Galápagos Islands Field Trips and Research (February-April 2007)

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From 18 February to 18 April I undertook my eleventh expedition to the Galápagos Islands over the last 39 years. My research during this year's expedition has had three major goals. First, as a continuation of my ongoing study of ecological changes in the Galápagos based on old photographs, I have begun a study of cactus growth rates, mortality, and replacement, based on images taken by myself and others, primarily in the 1960s and 1970s. Longevity among Galápagos cacti is uncertain owing to long lifespans that exceed 100 years. Lifespan can nevertheless be inferred from how long it takes a cactus to grow to its maximum height, and how long it generally lives after reaching a maximum height, which for Galápagos *Opuntia* (prickly pear cactus) is a much as 12 meters. (*Jasminocereus*, or candelabra cactus, the other large cactus present in these islands, grow to a height of about 7 meters). With the use of old photographs and repeat photography, it is possible to model growth, mortality, and replacement over time, as has been done for some species of long-lived cactus in other parts of the world. Also, cactus have been disappearing in some places in the Galápagos Islands, and the method of repeat photography provides a useful way of determining just how extensive these losses are, and whether they are being caused by natural processes or, in contrast, by depredation stemming from invasive species such as goats and donkeys.

***Polistes versicolor*, tending a nest. The wasps are fanning the nest with their wings, to cool the larvae during the intense heat of the mid-day.**

In collaboration with Philip Starks, a biologist at Tufts University who is an expert on wasps, I began a second study this year that involves the invasive "paper wasp" *Polistes versicolor*. This wasp first invaded the Galápagos in 1988, probably as part of a cargo of fruit or construction materials shipped from the continent,

and the wasp has since spread to every major island. Such invasions of an oceanic archipelago offer a unique opportunity to study genetic bottlenecks in the introduced species, which are generally established by a small number of individuals. As a consequence of the resulting "founder effect," as Ernst Mayr has termed it, variation is lost and must be built up again over succeeding generations. This initial loss of variation is sometimes associated with rapid evolutionary events, or what Mayr called "genetic revolutions," which tend to occur in small, isolated populations that allow certain unusual combinations of genes, and associated selection pressures on these genes, that would not occur in larger, more variable continental populations. In addition, the invasion of the Galápagos Islands by *Polistes* wasps offers and opportunity to test various theories of island biogeography proposed by Robert MacArthur and Edward O. Wilson in the 1960s.

My third project during this year's Galápagos expedition has involved the location of the "springs" visited by Charles Darwin on Santiago, an island on which Darwin camped for nine days and on which he did the bulk of his biological collecting. Hitherto, the location of these springs has remained undetermined. The site has a particularly enhanced interest in the history of science, because Darwin apparently discussed here, with his Spanish guides, some of the evidence that was later to revolutionize the biological sciences in the form of Darwin's theory of evolution.

First Field Trip: The Mystery of Disappearing Cactus

My first field trip included stops at six different locations, with campsites at three of them. By comparison with some past field trips, during which we have hiked deep into the interior of islands or summited some of the major volcanoes (which reach heights of over 5,000 feet or 1,700 meters), this first field trip was relatively easy as all of our camp sites were near the coast. Still, it was necessary for us to transport nearly 1,000 pounds of food, water, and equipment to each of these campsites from the Charles Darwin Research Station on Santa Cruz. These supplies included 15 *chimbuzos* of water (a *chimbuzo* holds 20 liters and weighs about 50 pounds), as well as half a dozen *cajas* or metal cases filled with food for 16-17 days in the field. Most of these items had to be carried several hundred yards from the coast to campsites that were out of sight of any tourist trails and also not visible from any vessels passing nearby (a requirement of the National Park Service). This year, our food supplies for each field trip included about 10 boxes of cereal; 50 tins of canned seafood (tuna, oysters, mussels, and sardines); 50 cans of vegetables (asparagus, hearts of palms, and artichoke hearts); 30 containers of Pringles potato chips; 10 containers of mixed nuts; 50 packages of peanut M&Ms (affectionately referred to here as "*eme-y-emes*"); 5 pounds of rice; several packages of spaghetti; 60 liters of soft drinks (Coca Cola and Fanta); and 24 liters of Gatorade. Calculation of these quantities of food and drink must be done carefully in advance, with an accurate estimate of just how much people tend to consume; otherwise one risks running short. This year we had a special culinary treat, as one expedition member brought from the United States about 30 pouches of Bumblebee brand tuna, salmon, and chicken precooked in various tasty sauces.

Cape Trenton (Santiago) at dawn. *Jasminocereus* (candelabra cactus) stud this landscape.

Expedition members on the first field trip included Eric Rorer, a professional photographer and veteran of last year's expedition, and also a regular trip leader for the Sierra Club. Eric leads groups each summer to the Brooks Range in Alaska. A second expedition member was Julie Chase, a veteran member of the Explorer's Club of New York, who has been on expeditions all over the world, including dinosaur digs in Mongolia. A third expedition member this year was David Luna, a 16-year-old Ecuadorian student in the local high school in Puerto Ayora. David's father is Captain of the *Samba*, a vessel I chartered for three weeks in 2002, when I was busy retracing Darwin's route in the Galápagos with a team of scientists I had brought together for this purpose. The National Park requires that visiting scientists invite students to accompany them into the field, as a means of educating young people about the archipelago in which they live. Although David had lived his entire life in the Galápagos, he had only previously visited two towns and the airport.

We began our first field trip at Cape Trenton, on the southeastern side of Santiago, which is my favorite island in the Galápagos--partly because Darwin spent so much time there, but also because the ecology of the island is so varied by altitude and by volcanic topography. Cape Trenton presents a lava-strewn landscape that stretches for about four miles (6 km) to a series of three or four craters that repeatedly spewed forth lava to form this corner of the island. The site is breath-taking in its sterile splendor—providing a view of the Galápagos that reflects its earliest days as these islands were first emerging from the ocean, and as unusually hardy insects and plants (mostly cacti) were first struggling to eke out a way of life on the barren lava flows.

The last recorded eruption in this area was around 1900. I first visited this hauntingly beautiful site in 1970, and at that time I took a series of large-format photographs (6 x 7 cm), which now form the basis of my repeat photography study at this particular location.

Being so young, most of the lava at Cape Trenton is barren. The last recorded eruption in this area was around 1900. Near the coast, however, a cluster of reddish hills is formed by older lava that sports a substantial number of *Jasminocereus* (candelabra) cacti. It was this population of cacti that I wished to study in order to determine trends in growth, longevity, and replacement. Compared with 1970, one difference was immediately apparent at this site. There were many more cacti, perhaps as a result of the favorable years for young plants that were presented by the El Niño events of 1982-1983, 1993-1994, and 1997-1998.

A Galapagos hawk at Cape Trenton.

The key to our survival at this site, where we stayed for four days, was our possession of a large tarp, about 12 feet by 20 feet. From about noon to about 3:00 PM, the lava fields becomes like an oven, radiating heat back onto anything that is not shaded from the sun. Lava blocks actually become too hot to touch during this part of the day, when we uniformly retired to the shade of our tarp while waiting for the heat to dissipate. To support this tarp, Don Ramos--a man in his seventies who has worked at the Darwin Station for as long as I have been coming to these islands--created for us an elaborate metal frame, which we reassembled in the field. However, in an ingenious feat of architectural innovation, Eric Rorer realized that we could use just part of the elaborate series of interlocking metal poles cut for us by Don Ramos to create an A-frame structure, which turned out to be much more comfortable and to provide a larger area of shade for ourselves, our food and water, and equipment. Still, space was sometimes cramped for four people as the equatorial sun crept in from the sides after about 2 PM.

Although largely devoid of vegetation, Cape Trenton proved to be even more interesting than I had anticipated. Along the nearby coast, we found many playful sea lions, several resident hawks, and at least 15 diminutive Galápagos penguins. The Galápagos penguin is normally restricted to the western side of the archipelago, where the waters are fed by the Humboldt Current and are colder as a result; but a few groups of penguins seem to like certain parts of Santiago, which is more or less in the center of the archipelago. This particular species of penguin obeys what is known as Bergmann's rule, namely, that closely related species in the same genera and sometimes families become smaller and smaller as they approach the equator. The reason for this trend is that small size is an advantage when one wishes to dissipate heat, whereas large size is an advantage when one wishes to retain heat. Hence the penguins of the Antarctic are the largest—and have perhaps fifty times the biomass of a typical Galápagos penguin, which generally stands only 12 inches tall. As for the hawks, they visited our campsite every day, curious about our presence, and sat perched

Tourists and penguins at Cape Trenton.

on lava observation posts only a few meters from our tarp and tents. One hawk killed an endemic Galápagos dove while we were there and, completely unfazed by my presence, allowed me to photograph from a distance of a meter or so while dining on its victim.

At Cape Trenton we measured 90 *Jasminocereus* cacti. Based on repeat photography of a given site, one can easily determine that a cactus has grown or died, or is new; but growth can only be assessed in relative terms. That is, one can establish that a particular cactus is, say, 30 percent taller than it was in an older photograph. To determine absolute growth over time, one needs to anchor the measurement scales relative to the current or prior height and size of each cacti. We were able to accomplish this anchoring of the scales in the following manner. Before traveling to the Galápagos, I inserted roughly a thousand small numbers next to the cacti in each photograph, which I had printed at a size of 9.5 inches by 14 inches and laminated in plastic for use in the field. In the field I stood at the place where each original photograph was taken, and where I also took new images. From this position, it was generally possible to recognize the surviving cacti, as well as to determine which ones were new. Using binoculars when necessary, I then directed my team to specific numbered cacti, each of which they measured for height, maximum width, and width at the base. A laser hypsometer was specially designed for me for this particular cactus study was used to determine the distance of each cactus from the site of the original photograph. Additionally, GPS measurements were also taken for each cactus. Most of these measurements were conveyed to me by radio and entered in a notebook that was preprinted with entries for all of the relevant information. Knowing that a cactus photographed in 1970 is 40 percent larger in

the present digital image, and that it is also, say, 4.2 meters tall at present, one can then calculate that the cactus was 3.0 meters tall in 1970. The process is a bit tedious, but it works.

From Cape Trenton we went to Dragon Hill on the northwestern corner of Santa Cruz Island, which is about 13 miles to the south of Cape Trenton. Dragon Hill is named for the sizeable colony of land iguanas that live there, attracted by the sandy soil of the hill, which allows them to create burrows in which they hide when threatened, or at night, in order to conserve heat. Two decades ago wild dogs brought this colony to the brink of extinction. Galápagos residents pitched in and helped to move the colony to a nearby islet named Venezia, which the feral dogs were unable to reach. To allow breeding, many tons of soil had to be transported to Venezia, so that the females could bury their eggs in the soil. After the successful elimination of the wild dogs by the National Park Service in the 1980s, land iguanas were repatriated to Dragon Hill, where they are now thriving.

I first visited Dragon Hill in 1968 and have several photographs taken from the summit, by me and by other scientists, in 1964, 1967, and 1968. These photographs show that about 80 percent of the *Opuntia* cacti have disappeared, owing to depredation by donkeys and goats. We measured forty of the survivors, as well as some of the new recruits, in order to assess growth and mortality rates. At Dragon Hill, where conditions were unusually moist this year, we were unfortunately besieged every morning and night by hordes of mosquitoes. Eric Rorer had a rain fly on his tent, into which the mosquitoes flew during night, attracted by his emissions of carbon dioxide. Trapped inside the rain fly during the day, these mosquitoes were baked by the intense heat of the sun. Taking off the rain fly, we estimated that more than five hundred mosquitoes had sought entry into Eric's tent and had died in the process.

From Dragon Hill we proceeded to South Plaza, one of my favorite places in the Galápagos, owing to its intimate size (a little over a half a mile in length), diverse populations of sea birds along the cliffs, and numerous land iguanas that have become so used to tourists that they hardly move at all when people walk by them on the trails. South Plaza presents something of a mystery that I and others have been trying to solve. The *Opuntia* cacti have steadily been disappearing over the last half century. More than half of the cacti have disappeared in just the last thirty years, as documented by Howard and Heidi Snell and by Paul Stone. Some scientists think that the root of the problem is the introduction of mice, following the 1982-1983 El Niño, when mice were washed off the edges of Santa Cruz by torrential streams of water and swam for their lives to South Plaza, which is only a quarter mile or so from Santa Cruz. Mice sometimes burrow into the roots of the *Opuntia* to create nests; so perhaps, the argument runs, the mice have weakened the root structures, causing cacti to fall over. However, cacti were disappearing even before the 1980s, so the mouse theory does not seem adequate to account for all of the losses.

***Opuntia* (prickly pear cactus) at South Plaza.**

Unlike the situation at Dragon Hill, the culprit does not appear to be a feral animal, as goats were eradicated from this island in 1961. Rather, a principal culprit appears to be the land iguanas, which, in spite of ever-present and nasty spines, eagerly devour every fruit and pad that falls from the cacti. Cacti can reproduce both sexually, through fruits, and as clones created by the rooting of fallen pads. But with all the fruits and pads being eaten by the resident land iguanas on South Plaza, there are almost no young plants in the population, as my photographs clearly show going back to 1970. Although the death rate of cacti on South Plaza may be higher than it is elsewhere, from some as yet unknown cause or causes, the most serious problem on this island is the lack of any replacement of older cacti by younger ones.

During my stay on South Plaza I encountered a naturalist guide, Ruben Salas, who was born on Santa Cruz and whose grandfather worked there as a fisherman in the 1950s. According to Ruben, his grandfather helped to bring land iguanas to the island, presumably from Santa Cruz, as they were plentiful at that time at neighboring Cerro Colorado, which is just across the strait about 400 meters away. Fishermen probably brought these iguanas over from Cerro Colorado because it is much easier to recatch them (or their offspring) on the relatively open and flat parts of South Plaza than at Cerro Colorado. Land iguanas have always been considered good eating since the days of the buccaneers; and fishermen, who over the years have regularly stocked islands in the Galápagos with goats for a supply of fresh meat, appear to have done the same thing with the land iguanas. Some land iguanas, it seems, were already present on South Plaza in the 1950s, when fishermen were trying to increase the resident population; and it is likely that previous generations of Galápagos residents, or even whalers and buccaneers going back to previous centuries, had the same

The Milky Way, painted across the Equatorial sky at 4 AM. Behind Cerro Colorado, the moon is just about to rise.

idea. Three land iguanas also exist on the tiny island of Camaño, at the mouth of the bay that forms Puerto Ayora on Santa Cruz; and someone also introduced a couple of land iguanas to Bartolemé, just off the coast of Santiago—an island were land iguanas were earlier drive to extinction by feral pigs and wild dogs not long after Darwin's visit in 1835.

One other consideration appears to be relevant to the demise of the cactus population on South Plaza. When people settled Santa Cruz Island on a permanent basis, beginning in the late 1920s, the farmers proceeded to shoot all the hawks, which naturally found newly introduced chickens to provide a tasty supplement to their regular diet of doves, mockingbirds, and finches. With most of the numerous hawks removed from Santa Cruz, the land iguanas on South Plaza found themselves in the idyllic situation of no longer having their major predator. Hence the population has thrived, and whatever natural equilibrium that would be expected to establish itself between the population of cacti and the population of land iguanas has not yet been reached. It is particularly noteworthy that on South Plaza parts of the island are quite barren, with the exception of *Opuntia*. It is precisely in these barren areas on the eastern end of the island that there has been no replacement of older cacti by new recruits. Having nothing else to eat, the land iguanas who have territories there must dine exclusively on fallen cactus fruits and pads.

During this field trip we visited Cerro Colorado and North Plaza, which are both separated from South Plaza by a short distance (less than 400 meters). Both sites lack land

iguanas. I was initially planning to swim from South Plaza to North Plaza, but a naturalist guide told us that a bull shark bit off a German tourist's hand last year, and that swimming and snorkeling are no longer permitted at this beautiful site. So I proceeded later to North Plaza by boat, on my way to Cerro Colorado. At both of these sites my team and I found *Opuntia* with numerous fruits and fallen pads regenerating at their base. Such fallen fruits and pads would have been consumed by land iguanas within a matter of minutes on South Plaza.

The story of the loss of cactus on South Plaza is instructive, as it shows that even resident organisms can raise havoc with the ecology of these islands if other constituents in their ecological web are removed or disturbed. For example, goats have now been successfully eradicated from Pinta, an island to the north. As a result, the vegetation is now returning dramatically. But the plants that are returning are not the ones that were there originally, since tortoises are extinct on this island. (A sole male, named Lonesome George, lives at the Darwin Station on Santa Cruz Island, in the hopes that a female might turn up somewhere else in the world, perhaps in a zoo.) The presence of tortoises is required for certain plants to thrive, as they are shaded out by other plants that the tortoises tend to consume. As a result, botanists have been urging the reintroduction of tortoises to Pinta from Española, which turns out to be the island with the closest genetic match to the Pinta population, as determined by recent DNA testing.

Sixteen days in the field took their toll. David Luna decided to quit three days early, when a boat from Puerto Ayora was scheduled to transport us from South Plaza to Cerro Colorado. Another expedition member was plagued by a nasty fungus infection, but stuck with the expedition when we moved to Cerro Colorado, which proved to be a relatively pleasant place to camp.

Second Field Trip: Searching for Darwin's Springs

My second field trip was far more physically demanding that the first, and pushed me to the edge of my physical limits. Members of this second field trip included Freddy Cabrera, age 30, and Miguel Sangoquiza, age 24. Together, the combined age of my two expedition mates was still less than my own, so keeping up with them was a challenge. Freddy Cabrera was in astonishingly good shape. As a member of the group of 12 National Park rangers who eliminated all the feral pigs and goats from Santiago over the last six years, he had visited Santiago nearly 150 times. Each of these trips lasted from 15 to 21 days, with 5 days back in Puerto Ayora, before Freddy headed back to Santiago once more to hunt feral animals. Freddy was away from home so much that his infant son, now two, hardly recognized him for a time when he would return from the field. Freddy and his fellow Park rangers shot tens of thousands of feral goats and pigs on Santiago (Freddy told me he personally killed more than two hundred in one day). They finally managed to eliminate the feral pigs with the help of specially trained dogs who had to wear leather boots to protect their feet from the sharp lava and spiny seeds in the soil. For anyone who knows the topography of this island, the feat was astonishing and is also one for the record books. Santiago (roughly 13 miles by 20 miles) is currently the largest landmass on earth from which an introduced quadruped has ever been successfully eradicated. The final elimination of goats from this island, which

A young *Jasminocereus* cactus near Puerto Egas on Santiago. In the background, the sun is setting behind Volcan Darwin (Isabela).

once numbered 85,000, had to be done by New Zealand sharpshooters operating from two helicopters.

Given that the climb to Santiago's Caseta, from which all the hunting efforts were coordinated and where the rangers generally lived, involves an altitude change of 2,400 feet (750 meters), and given that Freddy either climbed every day toward the summit of the island (3,000 feet or 900 meters) or descended toward the lower parts, his six years in the field amount to his having climbed the equivalent of Mount Everest from sea level about 50 times. He was capable of carrying 30-40 kilos (66 pounds) while walking just as rapidly as he would without a backpack. To keep up with Freddy in the field, Miguel and I both almost needed to run while carrying our 50-60-pound packs. To keep myself from being blinded by all the sweat I was producing as I walked I had to wear a towel around my neck. During my 17 days on Santiago I regularly consumed four liters of water a day; but Freddy (who deserved to be called an "hombre chivo" or human goat) hardly sweated at all and got by on just one liter.

The trails on Santiago are almost nonexistent in places. Now that the goats have been eliminated from this island, the vegetation has come back, making the trails even more difficult to find and follow. The vegetation is now often up to one's waist, or even over one's head, so navigating the old trails requires the use of a machete. Every trail is studded with hidden rocks, roots, and vines that get tangled around one's boots and constantly untie one's shoe laces. Spider webs are everywhere; and as one walks, the webs stick to one's

My two assistants, Freddy Cabrera and Miguel Sangoquiza, measuring *Jasminocereus* cactus on the large lava flow at Puerto Egas on Santiago.

face—especially one's eyebrows and eye lashes, interfering with one's vision. Sections of volcanic gravel create dangerous slides that must be carefully negotiated, and invisible potholes lurk below one's feet, obscured by the dense grasses and weeds. I fell about ten times during this second field trip and, after one particularly bad fall on a'a lava, I was pinned for several minutes by my backpack, which was caught on the sharp edges of lava rocks. I now have two new scars on my left hand, to add to my collection from the Galápagos Islands.

Over a period of five days, Freddy, Miguel, and I measured more than two hundred cacti on a three-mile lava flow that descends from 900 feet altitude to the coast at Puerto Egas, on the western side of Santiago. (Darwin once walked across a section of the lower part of this flow in 1835, on his way to a prominent crater with a salina at the bottom.) In connection with this project I carried with me 14 laminated prints of photographs taken on this flow in 1970, 1981, and 2002. Finding just the right cacti in the photographs, among the several thousand on this lava flow, was not easy; and we spent an entire day locating where the first batch of photographs was taken at an altitude of about 800 feet and a distance of about 2.5 miles (4 km) from the coast. In order to properly assess the growth rates of the surviving cacti, and of new recruits (of which there were many on this flow), I needed to take photographs of my assistants standing next to each cactus holding a 4-meter stick. Three different sets of photographs were necessary for the assessment of each cactus: one with the meter stick at the base of the cactus, one with the meter stick raised upward so I could see its base and gauge the amount of the lower part of the cactus hidden behind lava rock, and one

with the meter stick extended horizontally (to assess the width of the cactus). Most of these measurements were transmitted to me by radio, given the large distances involved.

The logistics for this second field trip were a major operation. To complete all the research on cacti, and to obtain the necessary wasp specimens, we had to camp in five different places. Food had to be transported to each campsite, and water to three of the five sites, which were located between 2 km and 12 km from the seacoast. In order to apportion the correct amounts of food for each campsite, I had to make more than 130 separate calculations regarding food quantities and estimated consumption rates. Fortunately, we were in luck this year because a party from the National Park Service was also headed to the Caseta, in the central part of the island at 750 meters, and they offered to take four heavy *cajas* of food to the Caseta for us by mule. In the lower sections, however, we were on our own, and we repeatedly had to backpack supplies to our lower campsites from Puerto Egas.

In the evenings, a barn owl (*Tyto alba punctatissima*) regularly visited our campsite near Puerto Egas.

Every day at our Puerto Egas campsite, we had to walk for three hours up and back down the large lava flow, mostly over reasonably negotiable sections of pahoehoe lava, with occasional sections of the dreaded a'a. A'a lava is like a blow up building, with blocks that are sometimes the size of cars. You generally do not walk over really bad a'a lava; rather, you climb your way through it, often hand over fist, much like proceeding through a fiendish obstacle course.

Freddy Cabrera cutting a trail up the side of one of the steep hills (an old crater) overlooking Central.

***Bulimulus darwini*, a Galápagos land snail. Land snails are highly endangered in the Galápagos, as a result of poorly understood consequences of human habitation, which have led to the extinction of nearly two-thirds of the more than 70 endemic species.**

After seven days at Puerto Egas, working on the lava flow there, we proceeded to Jaboncillos in search of the springs that Darwin describes having visited in 1835 near the summit of the island in 1835. Last year I was able to locate these springs, which have previously remained unidentified, and I have since written an article on the subject. Before submitting this article for publication, I needed to check several alternative sites of water in the highlands, and to obtain GPS measurements for the springs, as well as to take more photographs of the area. We stayed at Jaboncillos for two days, locating three different springs with water running from underground crevices as the water drains down from the slopes of the island summit, about 150 meters above. Darwin presumably drank from one of these three springs in October 1835. During Darwin's visit to the highlands, he was told by his two Spanish guides that the giant land tortoises differed from one island to another, and that they could tell from what island a tortoise had been brought just by looking at the carapace. The full impact of this information, which was previously conveyed to Darwin on Floreana by the Vice-governor of the islands, did not sink in right away, but it did simmer in his mind, producing, about nine months later, Darwin's first private statement, in an unpublished manuscript, that evolution might be a possibility. At this time, however, Darwin was still personally doubtful that the available evidence warranted such a revolutionary conclusion. Alas, having failed to collect any adult specimens of tortoises from the four

islands he visited, Darwin also lacked the physical evidence to back up the Spaniards' claims. In addition, having failed to keep his ornithological collections separate from one island to another, Darwin had severely muddled the much better evidence provide by his famous finches and other bird species.

Only later, after his return to England, did ornithologist John Gould's analysis of his Galápagos bird collection drive him to a committed evolutionary conclusion, at which time Darwin quickly realized his previous error in having failed to bring home any adult Galápagos tortoises, and in having failed to label the bulk of his birds by island. Fortunately, he was able to borrow the necessary evidence he lacked from three other collectors on the *Beagle* voyage, who had all labeled their Galápagos birds by island.

So the site of Darwin's "trifling" springs on Santiago is in many ways the site of the beginning of a revolution in science that only became a reality 18 months later, after Darwin's return to England. Still, it was a special experience to be able to stand many kilometers from the seacoast, in a place where Darwin himself once stood and where he watched hordes of tortoises coming and going in search of fresh water at the springs, and to realized that a revolution in science was beginning to percolate in his mind, even if ever so slowly, and from the incompletely digested wellsprings of previous insights and research, much the same way that the "trifling" springs at Jaboncillos percolate ever so modestly from the damp, cloud-drenched soil of the Santiago summit.

From Jaboncillos we proceeded to a region called Central, about five kilometers away over a reasonably good trail. In Central we stayed at the Caseta, a structure built by the National Park Service in the 1980s so that park wardens could hunt feral goats and pigs. At the Caseta is a stove for cooking hot meals, about a dozen bunk beds, a dining table, benches, and numerous mattresses hung from the ceiling in order to keep rats and mice from defecating on them. The Caseta also has its own resident tortoise named Flavio, whose lower mandible is severely dislocated—probably by a powerful kick from a donkey many years ago. Flavio likes to hang around the Caseta, where he is used to being treated to left over rice and other scraps of food.

My assistant, Miguel Sangoquiza, preserving a specimen of *Polistes* wasp in alcohol, for subsequent DNA analysis of possible genetic bottlenecks in this invasive species.

At the Caseta we were pestered by three large rats. Rats were first introduced to Santiago by buccaneers and whalers, and they are responsible for the near extermination of marvelous little rice rats that live on this and other islands. The rice rat holds a world's record of sorts, as it has dispersed farther across the ocean than any other terrestrial quadruped. Only bats have managed to disperse a greater distance.

The site of one of my 1970 landscape photographs, in the hills overlooking Central in the highlands of Santiago. On the horizon, to the right, is Rábida and, behind it, Pinzón.

Twice I was awaked during the night by feeling a rat or mouse walking on my toes. Ironically, a barn owl had made a roost in a shed attached to the Caseta, but this owl was probably unequal to the task of taking on a large rat weighing several pounds and exceeding eight inches in body length, not including the tail. Like the Galápagos Penguin, the native barn owl (and endemic subspecies) is diminutive in size, confirming Bergmann's rule.

While in Central we collected many *Polistes* wasps for my study of genetic bottlenecks with Phil Starks at Tufts University. One of my assistants lost my long tweezers for collecting wasps, so we were forced to collect wasps with our hats, socks, towels, and even a machete, which Freddy Cabrera used to stun wasps in mid flight. In Central I also rephotographed several previously tree-filled areas, originally photographed by myself in 1970, which are now largely devoid of trees as a result of depredation by feral animals. Now that the pigs, burros, and goats are finally gone from this island, the vegetation is rapidly returning.

After five days in Central we returned to the coast over a difficult and largely overgrown trail studded with hidden rocks, stumps, and pot holes. The descent took us seven hours over two days, but Freddy Cabrera could probably have done it in about four and a half hours had he been on his own. After the descent, every tendon and bone in my feet, ankles, and knees ached so badly that I had to take a potent prescription painkiller just to sleep that night.

Altogether, over two Galápagos field trips totaling 33 days, I and my five expedition members measured more than five hundred cacti, collected 139 *Polistes* wasps, and documented ecological changes from 79 old photographs taken between the 1950s and the 1980s. From these two field trips I will doubtless have many months of future research to do, including my analysis of the data from all of the measured cacti and from roughly 8,000 digital photographs from the ten major sites that we visited. But even though the work is not done, it always feels good to get back to an inhabited island and savor the thought that one has survived Darwin's harsh and lava-strewn land of "the mystery of mysteries."