birds. At this time there are nearly 500 free-ranging domestic pigeons on San Cristóbal. They live principally around the human settlements but fly out into the adjoining areas facilitating the spread of any new disease or parasite which arrives as new domestic animals are brought to the islands.

During the April surveys I was informed of the existence of two or three parrots that had been introduced. I do not know if these are one or more species, but they live in a semi-wild state flying between the urban zone of Puerto Baquerizo and the National Park much like the pigeons. I observed one of these parrots on April 21, 1996 just south of the town and identified as the Red-masked parakeet (*Aratinga erythrogenys.*) Ironically, this is an endangered species on continental Ecuador.

The blackberry vine (*Rubus niveus*), the guava (*Psidium guajava*) and Pomarosa (*Eugenia jambos*) have invaded extensive areas of the agricultural zone and have begun to invade National Park land. The rapid expansion of these and other introduced plants along with the habitat alteration of the agricultural zones are causing a reduction of the native floristic diversity and thus altering the habitat for the native and endemic birds.

Introduced insects and their ecological impacts have hardly been studied in Galápagos and their influence on the whole of San Cristóbal is probably graver than we can even imagine. An illustrative example is the propagation of a scale insect along the coast where it had not been noted previously. This insect was initially reported around Puerto Baquerizo Moreno on *Parkinsonia aculeata*. On this trip it was found on *Prosopis juliflora* at the site called Veinte Varas; on *Cordia lutea*, and the two endangered endemic plants of *Lecocarpus darwinii*, and *Calandrinia galapagosa* at Cerro Colorado and on *Scaevola plumieri* at Bahía Sardina and Punta Pitt. The scale appears to be causing mortality in the plant *S. plumieri* at these last two sites. This recent survey shows the problem of the scale insect to be very widespread on San Cristóbal.

We may be at the point of witnessing one of the biggest losses of bird diversity on an island in the Galápagos to date. If the trend continues , first there will be the loss of specific island populations of birds (like those of San Cristóbal) and later the entire species. Without studies and probable conservation measures, it is just a matter of time.

**Hernán Vargas, Ornithologist Charles Darwin Research Station, Puerto Ayora, Galápagos.**

# *SCALESIA ATRACTYLOIDES*: ONE BITE FROM EXTINCTION

## By: André Mauchamp

*Scalesia atractyloides* Arn. vars. *atractyloides* and *darwinii* (Hook F.) Eliass., is an Asteraceae endemic to Santiago last seen in 1990 on 2 small craters of the west coast (Adsersen pers. com.). *Capra hircus* L. (commonly known as a goat) is a mammalian herbivore that originates from the mideast and can be seen throughout the world where it reproduces almost as fast as rabbits (unpub. observation). Santiago is one of the central islands of Galápagos, north of Santa Cruz. It measures 585 km$^2$ and its native and endemic vegetation totals 318 species. It has very few introduced plants, and none of them are invasive. Unfortunately the above mix is not compatible when goats are added to the island.

The genus *Scalesia* represents for plants what tortoises demonstrate for animals in the Galápagos Islands. It is an excellent example of radiation in an endemic genus, with 15 species, 19 taxa including varieties and subspecies, and a lot of morphological variability. Certain species, like *S. pedunculata*, have a wide distribution; others, such as *S. retroflexa* or *S. helleri*, are restricted to very small areas and we don't understand yet why. If goats and donkeys drive them to extinction before we answer that question, we will never know.

The last time H. Adsersen saw *S. atractyloides* was when he found a few plants in 1990 on cliffs of old volcanoes on the west coast of Santiago (pers. comm.). He described the sites as small scoriaceous red craters that showed clear signs of the plants being damaged by goats, and erosion (also being caused by the goats). In 1974, sixteen years earlier, he had described the damage that goats were causing to that plant species in particular. On the label of a Herbarium specimen in the CDRS collection he noted, "on steep slopes out of range of goats ... very few adult specimens left but many juvenile plants ... suffers severely from grazing" (Adsersen #1003, 10-10-74). The year after Adersen last saw S. *atractyloides*, H. Valdebenito could not find a single plant remaining at those locations (Carta Informativa #32, July 1991).

Since then, despite several field trips, no one had seen any *S. atractyloides* plants on Santiago. We were just putting the final revisions into a manuscript for publication to declare the species extinct in the wild. Eight specimens do exist in the Botanical Garden of Copenhagen (O. Hamann pers. com.). Given the grim outlook for this plant species, Ole Hamann started a project to attempt seed production, to produce plants for repatriation in Galápagos. These 8 individuals had been propagated from seeds. Since they were seeds from the same "mother" plant the genetic diversity is very reduced however faced with extinction it is the only alternative.

In the early days of October 1995, the Park Wardens from the hunting group in Santiago, arrived with news of finding 5 plants which indeed looked like our nearly extinct shrub. They brought samples to the Station Herbarium and we confirmed their discovery. The five adult plants were *S. atractyloides*, probably the variety *darwinii*.

The mature plants were located on cliffs inaccessible to goats, in a crater similar to those where Adsersen had made his earlier observations. This site is much further east, at 280m in altitude and near the middle of the island. Only one old collection by J. Villa (found in the CDRS Herbarium) verified the existence of *S. atractyloides* this far east, 6.5 km inland from Sullivan Bay and at an altitude of 200 m.

At the end of February 1996, during a field trip for the regular monitoring of the fenced areas in Santiago, we determined the exact position of the spot with a GPS receiver (0° 14.9′ S, 90° 41.5′ W), and inventoried the flora at the site. The scarce vegetation was dominated by *Bursera graveolens*, *Erythrina velutina*, *Sarcostemma angustissima* and a few plants of *Galvezia leucantha* ssp *pubescens* also restricted to cliffs. During that trip, we also collected mature flower heads. Seeds from these were sown in a small plot in the fenced exclosure area called 14 Millones, which is closest to the present site, and more were planted next to the Park Wardens "caseta" (shelter), in the highlands. The remaining seeds were brought to the Botany Lab of the Station with prior Park permission.

From these mature flower heads, 350 akenes (a one-seeded fruit) were sown in petri dishes with the same method we have been using successfully to produce *Scalesia helleri*i. Fifty akenes are placed in a dish and watered with distilled water and occasionally with captan, a fungicide. After 2 weeks, all the akenes are checked and we kept only the ones that actually contained an embryo. This phase is delicate since it is easy to damage the embryos. Despite this, we usually obtain a 60 % germination with *S. helleri*. The embryos are then placed in small pots with soil. The germination work was done by O. Landazuri, an Ecuadorian student volunteering at the Station who first learned the procedure with other species. She is proud to announce the birth of three little *S. atractyloides* plants, hopefully the first ones of a large family in the future.

This will not be an easy propagation experiment however, only 25 akenes (7 %) actually contained an embryo, compared with 15 % of the similar Santa Cruz species *Scalesia helleri*. Our 3 plants represent 12 % of the embryos and 0.8 % of all the seeds. The task of producing or finding enough seeds to get a reasonable number of embryos that will grow to seedlings will be difficult.

A logical idea under consideration is to fence the crater on Santiago where the 5 adult plants were found. At the same time to continue the production of seedlings and to repatriate them into the fenced exclosures thus rebuilding several small populations of *S. atractyloides* on their native island of Santiago. This is a long-term project, but each one of the unique species of an island of the Galápagos is worth whatever effort it takes.

**André Mauchamp, Head of the Botany Department, Charles Darwin Research Station, Isla Santa Cruz, Galápagos, Ecuador.**

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