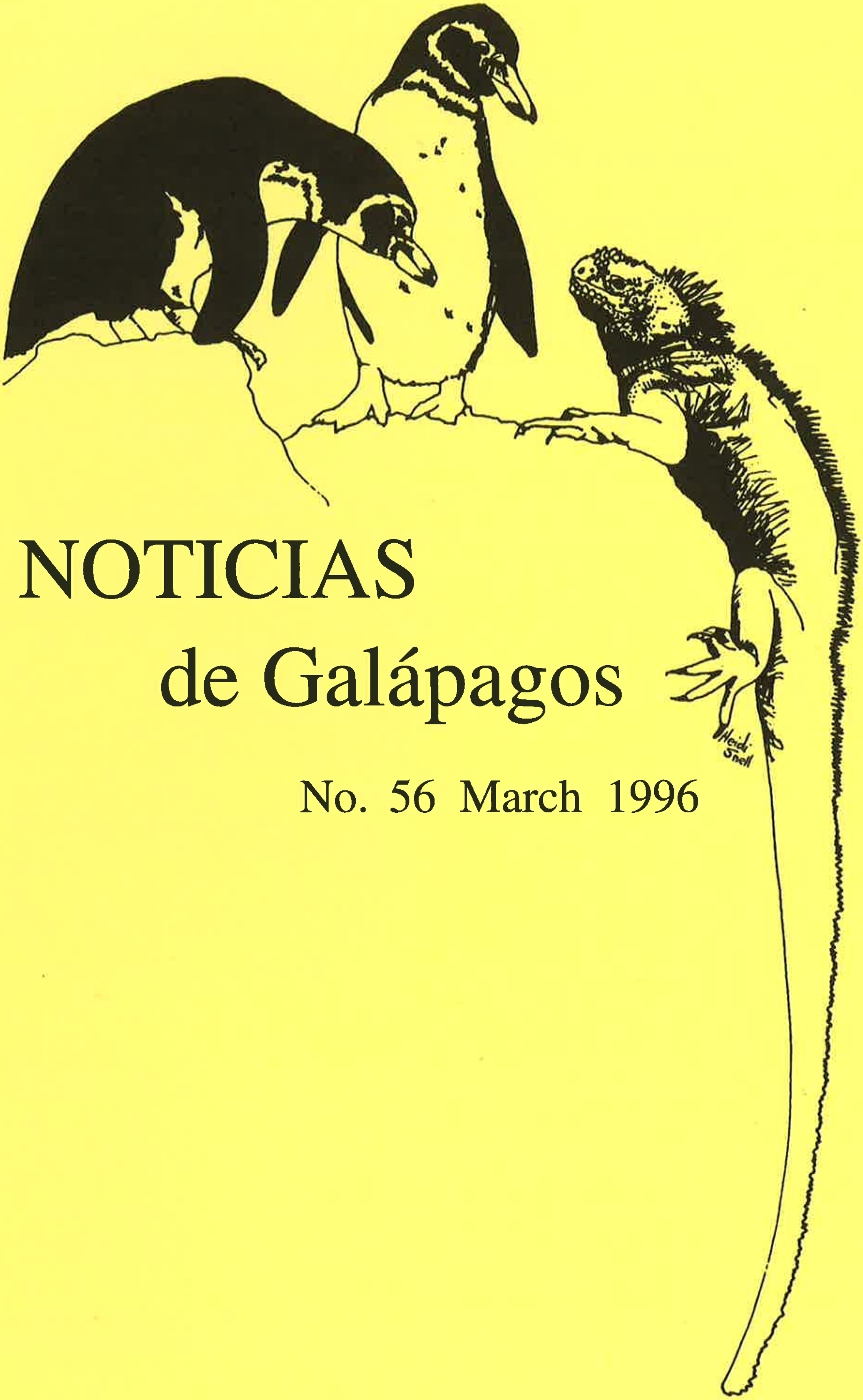

NOTICIAS de Galápagos

No. 56 March 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.

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We are grateful for your steadfast support and help.

NOTICIAS DE GALAPAGOS

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

No. 56 March 1996

Contents

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NEWS FROM ACADEMY BAY

PLANT NURSERY AT CDRS

The Botany group at the CDRS has constructed a plant nursery at the Station where they are conducting experiments with several species of Galápagos plants. Many of the individuals have come from germination experiments begun in controlled laboratory environments. The *Opuntia* seedlings germinated in an experiment by Sabina Estupiñan and David Hicks, are growing well. Of the 40 tiny cacti, some have been transplanted into a native garden. We may someday have an answer to the questions of age and growth rates in *Opuntia*! Other individuals will be given to interested people willing to plant *Opuntia* as an experiment for the future. In addition to the *Opuntia*, individuals of *Scalesia*, *Croton* and most importantly, 30 of the rare and endangered *Calandrinia galapagosa* from San Cristóbal. These *Calandrinia* will soon join the 50 or so raised by Jorge Sotomayor, the CDRS representative on San Cristóbal, which were repatriated 6 months ago within the fenced natural population. This attempt to rebuild a small threatened population was very successful (only about 15% mortality) and was the first repatriation of a species of plants in Galápagos. The *Calandrinia*, *Scalesia helleri* and *S. crockeri* were germinated from seeds as an experiment conducted by Milton Arsiniegas. Other plants in the nursery are: 4 matazarno (*Piscidia carthagenensis*), 50 *Croton scouleri*, 6 flame trees (*Erythrina velutina*), 15 Galápagos cotton (*Gossypium darwinii*), 10 *Scalesia helleri*, 7 *Scalesia crockeri*, *Sesuvium edmondstonei*, 3 *Clerodendrum molle*, and 6 *Cordia lutea*.

Ironically the main predator on the defenseless seedlings are Darwin's finches. Wire cages had to be constructed to protect the tiny seedlings from fatal "pruning" by their endemic neighbors!

About a year ago a "minga" (community effort) was held by Station personnel to clean up an overgrown area behind the Museum/Library. The area was transformed into a native plant garden, for species of plants which occur on Santa Cruz from coastal zone where the Darwin Station is located. There are adult specimens of various plants such as *Cryptocarpus pyriformis*, *Croton scouleri*, *Maytenus octogona*, *Opuntia echios*, *Clerodendrum molle*, *Cordia lutea*, *Cyperus andersonii*, and *Tournefortia psylostachia* and *T. pubescens*. Several station residents raised what they thought to be native cotton plants from seedlings and these were some of the first new plants placed in the native garden. Later they were found to be the introduced cotton *Gossypium hirsutum*, and now those plants are slowly being removed and individuals of the proper endemic cotton, *Gossypium darwinii* Watt, (Paul Fryxell, 1979) have been germinated and are growing well enough to soon be transplanted. The native garden has several lovely young *Scalesia helleri* from the population just beyond Tortuga Bay. Naturally, they came from a germination and growth experiment by Milton Arsiniegas. Hopefully both the nursery and native garden will support a variety of native and endemic plants which serve as examples for utilizing Galápagos plants in community landscaping as well as a site where scientists, students and interested people can easily view and learn some of the plants. Several people from the Botany Group have done a great job in maintaining the garden and adding native plants around the station grounds. Many will yield valuable information about their natural history but in the meantime we all receive the benefit of their beauty.
Heidi M. Snell, André Mauchamp, and Iván Aldáz.

TORTOISES FROM CERRO PALOMA, ISABELA THREATENED

The tortoise population of Cerro Paloma (between Sierra Negra and Cerro Azul, Southern Isabela) may be closer to extinction than the Española population was in the 1960's -70's! There are apparently less than *twenty* individuals, and so far we (CDRS & SPNG) have found only two adult females (the surviving Española population was twelve females; and three males, two mature and one immature).

A molecular genetics study now being completed by Edward Louis of Texas A&M University indicates that this population appears distinguishable from the others of southern Isabela (Louis personal comm.). So with only two mature females from Cerro Paloma, the situation is grim.

There are currently eleven tortoises from Cerro Paloma in the Arnaldo Tupiza Chamaidan Breeding and Rearing Center in Puerto Villamil: 4 adult males, 2 adult females and 5 juveniles of unknown sex. One of the females has nested and we anxiously await the first hatchlings from this group. Park wardens continue to search the Cerro Paloma area for additional tortoises. We believe there are at least a few adult males left. Ironically, the original population was relatively intact up until around 1946-1959, when the penal colony of Villamil sent out prisoners to kill the tortoises and collect their oil for export to the continent. This intense predation which has declined but continues even now, has brought this population to the brink of extinction.
Linda Cayot and Heidi M. Snell

GOATS DAMAGE VOLCÁN ALCEDO, ISABELA

Since the early 1990's the population of feral goats previously limited to the southern slopes of Volcán Alcedo, Isla Isabela has grown to tens of thousands. These goats have caused serious destruction of vegetation centered on the southern rim and slopes, the very area where tortoises concentrate in the dry season. Because it is a small region, the destruction has been rapid. Due to extremely steep slopes, erosion could be devastating with the coming rains of 1996. A major Alcedo Campaign was initiated in 1995 with the following objectives:

1. Goat control and eventual eradication.
2. Long-term monitoring of vegetation and tortoise populations.
3. Development of a proposal for long-term research and management for the entire island of Isabela.
4. A major fund raising campaign.

We have available a seven-minute video documenting the damage to Alcedo and the activity of the goats for any of our readers who are interested in donating to this campaign or who would like to help us spread the word to other potential donors. If you want to donate to the campaign or receive a copy of the video, please contact Johannah Barry of the Charles Darwin Foundation, Inc. (see inside front cover). This video will also be available in European format (PAL) in early 1996. For Alcedo and the giant tortoises, time is critical.
Linda Cayot and Heidi M. Snell

COLLECTIONS AT THE CDRS MUSEUM

The CDRS Museum is a place where students, visitors and scientists gather. It has a small reference collection of organisms collected in the Archipelago since the founding of the Charles Darwin Research Station. The mollusk, fish, bird, reptile and insect collections are being well curated and managed. Catalogs have been entered in computerized databases to facilitate access of the collection information.

Curatorial work has been sporadic throughout the history of the CDRS Museum mainly due to lack of interested or experienced personnel and, as always, a shortage of funds. At the present the Station is fortunate to have Lazaro Roque Albelo, B.S., a Station volunteer with experience working in Natural History Museums in his native country of Cuba. Unfortunately the Station does not have the funds to continue this work. Any donations to help maintain the collections and their curation will preserve the efforts of scientists and community members interested in the conservation of Galápagos.
Heidi M. Snell and Lazaro Roque

GOATS ON PINTA - AGAIN?

Some time during the middle to late 1950's, a male goat and two females were released onto Isla Pinta by local fishermen. These goats multiplied rapidly and by the early 1970's they were the direct cause of severe destruction to the soil and vegetation. The Galápagos National Park Service began a hunting campaign which suffered from sporadic funding for almost twenty years. Because the campaign was not a constant effort, the population of goats was able to frequently rebound from several thousand to the estimated standing population of 15,000. Efectively, the campaign had to start anew everytime that the population increased when funds for continued hunting were lacking. Due these rebounds it was necessary to kill an estimated 40,000 goats before the population was apparently eradicated in 1990. Since then a few scientists and park wardens have visited Pinta for other projects, but no goats were ever reported from those recent trips.

Unfortunately, a rumor tracked down at the end of August 1995 was based on fact. At least six goats had been seen on Pinta once again. Once the rumor was verified, National Park personnel were notified and they immediately sent a hunting group of four men to Pinta. The group was on the island six days and killed four goats, one adult female and three juveniles, and they found evidence of additional goats.

During September eight hunters and three dogs made another trip of five days. Three groups were formed to cover the island more efficiently as the vegetation is quite dense in some areas, making locating the goats difficult. During this trip three males and eight females were eliminated from a group of approximately twenty-five animals. That left at least fourteen known goats on Pinta, however, four of the eight females killed were pregnant at the time, so their numbers were constantly increasing.

A third trip was made during the last half of November, this time with seven hunters. They divided into two groups and were on the island for five days. They killed ten goats, four males and six females, both adults and juveniles. Four goats escaped onto the lava and were not seen again. The Park plans to send another hunting group to continue searching and eliminate the remaining goats. The experienced hunters will use colors and markings of the goats to recognize individuals and to identify those which they are unable to kill. This way different groups of hunters will know if they are dealing with previously observed goats. When the numbers get low and the individuals are recognized, then the hunters can be reasonably sure when the eradication is complete. Hopefully that will be very soon.

Unfortunately, it is possible that these goats represent a new intorduction to Pinta. However, at this time we can't rule out the possibility that a few remained from the previous campaign.
Heidi M. Snell and Howard L. Snell

IS THERE A *GUADALUPE RIVER* IN GALÁPAGOS?

In July of 1995 a new boat for the Galápagos National Park Service arrived in Puerto Ayora. The *Guadalupe River* was constructed in 1980 and served as a crew boat for oil drilling platforms in the Gulf of Mexico. She is powered by three Detroit Diesel engines which exceed a total of 2,000 hp and give a maximum cruising speed of 17 to 20 knots. She is 101 feet long, with a hull constructed of aluminum. Combining her great horsepower and her aluminum construction yields a very light and fast vessel. Her decks can support a cargo of 30 tons which makes her ideal for a wide variety of uses. She has derricks and winches for loading smaller vessels aboard. This allows her to serve as a mother ship for wide ranging patrol activities combining the *Guadalupe River* with a number of smaller launches. Her satellite navigation system and radios will promote the accuracy necessary for patrolling the Galápagos Marine Reserve, where various activities are restricted to different distances from shore.

The current crew is seven and will soon be increased to 8 since many of the patrol routes will require trips lasting longer than 24 hours. The boat was originally designed to move people quickly for short trips lasting less than a day and was constructed with seats for 45 persons in the two forward cabins. Unfortunately, she had very little sleeping space. The Park Service is dividing the forward two cabins into eight with several berths each. With the extra cabins there will be space for additional personnel from the Ecuadorian armed forces. These military personnel will provide armed patrol trips around the islands in conjunction with the Galápagos National Park Service. Obviously the character of conservation management in the Galápagos has changed!

The *Guadalupe River's* tasks have been wide-ranging and numerous already. She has made several trips to the western side of the Archipelago and once brought back pangas confiscated from illegal fishing camps. She regularly carries hunters and researchers with assorted equipment to various islands. She has carried school children on educational visits and on one occasion a large number of teachers attending a course held by the Park. The Guadalupe River was instrumental in mobilizing the large group of volunteer searchers sent to Santa Fe when a student was lost there. Because she is so fast and can easily carry cargo on her tremendous aft decks, she is an ideal vessel for the National Park Service. Though she now resides far from her namesake the Guadalupe River, Texas, USA, she is a welcome and needed addition to everyone supporting the Conservation of Galápagos.
Heidi M. Snell & Michael Bliemsrieder

EASTERN KINGBIRD SIGHTING

Diego Andrade Torres, a Galapagos Guide, along with Paul Coopmans as tour leader of a British birdwatching group, identified an Eastern King Bird on Isla Santa Fé on the 9th of June of this year. This group was ashore in the early afternoon and saw the Eastern King Bird at the Northern end of the tourist area in a large *Opuntia* forest.

WORDS OUT OF THE PAST

While reading about the Galápagos in the published works of D. Porter of the *U. S. Frigate Essex* during the latest occupation of the CDRS in the first days of September 1995 (see *Conservation Gets Personal* later in this issue), I found the following paragraph of interest:

> "I shall leave others to account for the manner in which all those islands obtained their supply of tortoises and guanas, and other animals of the reptile kind; it is not my business even to conjecture as to the cause. I shall merely state, that those islands have every appearance of being newly created, and that those perhaps are the only part of the animal creation that could subsist on them, Charles' and James' being the only ones where I have yet been enabled to find, or been led to believe could be found, sufficient moisture even for goats. Time, no doubt, will order it otherwise; and many centuries hence may see the ***Gallipagos as thickly inhabited by the human species as any other part of the world*** (emphasis mine). At present, they are only fit for tortoises, guanas, lizards, snakes, etc. Nature has created them elsewhere, and why could she not do it as well at those islands?" -*D. Porter Cowan's Bay (James Bay) August 1813*

It seemed ironic that he wrote the words 182 years almost to the day.
Heidi M. Snell

ON THE EMERGENCE AND SUBMERGENCE OF THE GALÁPAGOS ISLANDS

By: Dennis Geist

INTRODUCTION

The age of sustained emergence of the individual Galápagos islands above the sea is an important issue in developing evolutionary models for their unique terrestrial biota. For one, the age of emergence of the oldest island permits estimation of when terrestrial organisms may have originally colonized the archipelago. Second, the ages of the individual islands and minor islets are required for quantitative assessments of rates of colonization and diversification within the archipelago. Emergence is not a straightforward geologic problem, because the islands constitute an extremely dynamic environment - the shorelines that we see today are transient features in a geologic (and evolutionary) time frame. It is beyond doubt that presently isolated islands were at one time connected, presently connected mountains were separated, and ancient islands have sunk below sea level. Unfortunately, the details of the emergence, submergence, connection, and isolation of the individual islands are nearly impossible to reconstruct with certainty because most of the evidence is under water or buried beneath young lava flows. Nevertheless, it is instructive to speculate on these issues, in order to address the range of possible features that might be expected.

EMERGENCE OF THE GALÁPAGOS ISLANDS

In principle, the determination of the age of emergence of a volcano should be simple: one identifies the oldest subaerial lava from geologic relationships and determines its age using radiogenic isotopes. The reality is that none of the oldest subaerial basalts are currently exposed in Galápagos but are covered by younger lavas. To compound the problem, absolute dating of Galápagos basalts is difficult. The lavas are notably poor in potassium, the most useful element for age determination, and almost never preserve organic material for ^{14}C dating. Further, paleomagnetic techniques are not useful because most of the lavas exposed on the islands are far younger than 700,000 years. These problems are particularly difficult for the western islands, and estimation of their emergence ages must be made by indirect means, including extrapolation of their rates of growth.

In order to estimate the rate at which the volcanoes grow above the sea, it is necessary to establish the various mechanisms by which the growth occurs (Figure 1). In the western archipelago, individual volcanoes grow and emerge above the sea due to two principal effects. First, as the Nazca plate travels over the Galápagos hotspot, the seafloor rises due to thermal expansion. The Galápagos thermal swell is predicted to be only 400 m high (Epp, 1984). The sea floor to the west of Fernandina is about 3200 m deep, so 2800 m of lava needs to pile up on the swell for an island to form. In reality, much more magma is required, because as lava erupts from an oceanic volcano, the extra weight causes the earth's crust to sag into the mantle, forming a deep root. Feighner and Richards (1994) estimate, for example, that the base of the crust is up to 7 km deeper beneath Isabela than it is to the west; in other words, for every 1 km of elevation growth of a volcano, about 4 km of "sinking" occurs. But volcanoes also grow from below, from magmas that freeze underground and from crystals deposited from magmas during their ascent. Crisp (1984) estimates that only 20% of the magma that intrudes the crust ever erupts from oceanic volcanoes, which suggests that to a rough approximation volcano sinking should be balanced by addition of magma that does not erupt.

Sierra Negra is a good example to begin with, because the work of Reynolds et al. (1995) has documented the ages and volumes of the lavas there thoroughly, exploit-

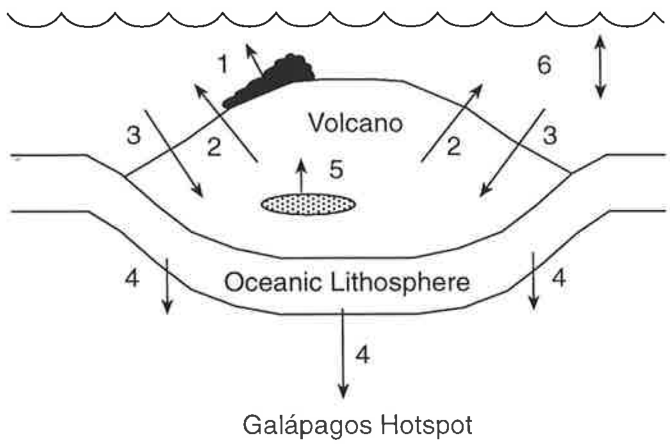

Figure 1: Schematic illustration of the different factors that lead to the emergence and submergence of a volcano. 1) Eruption of lava builds the volcano from its surface. 2) As the oceanic lithosphere passes over the Galápagos hotspot, it expands due to heat from the hotspot. 3) As magmatic rocks cool after eruption and being carried away from the hotspot, they contract. 4) The weight of the newly emplaced rocks cause the oceanic lithosphere to subside. 5) An unknown amount of magma is emplaced into the guts of the volcano, causing it to expand. 6) Sea level rises and falls, mostly due to interglacial - glacial cycles.

ing a technique recently developed by our colleague Mark Kurz that utilizes cosmogenic ^3He. The oldest exposed lava at Sierra Negra is only about 6900 years old, implying that the volcano is resurfaced every 7000 years. From age determinations and field determination of lava flow volumes, the growth rate of Sierra Negra is estimated to be about 1×10^6 m^3/y (1,000,000 cubic meters/year). The subaerial volume of Sierra Negra is about 7×10^{11} m^3, so the volcano probably emerged less than 700,000 years ago. Historically (where the calculations are more certain), Sierra Negra has erupted at a tenfold higher rate, so it is conceivable that Sierra Negra emerged only 70,000 years ago.

Fernandina is often said to be 700,000 years old, but this is a misconception because our only constraint (from paleomagnetism) is that it is *less than* 700,000 years old; how much less is completely uncertain. The subaerial volume of Fernandina is approximately 9×10^{11} m^3. Using an estimated eruption rate of 3×10^6 m^3/y (Reynolds, 1994), Fernandina could have grown from sea level to its present size in less than 300,000 years.

Alcedo is certainly older and less active than the other western volcanoes. Rocks as old as 150,000 y are exposed on its surface, and the assumption of constant growth rate yields an estimate of emergence at 200,000 to 300,000 years (Geist et al., 1994). This estimate is likely to be too conservative, because Alcedo could be old enough to have subsided by other mechanisms (see below), and the techniques used to estimate the emergence ages of the older islands might be more appropriate (Table 1).

The other western volcanoes are so poorly known that one can only speculate on their age of emergence. On the basis of the historical eruption rates, their great altitude, and their juvenile morphology, Volcan Wolf and Cerro Azul probably emerged roughly at the same time as Fernandina, and Darwin intermediate between Alcedo and Fernandina.

It is important to note that each of the volcanoes of Isabela may have formed individual islands after they emerged but before they coalesced with their neighbors. This is particularly obvious at Perry Isthmus, where very young lavas from Sierra Negra lap onto Alcedo, building an isthmus of lavas only a few meters above sea level. The implication is that terrestrial species currently inhabiting Sierra Negra and Cerro Azul may have evolved with long periods of isolation from populations of northern Isabela. Likewise, the very young lavas connecting Volcan Ecuador and Volcan Wolf suggest that Volcan Ecuador may have originally been an isolated island before a lava-bridge formed. The evidence is less certain for the other volcanoes, but it is likely that each stood as a separate island for at least a short time after emergence. It is possible that, in the future, Fernandina will coalesce with Isabela, as the water in Bolivar Channel is shallow and could easily fill with lava. It depends, of course, on whether the volcanoes will continue to build up lavas more quickly than they are subsiding.

Table 1. Estimates of years emerged for selected Galápagos volcanoes.

Volcano	Minimum	Maximum
Fernandina, Wolf & Cerro Azul	60,000	300,000
Sierra Negra & Darwin	70,000	700,000
Alcedo	150,000	300,000
Santiago	770,000	2,400,000
Rábida	1,000,000	2,500,000
Pinzon	1,400,000	2,700,000
Santa Cruz	2,200,000	3,600,000
Floreana	1,500,000	3,300,000
Santa Fé	2,800,000	4,600,000
San Cristóbal	2,300,000	6,300,000
Española	2,800,000	5,600,000

The age of emergence of the older islands is bracketed by two forms of data. First, the oldest exposed subaerial lavas have been reliably dated by the potassium - argon technique (most recently compiled by White et al., 1993). These data set a *minimum* age for emergence. The maximum age can be estimated using the hotspot model, where it is postulated that each volcano first emerged where Fernandina is now, and has since been carried to its present position by the motion of the Nazca plate (37 mm/y; Gripp and Gordon, 1990). The results of these calculations for the major islands and Alcedo are reported in Table 1.

The maximum estimate may be substantially greater than the true age of emergence, because some of the volcanoes may have emerged far "downstream" of Fernandina. Many of the minor islets, such as Daphne Major, Champion, and the four Guy Fawkes almost certainly emerged well to the east of Fernandina and are probably no older than several-hundred thousand years. It was once thought that Española and Santa Fe emerged due to fault-uplifting of older sea floor (McBirney and Williams, 1969), but it has since been shown that they are remnants of subaerial shield volcanoes, so the ages of their lavas also reflect minimum ages of emergence. There are certainly some minor islets that are due to tectonic uplift of older submarine lavas, namely Baltra, Seymour, and Plazas. Otherwise, other than minor uplifts at Punta Espinoza, Urvina Bay, and Villamil, most emergence is due entirely to volcanism.

The final factor that is important for the emergence of the islands and islets is the change in sea level driven by the glacial - interglacial cycles. The glaciers and ice caps of the earth have advanced and retreated more than 20 times over the past 1.6 million years; we are presently in the interglacial part of the cycle, as the glaciers are in retreat. As the glaciers grow during a glacial interval, water

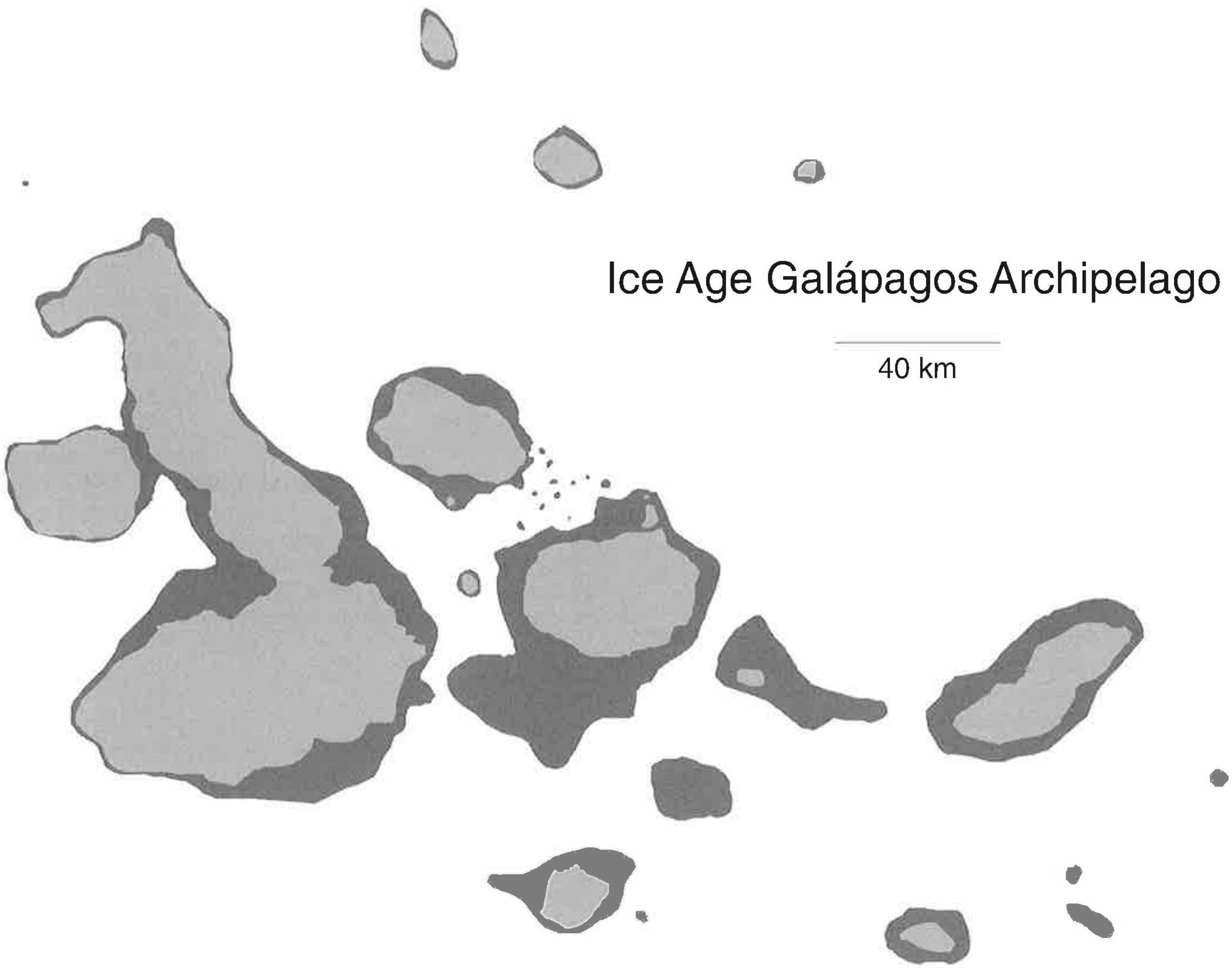

Figure 2. Map of the proposed "Glacial Galápagos". This map was constructed by contouring 130 m depth from navigational charts of the complete archipelago (DMA 22547 and IOA 2020 and 21). The dark regions represent additional surface area above sea-level during periods of glacial maxmia. The light regions represent the current arrangement of islands.

from the oceans is incorporated in ice and the overall temperature of the oceans decreases, resulting in thermal contraction of sea water. As a result of these complimentary processes sea level decreases, and formerly submerged seamounts may emerge. The amount of sea-level fall is difficult to predict with confidence owing to complicated feedbacks. The most relevant data for Galápagos come from Bermuda, which is likewise far removed from local effects of glaciers and continents. Sea level at Bermuda has been shown to have been 130 (±10) m lower 17,000 years ago, during the last glacial (Fairbanks, 1990). That glacial was a relatively large one and was superimposed on a longer-period fall in sea level (due to a long-term cooling cycle), so it is unlikely that sea level has been lower in the recent (past 10 million years) geologic past. It is startling to see the map of the glacial Galápagos (Figure 2). Among other things, a series of islets separated by only several kilometers of open sea extended from Santiago to Daphne Major, and Daphne Major and Santa Cruz were almost surely connected. This currently submarine ridge is likely a volcanic fissure that is part of Santiago volcano, and presumably it is at least as old as the last glacial maximum. Another interesting feature is that Fernandina may have been joined with central Isabela, although this is more uncertain because there may have been significant additions of lava to Bolivar Channel in the past 18,000 years. Undoubtedly, several other present seamounts were exposed, some of which were sizable. A potentially important impact of the glacial - interglacial cycles on Galápagos life is that the sea level is thought to recede slowly (over about 100,000 years) but rises catastrophically (over about 10,000 years) (Broeker and Denton, 1989).

It is interesting to speculate on the future. It has been proposed that the ice caps will recede even further in the next couple centuries, owing to an anthropogenic greenhouse effect. Melting all of our planet's ice would cause sea level to rise 70 m. This has been proposed as a "super-interglacial", because earth has not seen a sea level that high in the recent geologic past. Such a rise in sea level would almost certainly isolate northern and southern Isabela and possibly drown many of the smaller islets. Modeling of atmospheric warming driven by current fossil fuel use suggests a rise of only 70 cm over the next 100 years (Oerlemans, 1989).

SUBMERGENCE OF THE GALÁPAGOS ISLANDS

Because it is well known that ocean islands throughout the world sink with age, the important discovery by Christie et al. (1992) of a 10 million-year old drowned island east of San Cristobal was predictable. Volcanoes subside due to three principal factors: 1) erosion, 2) flexure of the oceanic lithosphere by the weight of the volcanoes, and 3) thermal contraction of the oceanic lithosphere. Erosion is probably not a significant factor because of the arid climate of the Galápagos, at least until the volcano nears sea level and wave erosion becomes important. Lava flows one to three million years old on San Cristobal have the appearance of fresh flows and virtually no soil formation (Geist et al., 1986), indicating little or no erosion. The only stream-cut valleys of consequence in the entire archipelago are on the windward side of San Cristobal. Because stream-transport of sediment is essential for denudation, it is unlikely that any significant erosion has occured in Galápagos.. Likewise, flexure is not important to consider, because it likely occurs in a matter of thousands of years after the last eruption.

Subsidence of the sea floor due to thermal contraction is known to be proportional to the square root of its age ($t^{1/2}$). Elevation data for the Galápagos volcanoes are consistent with this model (Figure 3). The observed elevations suggest that the Galápagos volcanoes subside at a rate that can be described by the equation:

Elevation (in meters) = 1857 - 0.67 * SQRT(age in years)

In addition to the 10 million-year-old submerged island documented by Christie et al. (1992), seamounts to the east might be as old as 18 million years might have been islands *if* they subsided at the same rate as the present Galapagos (Figure 3).

The ultimate question remains: how old is the oldest Galápagos Island? It has been suggested that the Galápagos hotspot started up about 80 to 90 million years ago (Duncan and Hargraves, 1984), which would be the maximum reasonable estimate of an age for the oldest island. Some of the rocks thought to be from the start-up are currently exposed on Gorgona Island, Colombia and others are thought to form the floor of the Caribbean Sea. It should emphasized however that there is no direct evidence that one or islands have been continuously emergent island for any longer than 10 million years, but the idea is

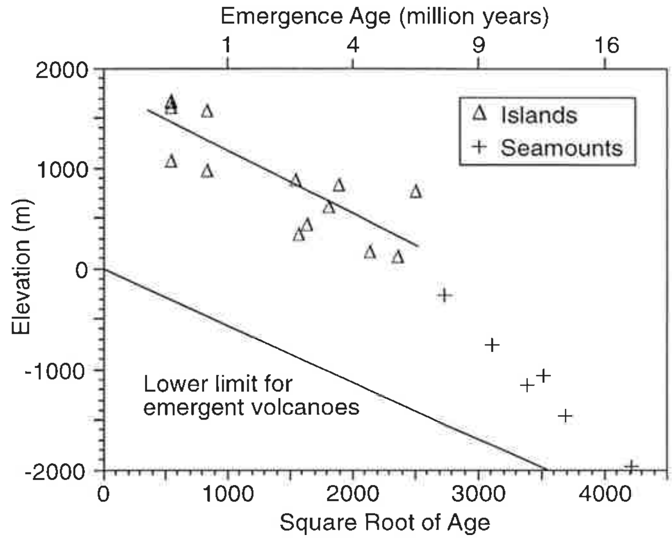

Figure 3. Elevation of the volcanoes versus the square-root of their maximum age (Table 1). From the slope of the regression line the subsidence rate of the islands can be calculated. The seamounts were not used to fit the regression line.

certainly conceivable, probably more to be expected than not.

Not only have plate motions carried the rocks far away from the hotspot, but they have also brought South America closer to Galápagos, at about 3.4 cm/yr. Thus, the 10-million year old proto-Galápagos Islands lay 340 km farther from South America than they do today, which may have affected which species were initially able to colonize Galápagos.

Finally, I want to emphasize that most of the estimates presented here depend strongly upon specific characteristics of the models. That is, the reported ages are based on very little concrete data, so they should viewed as estimates. The purpose has been to present a range of rational possibilities, and the details of diagrams such as Figures 2 and 3 are certainly speculative. Nonetheless, they represent the most reasonable estimates I can come up with using my present understanding of the islands and how ocean islands work in general. By far the most important issue raised is that the map of the Galápagos Islands changes markedly on time scales of 10,000 to 10,000,000 years, and evolutionary models should take this into account.

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THE ARTHROPODS OF THE ALLOBIOSPHERE (BARREN LAVA FLOWS) OF THE GALAPAGOS ISLANDS, ECUADOR

By: Stewart B. Peck

INTRODUCTION

Hutchinson (1965) proposed the term allobiosphere to encompass habitats where photosynthesis is absent because of environmental extremes, and life is supported only by imported food materials. Examples are the animal communities of caves, the ocean depths (Edwards 1988), and above the snow-line on mountains (Edwards 1987). The word is based on the Greek "allo", meaning different or of another kind, suggesting that these habitats are not operating as parts of the normal biosphere. Of interest to us here are young and barren lava flows that have not yet been colonized by plants.

Howarth (1979) was the first to recognize that recent lava flows in the Hawaiian Islands are rapidly colonized by arthropods within months after they have cooled, and long before the appearance of macroscopic plants. The animals scavenge on the wind-born (aeolian) fall-out of organic debris (Swan 1992). The lava flows are barren, xeric, windy, and subject to both high insolation and large daily temperature fluctuations (Howarth 1987). The animals usually are nocturnal foragers and they retreat to deep cracks and crevices in the daytime. They may feed as generalized scavengers but some species may also be remarkably specialized and restricted to such habitats.

Since the work of Howarth on Hawaiian lava flows, allobiosphere arthropod communities have been found to

Table 1. Data for arthropod bottle traps in lava flows on the Galápagos Islands.

Sample	Island	Lava Flow Location	Dates	Elevation	Life Zone
Young Barren Lava Flows					
91-140	Fernandina	Cabo Hammond	May 3-10	sealevel	arid
92-22	Marchena	Punta Espejo	March 11-24	sealevel	arid
92-35	Pinta	Playa Ibbetson	March 13-21	sealevel	arid
92-99	Santiago	Playa Espumilla	April 4-14	5 m	arid
92-104	Santiago	Espumilla to Aguacate	April 6-13	200 m	transition
Older Forested Lava Flows					
92-30	Marchena	SW Playa	March 12-24	sealevel	arid
92-57	Genovesa	Bahia Darwin	March 10-25	5 m	arid
92-74	Santa Cruz	Darwin Research Station	March 6-30	10 m	arid
92-89	Santa Cruz	Darwin Research Station	April 1-17	30 m	arid
92-113	Santiago	Aguacate Camp	April 7-13	550 m	humid

exist in recent lava flows of the Canary Islands (Ashmole and Ashmole 1988, Ashmole et al. 1990, 1992; Martin et al. 1987, 1990) and Anak Krakatau Island, Indonesia (New and Thornton 1988). These workers found that lava-flow arthropods are most successfully collected by baited traps.

I thought it of interest to apply similar sampling techniques to see if such a fauna exists on young and barren lava flows of the Galapagos Islands, Ecuador.

METHODS AND MATERIALS

Trapping stations were placed in both young and old pahoehoe lava flows on the Galapagos islands of Fernandina, Genovesa, Marchena, Pinta, Santa Cruz, and Santiago. The ages of the young lava flows are not known but they have not been appreciably weathered and are not colonized by macroscopic vegetation. On each flow a total of 10 trap stations was set for a period of at least 7 days. The traps were set at least 4 meters apart, depending on the terrain. For comparison we also set traps on older, weathered, vegetated lava flows.

The trapping procedure was similar to that employed by Ashmole and Ashmole (1988) and Ashmole et al. (1990, 1992). The traps were 250 ml disposable glass or plastic bottles with about 50 ml of Turquin's liquid (which both attracts and preserves arthropods) and a bait of 5 cc of Danish blue cheese. Traps were placed as deep as possible into crevices in the lava, and set at a 45° angle. Small rocks were placed around the tops to ensure easy access for crawling animals. A modified formula of Turquin's liquid was made from 15 g chloral hydrate, 20 ml concentrated formalin (40% formaldehyde), 10 ml glacial acetic acid, 1 ml liquid dish-washing detergent and beer added to make 1 liter of fluid. Turquin (1973) used only 5 ml of formalin, 10 g of chloral hydrate, 5 ml of glacial acetic acid, 1 L of beer, and no detergent. I found that this older formulation has less capacity to preserve the captured arthropods. Turquin fluid itself is a bait as well as a preservative. It attracts a wider diversity of fauna than an exclusively formalin- or a vinegar-based preservative fluid (Borges 1992).

In addition to trapping we made visual searches for arthropods around the first station at each site: 15 minutes were spent turning over rocks and 45 minutes searching on the surface and in accessible crevices.

The data for trap locations are in Table 1.

RESULTS

No fauna was found in the daytime visual searches in the new lava flows. This serves to reinforce the general observation that young lava flows are barren of life.

The results of the trap catches are in Table 2. A somewhat higher diversity and much larger number of specimens were caught in the old and vegetated lava flows than in young and barren flows.

The catch numbers have not been adjusted for the different periods of time the traps were operating. The fauna caught on the barren flows are mostly wide-ranging winged species. No distinctive species were found which seem to be specialized to life in or on young lava flows. The cricket *Gryllodes sigillatus*, which is an introduced species, was found on Santiago, Pinta, and Marchena for the first time. It has not been reported in the literature, and was previously otherwise known to me only from CDRS, Isla Santa Cruz, and Bahía Darwin, Isla Genovesa. At present, this species seems to be limited to coastal areas of the arid zone, and is not moving into interior habitats.

DISCUSSION

An adequate sample is not yet available from young and barren lava flows to definitely determine if they have a distinctive and specialized fauna as is known for the

Table 2. Fauna captured in bottle traps place in lava flows of the Galápagos Islands.

	Young Barren Lava Flows					Old Vegetated Lava Flows				
	Fer.[1]	**Mar.**	**Pin.**	**San.**	**San.**	**Mar.**	**Gen.**	**S. Cz.**	**S. Cz.**	**San.**
	140[2]	**22**	**35**	**99**	**104**	**30**	**57**	**74**	**89**	**113**
Gastropoda										8
Crustacea; Decapoda, Brachyura (crab)			1							
Isopoda, Oniscoidea			11	1	3		18	1	200	
Aranea		1					2		1	1
Acari; *Galumna* sp.		18								12
Gamesina						2	1		1	
Austrocarabodes sp.										3
Sacculobates "tenuipilosus"										1
Diplopoda										1
Chilopoda, *Scolopendra galapagoensis*		22	6			8	27	4		
Hexapoda, Collembola			2	5	5	255			200	7
Insecta										
Thysanura, Lepismatidae						5	2		1	
Orthoptera, Gryllidae, *Gryllodes sigillatus*		90	119	6		1	196	3		
Hygronemobius sp.	5									
Blattodea, Blatellidae, *Symploce pallens*							22			
Blattidae, *Periplaneta americana*						2	104	4	7	
Hemiptera										
Lygaeidae									5	
Anthocoridae		1	1							
Miridae										1
Homoptera, Acanaloniidae						1				
Cicadellidae					1				2	
Delphacidae										3
Psyllidae						6			1	1
Psocoptera									1	
Thysanoptera									1	
Coleoptera, Carabidae, *Pterostichus* sp.								1	2	
Histeridae, *Euspilotus* sp.							825		3	
Hydrophilidae, *Oosternum costatum*										1
Staphylinidae			1	1		7				16
Ptiliidae										4
Scarabaeidae, *Ataenius arrowi*										1
Dermestidae								1		
Nitidulidae, *Stelidota insularis*		1		35	11			1		31
Acribus sp.									1	
Urophorus humeralis								1		
Tenebrionidae										
Ammophorus sp.				5	3				120	
Stomion sp.				1	1	2	5			
Chrysomelidae, *Docema* sp.		2								
Bruchidae, *Scutobruchus* sp.								1		
Scolytidae, *Xyleborus ferrugineus*				1		9	1			
X. spinulosus										3
Hypothenemus cylindricus				1		1				1
Platypodidae, *Platypus santacrucensis*					1					
Lepidoptera (moths)	1	1		9	3		4		1	
Diptera, Muscidae	9	2	7	76	95	23	9	1	6	44
other families			41	19			49			23
Hymenoptera, Formicidae	31									
Solenopsis sp.		1	7			5	43	1	159	
Tapinoma sp.		2								
Paratrichina sp.			2	2		1			5	
Wasmannia auropunctata				292	328	134			48	174
Pheidole sp.							4		59	
Campanotus sp.								1	4	
Crematogaster sp.									2	
Monomorium sp.									1	
Microhymenoptera				1		1			2	1
Totals	46	141	198	454	451	462	1312	20	833	336

[1] Islands: Fer. = Fernandina, Mar. = Marchena, Pin. = Pinta, San. = Santiago, Gen. = Genovesa, S. Cz. = Santa Cruz.
[2] Collection sites, see Table 1 for descriptions.

Canary Islands and Hawaii. On those islands it is known that the distinctive fauna vanishes as biotic succession proceeds, and that some of the specialized fauna is present only near the sea coast. In both those island groups a more diverse fauna also occurs on new lava flows at higher elevations, where there is more wind-borne detritus as a base to the food chain.

If this allobiosphere sampling program can be continued, especially on other islands, it will be possible to state more conclusively whether or not a specialized pioneer fauna exists on or in new lava flows. Then it will also be possible to analyze the makeup of the fauna, from the viewpoint of detritivores and predators. At some sites the biomass of the predaceous centipede *Scolopendra* exceeded the biomass of all the rest of the catches combined. The other notable predators are the anthocorid bugs, the *Pterostichus* carabids and the *Euspilotus* histerids. The *Euspilotus* came from a very large population which was feeding on fly larvae in dead sea-birds in a nearby colony on Isla Genovesa. The scavenger arthropods themselves are all broadly-feeding generalists. The Hemiptera (not Anthocoridae) and Homoptera are probably phytophages. They were more abundant on the forested lava flows. Their attraction to the traps is not understood, but most may be aerial waifs and part of the food supply rather than members of the community.

In addition to an aeolian source of organic detritus in the young lava flows, there may be a sea-borne source of debris and food. This idea is supported by the fact that some of the specialist fauna of new lava flows in the Hawaiian and Canary Islands is found only in coastal areas, and not far inland. We found that there is only a general decline in numbers of individuals and of species away from the coast.

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CONSERVATION GETS PERSONAL

By: Heidi M. Snell

September 1995 began like any month in the Galápagos until Saturday, 3 September, when we began hearing rumors about planned closures of the airports on Baltra and San Cristóbal; offices of the Galapagos National Park Service on Isabela, San Cristóbal and Santa Cruz; and the Charles Darwin Research Station (CDRS). Apparently some residents of the Galápagos wished to repeat the protests of January 1995. Chantal Blanton, director of the CDRS, had been in Quito for meetings of the Charles Darwin Foundation (CDF) the previous week and was scheduled to return on Sunday, 3 September. To avoid being completely stalled in case the threats were realized, several Station scientists who had heard the rumors came to their offices over the weekend to pick up work for home. Since the Station had been closed by protesting fishermen for an entire week in January of 1995, they felt there was some reason to believe the local gossip.

On Sunday morning, 3 September, protestors had blocked the main road that crosses Santa Cruz and provides access to the Baltra airport. Jim Pinson set out in a bus to Baltra, to assure the safe return of his wife Chantal. By Sunday afternoon townspeople began gathering at the gate of the entrance to the Charles Darwin Research Station and the Galápagos National Park Service (GNPS). While at the airport Chantal and Jim had been alerted of possible problems with ground transportation on Santa Cruz, so they travelled to Puerto Ayora on the ship, *Delfin II*, and then came by panga (skiff) directly to the CDRS dock to avoid a confrontation with the protestors. Chantal contacted the Port Captain of Puerto Ayora and requested that he clear the entrance to allow CDRS/SPNG personnel and visitors access. Personel at the Port Captain's office related a rumor that the protestors were threatening to take hostages. After hearing this, personnel remaining at the CDRS were reluctant to return to their homes in town through the CDRS entrance, so they left the station by pangas and went to the dock in town. At 4 pm, an E-mail message was sent to CDF officials informing them that the Park Headquarters were 'occupied' by protestors who arrived via the GNPS dock, and thus bypassed the GNPS guards at the gate. That evening Chantal turned away a group of students who came to occupy the CDRS dock and block access to the only other route to and from the Station. During the January 1995 protests the blockage of the CDRS dock had severely restricted access to the CDRS. Chantal was persistent and turned the students away twice before she chained and locked the gate on the road to the dock.

Throughout the world Monday mornings seem the beginning of the most hectic and troublesome day of the week and this one was no exception. Employees of the CDRS and GNPS arrived for work at 7 am and were denied access by the protestors at the gate. Chantal went to the entrance and met with a group of angry protestors, including Fanny Uribe, the Santa Cruz alternate to Diputado Eduardo Véliz (the Congressional Representative for the Province of Galápagos). This sort of protest, where an independent agency is closed by outside protestors, is strictly illegal in Ecuador. However, it is customary for law enforcement personnel to "allow" the protests as long as there is no violence nor property damage. This protest was no exception to that custom, and the local law enforcement personnel did not remove the protestors and informed us that they would act only in the case of harm to people or property. Several police were watching the entrance and the Park Headquarters where there was a large group of protestors. Having "learned" the customs during past protests, Chantal asked that food be allowed in for people and animals, and that key CDRS workers be allowed access. The protestors stated they were in complete control, no food would be allowed in for tortoises, iguanas, or people (later they negotiated that issue and eventually food for captive animals was allowed to pass), and no personnel who lived outside the CDRS or GNPS grounds would be allowed in. This same Monday morning, the road to the airport on Baltra was again blockaded, and the airport of San Cristóbal was shut down by another group protestors (the San Cristobal airport may have been shut down on Saturday also).

The occupation of the offices of the GNPS and the main gate to the GNPS and CDRS grounds by the protestors developed throughout Sunday and Monday. By mid-day Monday the area behind the gate was inhabited by as many as 50 people living under tarps and cooking over small fires. As the protest continued, most of the cooking activites were moved to open areas among the offices of the GNPS, some 500 m from the gate. The gate was reinforced with wooden planks and brush. A small opening remained in this barricade through which a single person could pass by bending low under a plank of wood. The protestors maintained effective control of who could pass the barricade by threatening anyone attempting to pass under the plank and through the opening.

By midday Monday we realized there was a greater potential potential for violence than we had thought. The CDRS comedor (dining room) is located near the dock past a locked gate. The police stationed at the the main CDRS/GNPS gate 1 kilometer away were given meals at the comedor. At noon several of them went through the gate and locked it behind them. They were followed by about 7 protestors carrying machetes and clubs and acting very aggressive. The locked gate did not deter them as they lifted it off the hinges and threw it aside. They were stopped at the Comedor door by a policeman and the CDRS cook Andrés. After looking at everyone dining and stalking around the dock area they finally left. We later heard they had been searching for the head of the National Park, Lic. Arturo Izurieta.

At the same time many people were listening to the congressional representative Eduardo Véliz on the local radio, as he attempted to incite people to riot against the National Park Service and the Charles Darwin Research Station. He encouraged the protestors to break out windows, sack buildings, and create havoc. It was hard to believe these were the words of an elected official of the government! The basic demands of the protestors and representative Véliz were not aimed at the CDRS or the GNPS. The majority of demands dealt with dis-satisfaction with a presidential veto of a somewhat pro-development law ushered through congress by representative Véliz. The CDRS and the GNPS were simply strategic targets for the protest. These two agencies may have been chosen for because of a combination of great visibility and operations that most inhabitants of Puerto Ayora would not miss if they were closed.

As the day progressed, the situation got worse. During the day the the diesel generating plant for Santa Cruz was siezed. Meanwhile, two visiting scientists collected data from the tortoises in the GNPS/CDRS captive breeding program during their last day in Galápagos. It was helpful to have their presence around the tortoise corrals since there were few people about to keep an eye on the CDRS grounds. Even though no employees or visitors were allowed onto the grounds by the protestors, the protestors themselves moved freely about the installations, often accompanied by reporters.

Late Monday afternoon additional rumors and news increased the tensions felt by everyone. By five PM we had heard from a Park employee that oil and diesel were being moved onto the Park grounds and placed near buildings. The Park vehicles had been moved to open places and wood and other combustible materials were stuffed under the chassises. Several individuals claimed the protestors planned to burn the CDRS souvenir shop and other buildings during the night. They also warned us of threatened beatings. The Port Captain phoned and asked that the CDRS personnel on the grounds be kept together and not be wandering around. He said there might be a military response to the protest, but asked that this information be kept confidential. We decided to have everyone gather later in the central conference building which also houses the museum collections and library. We felt that this would provide the most protection for people and the irreplaceable archives. Some individuals remained in their homes rather than join the group in the conference building. Some of those that remained in their homes refused to be threatened easily and others did not believe any actions would be directed against them.

Uncertainty increased as the evening grew darker and nothing more was known. Several people were concentrating on the logistics of sending the two visiting scientists home from Galápagos the next day. The first challenge was to get them out of the Station, and then to the airport. One of the goals of the protest was not only to close the Park and the Station, but to cause a general shutdown throughout the islands. On Santa Cruz this was accomplished by blockading the only road across the island, slowing down general transportation, and more significantly closing down the land route to the airport on Baltra. The only alternate route to the airport was via boat. So, the CDRS vessel, *Beagle*, was readied and the scientists with their equipment and data were smuggled directly aboard from the CDRS dock by panga under the cover of darkness and left late that night for Baltra.

As the scientists were transported to the *Beagle*, a misty, cold and wet garua settled in obscuring visibility on land and sea. Station personnel inside and outside were trying to communicate by phone and VHF radio among themselves, the neighboring islands (to assess the situations there), and to the outside world. Protestors interrupted many VHF radio transmissions with continued threats. At one point everyone heard lot of shouting from the direction of the National Park offices and we could see the glow of fire. Speaking on the Station's radio frequency, Chantal asked anyone listening to please contact the Port Captain and inform him of the fire. This last transmission caused many CDRS personnel still at the Station to recant their decision and an evacuation was called for. Two scientists and a resident of Puerto Ayora came to the Station dock in pangas, and we transported students and families to a hotel on the other side of the bay. A small group of dedicated people decided to stay and watch over the Station and the animals despite the threats and commotion. During the night a group of 26 Ecuadorian Marines entered the Park grounds via another route. They remained there to prevent violence and protect the buildings. Nearly all the Park officials and their families had evacuated during the day leaving the GNPS nearly empty of personnel. Later during the night we found that the fire was a pile of diesel-soaked wood and debris, rather than a building or a vechicle.

Prior to the evacuation of the CDRS personnel a fishing net was discovered across the channel through the reef to the Station dock. The last panga out became entangled, but the because the drivers had been alerted the panga was able to continue on after freeing the fouled propeller. The situation on the Station and Park grounds remained extremely tense throughout the night. Nobody was able to rest, some managed to doze off with their radios as pillows, but it was an uncomfortable and uneasy night. As Chantal was an obvious potential she and Jim avoided the Director's residence and spent the rainy night out in the bush watching over the Station and the goings on. Thankfully nothing more serious occurred during the darkness.

The following Tuesday morning all non-resident Station personnel once again were denied entrance to their workplace. The protestors were hostile towards them as they waited near the barrier at the front gate. The protestors claimed they exercised complete control over the situation. A man with a wooden club loomed over the small opening in the barrier and threatened any one wishing to pass. Other times a group of people would just move forward, physically blocking any opening. It was sufficiently daunting that was willing to see what the reaction would be if they walked through despite being verbally denied access. On the inside, there were military personnel guarding the homes and buildings at the Park, and largely due to their presence, nothing had been damaged during the night. However, they were not allowed to pass to the Station and post people there. The situation was tense but the evacuees returned to the Station via panga and some attempted to carry out their normal work routines, but most found that simply keeping the Station running consumed all their time and energies. The phones rang constantly with calls from reporters, worried parents and families. Many of the callers were CDRS personnel stuck outside who needed information and materials to continue their work as well as apprising those within the CDRS of how the situation was developing in town.

Chantal continually tried to ensure the safety of the people and property of the Station and repeatedly asked that key support people be allowed entry to carry out essential maintenance work, a burned out water pump, a faulty incubator for the tortoise eggs, and the key people to deal with the nesting Española tortoises. She also made it clear that the daily food supply for the tortoises, iguanas and the Ecuadorian military personnel could not be obstructed. Some staff managed to get through once in a while simply because they were personal aqquaintences of protestors guarding the gate.

Wednesday morning dawned much brighter for those inside when they met with nine military "Rangers" who arrived at the Station during Tuesday night. They kept a low profile for the first few days but were quick to assure everyone they would remain throughout the situation. It was a great relief to have them at the Station. That same morning protestors finally relented when Chantal was filmed by a prominent reporter from Ecuadorian television and radio, while making her daily requests for food for people and animals to the secretary of the protest group, Mrs. Gulnara Garcia. Mrs. Garcia was quick to assure to the media that the needs of people and animal would be met. At mid-day personnel within the station received a call from some of the CDRS personnel in town reporting that in town protestors were reputed to be actually gathering guns and saying that they would burn the GNPS offices on Friday if the government did not meet their demands. This report increased tensions within the CDRS greatly, and the remaining individuals were relieved to have the Rangers on the grounds. Wednesday night three American consulate members and bodyguards arrived in Puerto Ayora, in response to several requests for help that were made to the American Embassy in Ecuador.

Despite the desire of the protestors to completely disrupt the activities of the CDRS, many of the CDRS personnel were committed to maintaining a functioning research station. They effectively divided themselves in a small group of scientists remaining within the CDRS who dealt with the administrative and scientific responsibilities, and another group of employees that operated remotely from the CDRS in Puerto Ayora. The logistics for visiting scientists were some of the most challenging issues. Maintaining contact and making arrangements was extremely difficult. Everyone was aware that failure to meet the needs of arriving scientists would destroy plans for research in the islands, and because many of the research parties had invested years of effort and great expense to get to Galápagos we wanted to prevent such failure. For the individuals remaining at the CDRS one of the most frightening aspects of the protest was the sense of isolation and the lack of information about efforts to curtail the protest and protect the GNPS and CDRS installations. To alleviate this isolation, the employees in town also spent time assessing the changing situation, attending town meetings and apprising those within the CDRS of the general goings on. Everyone felt the intense frustration of being unable to do their jobs well. On the inside, the Education & Interpretation Departments and Teniente Gavilanes, the leader of the Ranger unit, began an information campaign to counter the propaganda sent out by the protestors. Meanwhile an inciting speech by representative Véliz had been taped and was transmitted to Quito for broadcast by television and coverage in the national press.

Beyond the borders of Galapagos, further actions were being taken against the protestors. In response to the messages sent from the CDRS immediately at the beginning of the protests members of the Charles Darwin Foundation (CDF) had begun acting to alert influential parties as to the situation and they demanded action. It was obvious that pressure to counter the protest had to come from beyond Galápagos because few residents of islands appeared willing to speak out against representative Véliz.

The presence of Dan Johnson (Untied States Consul to Ecuador), Bill Hunt (United States Navy) and Dennis Ravenshaw (US Embassy Security, Quito) created some pressure on the protestors. On Thursday there were several meetings of this group, Chantal, and others. After one meeting, held at the Station, the group and some press people were escorted to the barrier at the gate for another meeting in Puerto Ayora. Before reaching the main gate the body guard of the US Consul found molatov cocktails hidden within a secondary barrier on the road, at the turnoff to the GNPS offices. The presence of bombs confirmed to us just how serious an intent to do damage existed. The protestors were immediately questioned about the bombs and offered a confusing array of statements before settling on a consistent explanation. They claimed the incendiary devices had been hidden there by an Israeli tourist, whom they had allowed past the barriers to search for her lost passport.

As the long days and nights of the protest continued, pressure and worry never left the people within the CDRS. The scholarship students and volunteers found themselves without supervision and with little guidance, but they did a great job of filling in for missing staff. They had immediately assumed responsibility for the care and maintenance of the captive tortoises and iguanas. The daily deliveries of fresh food collected in the highlands of Santa Cruz had to be moved by hand over the two barriers set up by the protestors. At each barrier the students were harrassed by protestors as they unloaded several hundred pounds of vegetation from wheelbarrows, carried it over the barrier, and loaded it into wheelbarrows on the other side. The whole process involved moving the food by hand and wheelbarrow for more than a kilometer and loading and unloading it all twice. Later in protest, after several direct threats to kill Lonesome George (the only living tortoise known to be from Isla Pinta), they took shifts to keep a continual watch over the grounds and the tortoise pens in particular. Students guarded the tortoise corrals 24 hours a day, but stayed closest to George. Heavily-armed marines kept constant watch over everyone. It was definitely not a normal sight to see combat-ready military patrolling the Station grounds!

Edison Encalada, an Ecuadorian student-volunteer was in charge of coordinating animal care. He also had the responsibility of monitoring the nesting Española tortoises and protecting the eggs in incubation. During the third night of the protest a heater in one incubator short-circuited and burned up. Thanks to Edison's constant observation, the fire was discovered before the incubator could burn. Edison transferred the incubating eggs to a second incubator, which prevented their deaths. This incident is only one example of the constant efforts by staff and students which prevented the protest from being as damaging as it could have been.

As the protest and occupation continued, some opposition began forming within the Galápagos community. A local group formed in Puerto Ayora called the "Comite de Paz y Bienestar" (Committee for Peace and Well-being), who opposed the protestors. They held meetings and a march demonstrating to the townspeople there were some residents who did not agree with the disruptive tactics favored by representative Véliz. The Ecuadorian press and television began showing both sides of the issue and local tour companies reported cancellations. The airport at Baltra was the only one functioning (it is a military base and so was not closed by the protestors), so both TAME and SAN airlines operated their daily flights from there. Tour boats changed itineraries and avoided the towns as much as possible. The San Cristóbal airport remained closed by the 40 or so people who occupied it, including representative Véliz. The National Park Service offices in San Cristóbal remained open but the vehicles were stored at a Navy base for security. On Isabela, at the town of Villamil, GNPS offices had been occupied by protestors since Sunday, and a GNPS vehicle was kept by them as well. This meant that food for the tortoises in the Isabela breeding center had to be delivered from the highlands in a private truck. On Santa Cruz, the Station was the base for the few remaining National Park Service personnel, student volunteers, CDRS residents and the Ecuadorian Rangers. The CDRS dining room served 3 daily meals to about 50 to 60 people. Meanwhile with things so well tied up in the clamor, the illegal fishing for sea cucumbers, sharks, and other species apparently continued unchecked.

The days seemed to go on and on without a change in the situation. About the time things would become moderately tranquil, there would be a meeting or a march and promises that representative Véliz would arrive from San Cristóbal to give strength to the protest. He apparently never did come to Santa Cruz, and even though his speeches were frequently read over the radio to the public, it finally seemed as though momentum was waning. Nine days after the closure of the Station, twelve employees came to work by panga. The following day employees again came to work by panga. We were finally able to get a few more employees back in the offices to try and pick up the pieces and carry on with their work. The traditional team spirit of the CDRS strenghtened and our spirits began to lift, only to be dashed to a new low. A little after noon on Wednesday, 13 September, Chantal received word from Isabela of the accidental death of Don Arnaldo Tupiza. He had been an employee and representative of the Darwin Station for 25 years. Station employees gathered at the main building and received the shocking news. It was a serious blow to the morale of everyone. The rest of the day was spent arranging everything from a coffin to money for the family and a boat to carry Station people and materials for the funeral to Isabela.

On Thursday, employees again came in by panga and a few others bypassed the barrier at the gate by climbing over an unguarded wall. Unfortunately they were seen by the protestors. This triggered a formal, menacing letter which stated that the Station had to respect the closure and stop using pangas to move people past the blockade or the protestors would not be responsible for the consequences. At the same time arrangements for the funeral of Don Arnaldo Tupiza continued and a group of people led by Chantal prepared to attend in Isabela.

Friday dawned with Chantal and a number of CDRS employees on Isabela for the funeral after traveling there overnight by boat. The Station closed in an official day of mourning for Don Arnaldo, and everything remained quiet. The department of Environmental Education from the CDRS had broadcast several special radio programs about Don Arnaldo, his life, his contributions, and his special stewardship of Isabela. In the early hours of Saturday, a very subdued group returned from Isabela.

Had it not been for the tragedy which occurred on Wednesday, the morning of Saturday, 16 September, would have been reason enough for celebration, the protestors had ended their siege and were taking down the barriers. Representatives from the GNPS, Ranger Special Forces, CDRS, and the protest committee jointly checked over the GNPS area to assess property loss or damage. Apparently stolen items included a Geographical Positioning System receiver, a computer, a marine radio, gasoline and other supplies, but at last everyone was free to come and go at will. While our freedom of access had been curtailed for only a relatively short two weeks, it was long and tense enough to cause our reflection on what that freedom meant to us.

Many of the students and staff celibrated the end of the protest by throwing themselves into the International Coastal Cleanup Program held worldwide on that day. The group centered at the CDRS collected about a ton of garbage from the coast on the north east side of Academy Bay. The CDRS team also had the help of some of the Rangers! That night the Marines moved to the Naval base in Puerto Ayora and kept guards posted at the front gate, because there were some protestors apparently eager to renew the occupations and protest activities.

As the days turned to weeks, without a renewal of the protests, the Station and Park slowly came back up to speed in attacking the problems that concern us most in the islands. We had all fallen drastically behind in the basic research and conservation programs. For me, the Galápagos Islands lost their innocent status and openly became a pawn for frustrating monetary and political ambitions during the two weeks under siege. While the threats and potential danger that we experienced during the strike were minor compared to parts of the world experiencing great levels of terrorist activity, I won't take take my personal saftely for granted again.

Conservation is defined as: *a careful preservation and protection of something; planned management of a natural resource to prevent exploitation, destruction, or neglect*. This is a word conoting action that we all take pride in, and it is what we have based our values for Galápagos on. Little did we realize how much we could be hated when the wrong mix of politics and agitation stirred up a local populace. Many of the people who dedicate their efforts to the Charles Darwin Research Station and the Galápagos National Park have an intense sense of commitment. Understandably it affects all of us when these deep convictions can cause such hatred to be thrown against us by one sector of the community. Having faced such a common danger, several of the groups that were occupied and threatened during the strikes and protests have gained an increased sense of unity. Cooperative programs between the National Institute for the Galápagos Islands (INGALA) and the CDRS and SPNG now reinforce a greater awareness and readiness for action on the part of many townspeople to assure the peace and well-being of Galápagos. Today the economic and political interests in Galápagos are increasing at an ever accelerating rate. In order to achieve our goals of conservation of these incredible islands we must all show continued strength of commitment evidenced by the students and everyone else during the strike. We can not allow greed and ignorance to determine the future of this unique archipelago.

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NEW RECORDS OF GALÁPAGOS FISHES

By: John E. McCosker and Paul H. Humann

INTRODUCTION

The shorefishes of the Galápagos Islands have received considerable attention in recent years with the advent of modern scuba diving and improvements in underwater photography. Since 1977, Humann has made more than 1,400 dives throughout the archipelago and, in preparation for the publication of his Galápagos Reef Fish Identification Guide (Humann 1993), discovered that many of his subjects were previously unknown, unreported and, in several cases, new to science. McCosker has made several trips to Galápagos and has also discovered new species and new records of fishes otherwise known from elsewhere in the eastern Pacific or from the Indo-Pacific.

The most recent estimates of the Galápagos ichthyofauna indicated approximately 325 shorefish species distributed among 92 families (McCosker and Rosenblatt 1984; McCosker 1987; and subsequent new records and species descriptions). As well, the recent El Niño events that have occurred in the eastern Pacific have added additional examples of Indo-Pacific fishes to the Galápagos (Grove 1985); however it is unlikely that many of them will establish reproducing populations. We add the following 13 new records of species previously unknown from Galápagos. Species common to the eastern Pacific mainland include: *Triakis maculata* (Spotted Houndshark); *Elops affinis* (Ten Pounders); *Uraspis helvola* (Cotton Mouth Jacks); *Haemulon sexfasciatum* (Graybar Grunt); *Hemilutjanus macrophthalmus* (*Ojo de Uva*); and *Kathetostoma averruncus* (Smooth Stargazer). New records of species common to the Indo-Pacific include: *Gymnothorax meleagris* (Whitemouth Moray); *Forcipiger flavissimus* (Long-nosed Butterfly Fish); *Thalassoma purpureum* (Surge Wrasse); *Naso brevirostris* (Spotted Unicornfish); *N. vlamingii* (Bignose Unicornfish); and *Cyclichthys spilostylus* (Yellow-spotted Burrfish). *Guentherus altivela*, also a new record, is from the southeast Atlantic and the eastern Pacific.

ACCOUNTS

Family Triakidae

Triakis maculata Kner and Steindachner 1866

An adult female Spotted Houndshark, ≈ 170 cm TL, was captured with hook and line above a 6-8 m bottom by McCosker on 25 July 1980 at Punta Espinosa, Isla Fernandina. It was photographed (Figure 1) and examined, then released alive. Its identification was verified by from the photograph and description (personal communication, L. J. V. Compagno). *Triakis maculata* ranges from Peru to northern Chile, includes *Mustelus nigromaculatus* Evermann and Radcliffe (1917) in its synonymy, and may reach 240 cm (Compagno 1984).

Family Muraenidae

Gymnothorax meleagris Shaw and Nodder 1795

An adult specimen of the Whitemouth Moray, *Gymnothorax meleagris*, was seen and photographed in March 1989, by Humann (1993, p. 175) off Cousins Rock, Isla Santiago, over a boulder strewn bottom at approximately 15 m depth. This species is unmistakable in appearance, and this individual represents the first example reported from the eastern Pacific Ocean. It is common in shallow tropical waters from Hawaii westward to the coast of Africa (Gosline and Brock 1960; Castle and McCosker 1986). Previously reported records of *G.*

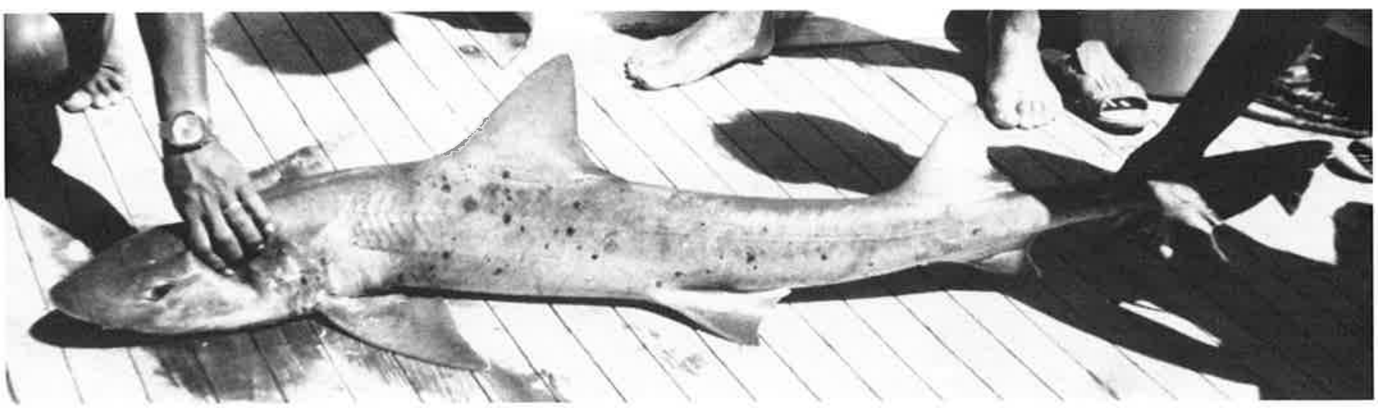

Figure 1. Adult female *Triakis maculata* (Spotted Houndshark), ≈ 170 cm total length, captured above a 6-8 m bottom at Punta Espinosa, Isla Fernandina, 25 July 1980.

meleagris from the Red Sea are based on mis-identified specimens of *G. buroensis* (Randall and Golani 1995).

McCosker and Rosenblatt (1975) reviewed the morays of the Galápagos and reported upon 16 species, four of which are also widely distributed in the Indo-Pacific. McCosker et al. (1984) subsequently recognized the eastern Pacific *Uropterygius necturus* (Jordan and Gilbert) to be a junior synonym of *U. macrocephalus* (Bleeker). Bussing (1991) described McCosker and Rosenblatt's "*Uropterygius sp.*" as *U. versutus*. The presence of *G. meleagris* in Galápagos brings the number of muraenids common to the eastern Pacific and Indo-Pacific to 11 (see Rosenblatt et al. 1972; McCosker and Rosenblatt 1975), including: *Echidna nebulosa, Enchelycore lichenosa, Enchelynassa canina, Gymnothorax buroensis, G. flavimarginatus, G. meleagris, G. undulatus, Gymnomuraena zebra, Scuticaria tigrina, Siderea picta*, and *Uropterygius macrocephalus*.

Family Elopidae

Elops affinis Regan 1909

Also known as Ten Pounders, Lady Fish, or *Chiro, Machete* are found in shallow inshore areas between Peru and southern California. We report them from Galápagos on the basis of our sightings and photographs (Humann 1993, p. 51) off Roca Redonda at 3-5 m beneath the surface, above a boulder bottom at 15 m depth. We presume them to be *E. affinis*, the only species known to inhabit the eastern tropical Pacific (Whitehead 1962).

Family Carangidae

Uraspis helvola Forster, 1801

We occasionally observed, and photographed (Humann 1993, p. 39), large schools of Cottonmouth Jacks off Darwin, Wolf, and Roca Redonda. We now cautiously identify this species as *U. helvola*, rather than *U. secunda* (Poey, 1860), until a generic revision is completed (pers. comm. W. F. Smith-Vaniz). In the eastern Pacific, it is also found from southern California to Costa Rica, typically near offshore islands.

Family Haemulidae.

Haemulon sexfasciatum Gill 1862

We observed and photographed (Humann 1993, p. 57) schools of adult Graybar Grunt at several Galápagos locations between 7-15 m depth, including the channel between Baltra and North Seymour, the north shore of Española off Isla Gardner, Corona del Diablo off Isla Floreana, and Cabo Marshall, Isla Isabela. It is unmistakable in coloration and is one of the commoner nearshore grunts living between the Gulf of California and Panama.

Family In Question

Hemilutjanus macrophthalmus Tschudi 1845

Humann regularly observed and photographed (Humann 1993, p. 65) groups of *Ojo de Uva* below 30 m at Punta Vicente Roca. McCosker observed three individuals at 35 m along the north entrance to Tagus Cove, Isla Isabela. They were ≈ 25 cm in length and hovered about 1 m above the rocky bottom. *Ojo de Uva* have previously been reported from the coasts of Perú and Chile where it is captured by fishermen using handlines over rocky bottoms (Hildebrand 1946). The familial relationships of *Hemilutjanus* are poorly understood, however recent studies (Johnson 1984) have determined that although it looks much like a snapper, it does not belong within the Lutjanidae.

Family Chaetodontidae

Forcipiger flavissimus Jordan and McGregor 1898

Humann photographed (Humann 1993, p. 29) adults of the Long-nosed Butterfly fish on numerous occasions at Isla Darwin (May 1991, November 1992, April and May 1993) and once at Wolf (May 1993). In each case they were swimming over rocky, boulder strewn bottoms between 8-10 m. *Forcipiger flavissimus* is widely reported from throughout the Pacific and Indian oceans (Burgess 1978). In the eastern Pacific, it is also known from Easter Island, the Revillagigedo Islands, Clipperton Island, and Cabo San Lucas.

Family Labridae

Thalassoma purpureum (Forrsk=E5l 1775)

Humann observed numerous individuals of the Surge Wrasse (Figure 2) at Isla Darwin during May and November 1994. They were appropriately swimming within the surge zone at about 3-4 m depth. This species is widespread in the Indo-Pacific and known from the Red Sea to the Hawaiian, Marquesan, and Easter islands, north to southern Japan and throughout Micronesia (Myers 1989). Randall (1995, p. 675) reported its occurrence at Clipperton Island.

Family Ateleopodidae

Guentherus altivela Osorio 1917

A postlarval specimen of *Guentherus altivela* was collected by Andre De Roy on 12 June 1978 using a benthic shell dredge in 200 m, south of Isla Santa Cruz. The damaged and poorly preserved specimen (Figure 3, CAS 47468) has the following counts and measurements (mm): standard length 109; head length 27; snout length 6.5; upper

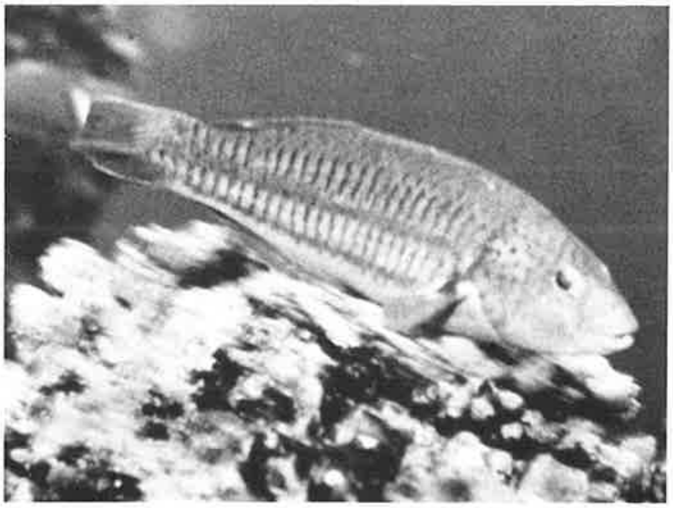

Figure 2. Adult *Thalassoma purpureum* (Surge Wrasse) photographed by Humann at 1-4 m depth in the surge zone off Isla Darwin in 1994.

jaw length 13.5; eye diameter 5.3; preanal length 44; tail length 65; dorsal fin rays 12; anal fin rays 75; caudal fin rays 11; pectoral fin rays 14; pelvic fin rays 11, the last two joined at their base; upper gill rakers 5; lower gill rakers 18. The specimen is too poorly ossified to allow a vertebral count to be made and fins were too damaged to allow accurate length measurements. The coloration of this nearly gelatinous specimen is similar to that of the 104.5 mm postlarva illustrated in Bussing and Lopez (1977), and possesses ten black smudged bands over a cream colored body, black fin edging, and spots (about equal to the eye in size) on the head.

Guentherus altivela is known from 360-700 m depth off southwest Africa to the Cape of Good Hope, and from Panama and Costa Rica in the eastern Pacific, between 220-302 m depth (Bussing and Lopez 1977). Their eastern Pacific specimens did not differ significantly from the Galápagos specimen in either counts or measurements.

Family Acanthuridae

Naso brevirostris Valenciennes 1835

McCosker was advised by Tui De Roy in 1984 that she had seen a "unicorn-snouted" surgeonfish off Islas Darwin and Wolf. Subsequent observations and photographs confirmed the presence of the Spotted Unicornfish by Humann along the northern edge of Isla Darwin in 10 m in November 1993, suggesting to us that De Roy had also seen *N. brevirostris*. The Spotted Unicornfish is easily recognized on the basis of its head profile (Figure 4) and coloration, and is well-known from the Red Sea to the Hawaiian, Marquesan, and Ducie islands, north to southern Japan, south to Lord Howe Island, and throughout Micronesia (Myers 1989). This represents the first record of its existence within the eastern Pacific.

Naso vlamingii Valenciennes 1835

We observed and photographed Bignose Unicronfish on separate occasions at the south side of Isla Darwin above 12 m depth in November 1993, and at 18 m off the north end of Isla Wolf in May 1994. The absence of a nasal horn, the elongate caudal filaments, and the blue bar beneath the eye identify this species (Figure 5). This represents the first eastern Pacific record for this species; in the Indo-Pacific it is known from East Africa to the Line, Marquesan, and Tuamoto islands, north to southern Japan, south to the southern Great Barrier Reef and New Caledonia, and throughout Micronesia (Myers 1989).

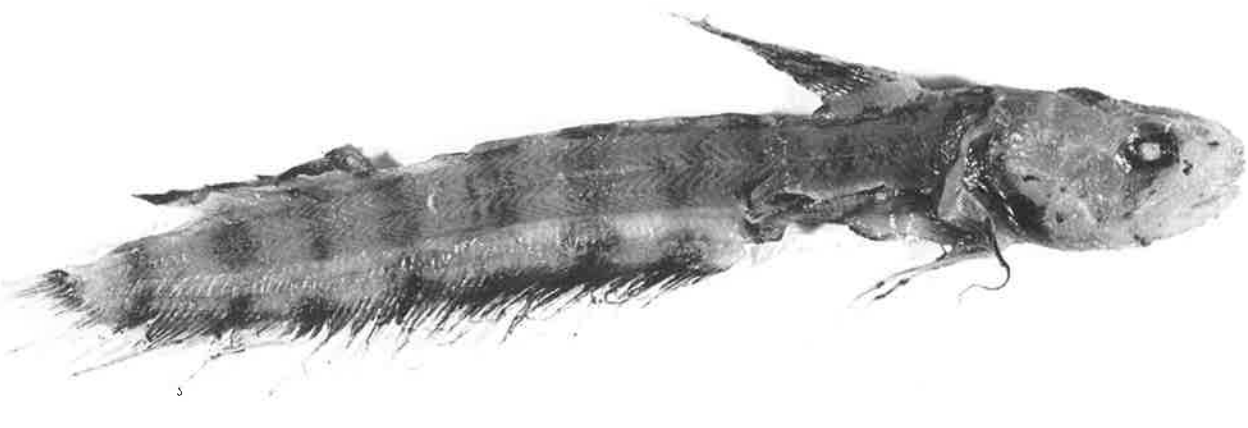

Figure 3. Postlarval specimen of *Guentherus altivela* (CAS 47468) collected by Andre De Roy in 200 m, south of Isla Santa Cruz.

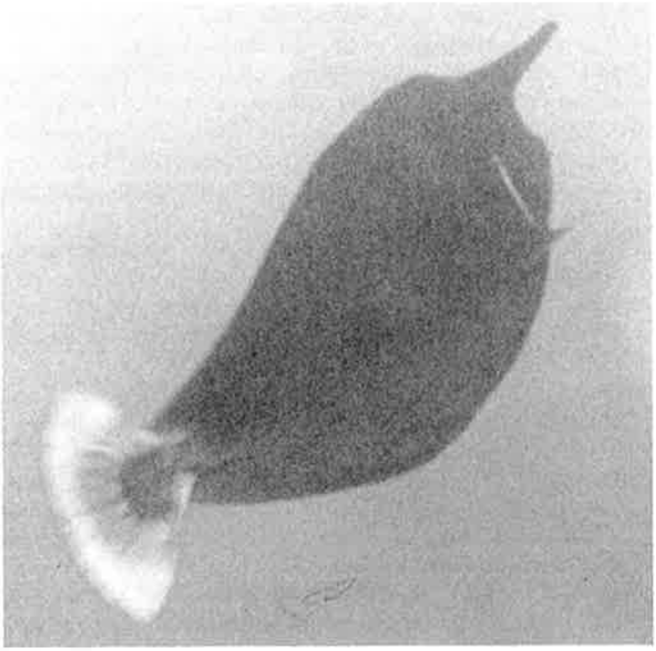

Figure 4. Adult *Naso brevirostris* (Spotted Unicornfish), photographed by Humann at 10 m at Isla Darwin, November 1993.

Family Uranoscopidae

Kathetostoma averruncus Jordan and Bollman 1890

A 117 mm (standard length) Smooth Stargazer (CAS 47470) was captured using a "coffee can dredge" by Andre De Roy in the Galápagos, location unidentified. *Kathetostoma averruncus* was described from specimens collected off Colombia and includes *K. ornatus* Wade (1946) from the San Benito Islands, Baja California, in its synonymy. The Smooth Stargazer inhabits sand bottoms over a wide range of depth (13-384 m) and is recorded from central California to Peru (Eschmeyer and Herald 1983).

Family Diodontidae

Cyclichthys spilostylus Leis and Randall 1982

An adult Yellow-spotted Burrfish was first seen and photographed in March, 1978 (Humann 1993, page 151), hiding beneath a ledge at 15 m at Tagus Cove, Isla Isabela. Humann observed a second specimen in November, 1994, at 20 m depth off Punta Vicente Roca, Isla Isabela. Described as *Chilomycterus spilostylus*, this burrfish has been subsequently referred to *Cyclichthys* and is known from the Red Sea, South Africa to the South China Sea, the Philippines, Japan, and Australia (Leis 1986, Matsuura et al. 1993).

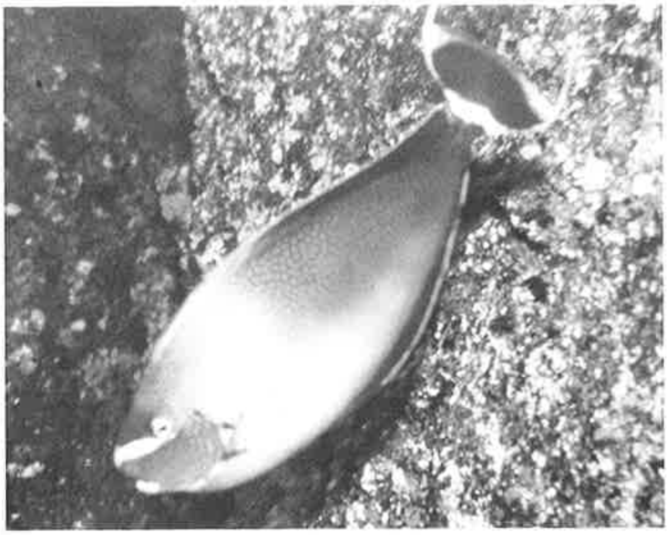

Figure 5. Adult *Naso vlamingii* (Bignose Unicronfish), photographed by Humann at 18 m at the north end of Isla Wolf, May 1994.

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Robert J. Lavenberg and Jack Grove of the Los Angeles County Museum of Natural History are preparing a volume about the fishes of Galápagos, and they, along with Richard H. Rosenblatt of the Scripps Institution of Oceanography and John E. Randall of the Bernice P. Bishop Museum, have kindly assisted us with the information that we report herein. We also thank Tui De Roy who provided advice as well as the specimens that her father had collected. Permission to collect and observe fishes at Galápagos was kindly made possible by a permit from Arturo Izurieta and Felipe Cruz of the Servicio Parque Nacional Galápagos and Byron Moya Reyes, Director General de Pesca. Logistical support was provided by Dr. Chantal Blanton, Laura Chellis, and Alfredo Carrasco of the Charles Darwin Foundation for the Galápagos Islands. We thank Eduardo and Dolores Diez of Quasar Nautica, for generously providing the use of their vessel *Mistral*. Specimens reported on are kept in the Ichthyological collections of the California Academy of Sciences (CAS), San Francisco, California, USA.

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MOLECULAR GENETICS AND CONSERVATION IN THE GALAPAGOS

By: Kornelia Rassmann

INTRODUCTION

For more than a century Galápagos has served evolutionary biologists as a natural laboratory for their studies. A major goal has been to describe the unique morphological and behavioral adaptations evolved by the diverse life forms of Galápagos organisms in response to their forbidding environment and to understand how these specializations have come about. Because the basic material of evolutionary changes are genes, understanding the genetic mechanisms of these processes has been an important step. Models derived from theories of population genetics can illustrate the processes influencing the genetic composition of populations or species, and therefore constitute an important part of current evolutionary research. These models attempt to describe the current genetic status of evolutionary systems, e.g. the amount of genetic variation within or among populations, and estimate the future prospects of populations with regard to their genetic composition. At the same time, the genes and the gene composition of a species or population serve as a record of the evolutionary events that occurred in its past and thus provide information on its historical - or phylogenetic - background.

In a rather sad way, population genetic and phylogenetic theory may become increasingly important for the practical aspects of research in the Galápagos. Over the past few centuries the populations of several endemic or native species declined, bringing some of them close to extinction and extirpating a few. The major reasons for these declines include predation by feral animals, habitat destruction and competition for resources by non-indigenous plants and animals introduced to the islands by humans, and human exploitation of indigenous species and their natural habitat (Trillmich 1992). Of course, there are also non-human-induced causes threatening Galápagos' fauna and flora. Sudden catastrophic events such as volcanic eruptions or epidemic diseases may endanger specific populations. Of more global nature are environmental changes such as the recurrent El Niño events -

climatological anomalies which sometimes lead to dramatic rises in the sea surface temperatures in the Galápagos. El Niño events influence the taxa in the Galápagos in different ways (Trillmich 1991). While some species thrive under an abundance of food, others are deprived of their natural resources and experience notable population declines. Thus, low population densities may occasionally occur naturally in some Galápagos species. However, the fossil record suggests that most extinctions in the Galápagos took place after the arrival of humans (Steadman *et al.* 1991). Together with the natural threats to Galápagos' biota, the increasing human impact on this unique ecosystem makes conservation biology an important and pressing field of research in the Galápagos today.

The diversity of the archipelago may now profit from what it taught us in the past. A new discipline, conservation genetics, applies the principles of population genetics and phylogenetics to conservation issues. It documents the amount and the pattern of genetic variation in endangered species and attempts to derive suggestions aiding their preservation. Among its applications are attempts to i) monitor and manage genetic variation in natural and captive populations, ii) predict demography in wild populations (e.g. the population size or the degree of gene flow), iii) recognize evolutionary distinct populations or subpopulations, which may need separate management or conservation, iv) determine the conservation value of populations or taxa based on their degree of genetic deprivation or their phylogenetic distinctiveness, and v) identify individuals or specimens of unknown origin or species affinity (Avise 1994, Hedrick & Miller 1992, Moritz 1994, Dobson *et al.* 1992).

However it is fair to ask, "Can genetic research indeed save endangered species?" Clearly, conservation genetics does not reduce the above mentioned risks of natural or anthropogenic changes of the environment and catastrophic events. Additionally there are two further categories of potential threats to the survival of populations, described as genetic and demographic causes (Shaffer 1981). In particular small populations can face a number of problems related to these categories. A predicted result from models of population genetics is that small populations lose genetic variation faster than large populations. This process is called genetic drift. Low genetic variation is generally assumed to have negative effects on the viability of a population. For instance, a lack of genetic variation may reduce a population's ability to respond quickly to future environmental changes. Also, pedigree inbreeding (e.g. the mating of genetically related animals) is likely in small populations, increasing the probability that deleterious recessive alleles are revealed, which may reduce the fitness of individuals in the population. Because a confusing terminology exists I refer you to a discussion of the different biological meanings of the term 'inbreeding', which need to be kept apart in order to avoid serious errors in management recommendations (Templeton and Read 1994). It is not clear whether the reduction of viability and fecundity in observed in inbred populations - commonly called 'inbreeding depression' - is always a consequence of pedigree inbreeding (Caro & Laurenson 1994, Laurenson *et al.* 1995). However, many authors still consider a management of genetic heterozygosity an important element in the preservation of endangered species (Avise 1994) that deserves greater attention in overall conservation planning (Hedrick & Miller 1992).

Managing the genetic variation in a free-living population is a long-term process, possibly too slow to deal with the population's short-term conservation needs. Also, in populations with low densities reproduction can be reduced for several non-genetic reasons, e.g. simply the lower frequency with which the opposite sexes meet. For such reasons it has been argued that demographic considerations (population growth and age structure) are of greater importance in the direct management of an endangered species than long-term genetic concerns (Lande 1988). Is 'conservation genetics' then of little practical value? Indeed, in the case of the Galápagos the most urgently needed steps towards its rescue might be immediate ecological actions, as well as political decisions and their enforcement. However, I feel that there is also potential in the data accumulating from the increasing number of molecular evolutionary studies in the archipelago.

GALÁPAGOS MARINE IGUANAS

The following serves as an example how a molecular genetic project may help to support the conservation of species. The objective of a study on the marine iguanas (Rassmann, unpubl. data) was to analyze the genetic differentiation within and among populations throughout the Galápagos. Samples of blood from iguanas were collected from 22 populations, including nearly all populations from major islands (Table 1). During the sampling trips in spring 1991 and 1993, populations from islands with introduced predators were observed to be small in numbers and characterized by an absence of juveniles, for example on Islas Isabela and San Cristóbal (Cayot *et al.* 1994). Previously it had been suggested that predation by feral animals was a likely cause for the conspicuous lack of recruitment in some marine iguana populations, and that in extreme cases, such as on Isla Isabela, this would potentially lead to their extirpation (Laurie 1983).

The consequences of artificially increased levels of predation on natural populations are not easily assessed when detailed information on the population's demography and the distribution is missing. It is possible, for example, that migration among different subpopulations from the same or neighboring islands is sufficiently high to make up for the increased losses due to predation. When conservation resources are limited, they need to be directed to the most critical cases. These should encompass not only the populations which are most threatened, but also

Table 1. Genetic variation within and among 22 genetically analyzed marine iguana populations.

Population	N^1_{mic}	N^2_{mt}	H^3	A^4	F ST[5]	Phi ST[6]
Española, Cevallos	12	6	0.69	3.25	0.159	0.729
Fernandina, Cabo Hammond	10	10	0.76	4.62	0.080	0.581
Floreana, Punta Montura	10	6	0.77	4.33	0.117	0.403
Fernandina, Punta Espinosa	10	6	0.77	5.44	0.067	0.553
Fernandina, Punta Mangle	13	6	0.77	5.44	0.074	0.468
Genovesa, Campamente	11	12	0.69	3.51	0.149	0.430
Isabela, Caleta Negra	10	6	0.81	5.42	0.060	0.466
Isabela, Caleta Webb	10	6	0.78	5.04	0.071	0.592
Isabela, Punta Albemarle	10	6	0.76	4.67	0.080	0.603
Marchena, Bahia Negra	10	6	0.64	3.97	0.087	0.470
Pinta, Cabo Ibetson	10	6	0.64	2.95	0.121	0.696
Pinzon, Dumb Landing	10	6	0.73	3.69	0.093	0.687
Plaza Sur	10	6	0.74	4.59	0.089	0.483
Santa Cruz, Caamaño	12	6	0.77	4.55	0.072	0.667
Santa Cruz, Estacion	10	6	0.78	4.84	0.064	0.667
Santa Cruz, Punta Estrada	10	6	0.78	4.67	0.063	0.536
Santa Fé, North	10	10	0.71	3.59	0.126	0.659
Santa Fé, South	10	10	0.76	4.33	0.093	0.553
Santiago, James Bay	10	6	0.74	4.03	0.069	0.464
San Cristobal, Loberia	10	6	0.63	2.86	0.168	0.761
San Cristobal, Punta Pitt[7]	10	6	0.50	2.19	0.231	0.887
Seymour Norte	10	6	0.73	4.26	0.088	0.384

[1]Sample size per population for microsatellite data.

[2]Sample size per population for mitochondrial DNA sequence analysis.

[3]Average heterozygosity H, i.e. the percentage of animals heterozygous for a particular microsatellite locus, averaged over three analysed loci.

[4]Number of effective alleles averaged over the three loci (Nei 1987).

[5]Average nuclear genetic distance between a specific population and all other populations, calculated from microsatellite fingerprint data as the average of the FST values of all pairwise comparisons (based on the computer program Fstat, Goudet 1994).

[6]Average mitochondrial genetic distance, calculated from the mitochondrial sequence data as the average of the Phi ST values of all pairwise comparisons (based on the computer program AMOVA, Excoffier 1995).

[7]The population from Punta Pitt on San Cristóbal not only has the lowest average heterozygosity and the lowest number of effective alleles, but also shows the highest degree of evolutionary distinctiveness with respect to its nuclear DNA (average FST = 0.231), and its mitochondrial DNA (average Phi ST =0.887).

those which are most diverged or unique, in order to preserve as much genetic diversity within the species as possible (Avise 1989). Genetic tools can, to some extent, help to find answers to such questions.

In the molecular study of marine iguanas, genetic data were obtained using nuclear DNA markers (three microsatellite fingerprint loci) and mitochondrial DNA markers (sequences of a 450 nucleotide fragment of the cytochrome b gene). Genetic distances calculated from the nuclear data revealed amazingly little differentiation among some of the populations. This suggested that gene flow among neighboring marine iguana populations was sufficiently high to maintain genetic variation even in some of the threatened subpopulations, for example, Isla Isabela. However, it has to be kept in mind that genetic models measuring gene flow or migration do this on an evolutionary rather than on an ecological time scale and thus might not be too meaningful for the current population demography (Moritz 1994). In other words, migration between neighboring populations may be high enough to maintain similarities in their genetic structure, yet it could be too low to prevent a decrease in the actual size of a particular population and thus its possible extirpation. The molecular data on the marine iguana populations do show that gene flow occurs - and where. Field studies can now be targeted to reveal the actual amount of contemporary migration among threatened and non-threatened populations (e.g. among the west coast of Isla Isabela and Fernandina), and thus determine more accurately their conservation status.

Especially disconcerting were the findings for the marine iguanas sampled at Punta Pitt on the easternmost tip of San Cristóbal. Only few animals were encountered and, as was the case on Isla Isabela, no hatchlings were seen and signs of predators were obvious. Results revealed that, whereas the Isla Isabela populations were still among the most variable of all population samples within the archipelago, the Punta Pitt animals showed the least degree of nuclear genetic variation (Table 1). Furthermore, the Punta Pitt animals carried a unique mitochondrial sequence type which did not occur elsewhere in the archipelago, although many other island populations shared specific mitochondrial types. The Punta Pitt population clearly deserves our attention. The reduced degree of nuclear DNA variation indicates that it may indeed consist of only few animals and that it receives little immigration from other populations. The unique type of mitochondrial sequence adds to the population's conservation priority, if our concern is to preserve as much genetic diversity as possible. The results of the molecular data therefore call for immediate action. A detailed census of the actual size of the Punta Pitt population is required, including all neighboring colonies (such as the iguanas on the near islet, Islote Pitt). Further genetic studies might then establish the degree of relatedness among the animals from such neighboring colonies and those from Punta Pitt, indicating which populations may serve as natural (or captive) stock populations. Most importantly, however, the management planning in the Punta Pitt area should include the immediate habitat protection and eradication of all feral animals from this region.

To return to the original question about the role of molecular genetics in conservation - can genetic data save endangered species - does it help rescue the marine iguanas? Ultimately, in the absence of ecological and behavioral studies, genetic data can lead to important, yet only preliminary information on a population's size and demography. Furthermore, recommendations based on molecular studies concerning the management of genetic variation and thus the evolutionary potential of a population are, of course, most relevant to the long-term conservation of a threatened species. Such information may therefore come too late for the survival of some populations.

On the other hand, genetic information provides a solid basis for planning ecological management, and can give support to urgent political decisions. As outlined in the marine iguana example, molecular data may lead to a ranking of populations according to their conservation priority, providing a framework which promotes the best use of limited conservation resources. Clearly, for many of Galápagos' endangered species more genetic information and its implementation is urgently needed. For example, detailed data on the evolutionary distinctiveness of many populations is still lacking, but would be crucial for focusing our present efforts in short-term ecological management and for outlining potential long-term genetic management plans. In the long run, such information may help to preserve as much of Galápagos' biological diversity as possible.

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VISITORS AND EVENTS AT THE CHARLES DARWIN RESEARCH STATION, 1995

Compiled by: Heidi Snell and Gayle Davis

January

- Fishermen closed the entrance of CDRS & SPNG for 4 days.
- Gerald Wellington, Univ. Houston, Benjamin Victor & Mark Meekan, assistants arrived to study reef fish.
- The annual flamingo census took place.
- Sabine Tebbich began a study of Woodpecker finches.
- Sandra Guerrero, Catholic Univ. Ibarra volunteered in Environmental Education.
- Sharon Virtue, librarian, Univ. Toronto volunteered for two weeks in the CDRS library.
- Mark Jordan, Univ. New Mexico & Sarah Bouchard Kalamazoo College, MI, arrived to work with Howard & Heidi Snell on the lava lizard study. Monica Calvopiña & Cassie Holman completed the group.
- Peter & Rosemary Grant, Princeton Univ., arrived to continue their studies of Darwin's finches.
- Jorge Gómez-Jurado joined Marine Investigations as a Technical Assistant.
- Milton Arsiniegas, Technical Univ. Esmeraldas arrived as a thesis student in Botany.
- David Hicks, Manchester College, IN spent his sabbatical in Botany working on the status of *Opuntia*.
- Gary McMurtry, Fraser Goff, Univ. Hawaii, & James Sitmac, Los Alamos National Lab., NM; Alfredo Roldan, National Electronics Institution Guatemala, & Rosemary Andrade, Univ. Guayaquil, made a geologic study on Sierra Negra.
- January 24th Fernandina erupted near Cabo Hammond.
- Peruvian troops trespassed into Ecuadorian territory provoking a war & disrupting both countries. Effect in Galápagos was increased patrolling activity.
- CDRS personel presented a Quarantine Workshop held in San Cristóbal.
- Tomato & papaya plants found growing in the fishermen camps on Fernandina were eliminated.

February

- Anna Fitter, Galápagos Conservation Trust of England visited.
- Verónica Toral, Cuenca Univ., volunteered in Marine Biology.
- Sabina Estupiñán, Univ. Luis Vargas Torres, Esmeraldas, volunteered in Botany.
- Olav Oftedal, National Zoo, Wash. DC, & Frank Allen, continued work with the captive reptile program.
- Washington Tapia began thesis work on Isabela tortoises.
- The war between Peru & Ecuador ended.
- Jack Kepper, Canadian Fund & Alfredo Carrasco, CDF Quito, visited the Station.
- Rosemary Andrade volunteered for the Snell/Jordan lava lizard studies before returning to Univ. Guayaquil.
- Bruce Kernan USAID & Alfredo Carrasco checked projects and worked on a Marine Investigation proposal.
- Fernandina continued erupting.

March

- Alegría Mejía & Olga Quevedo, Univ. Guayaquil, arrived to volunteer in Protection & Monitoring.
- Daniel Evans, former Director of CDRS, visited with a group from the Point Reyes Bird Observatory, Calif.
- Roger Tinoco, Inspector National Institution Meteorology & Hydrology gave a course to the personnel of CDRS.
- Verónica Toral represented Ecuador/CDRS at the World Forum for Youth & Development in Israel.
- The National Television of Japan (NHK) made a live telecast from Galápagos from several locations.
- Hugo Valdebenito, Günther Reck & students, Univ. San Francisco Quito, arrived for an ecology course.
- Gustavo Yturralde, Univ. Guayaquil began assisting Mark Jordan with studies of lava lizards.

April

- Chantal Blanton left for the London CDF meetings.
- Helene Collombat, Pierre Rochette, ORSTOM & Pablo Samaniego, Quito, studied paleomagnetism.
- Heye Rumohr, Univ. Kiel, Germany gave a Marine Monitoring course.
- Yoshikazu Shimizu, Univ. Komazawa, Tokyo, and assistant Santiago Buitrón, Univ. San Francisco, studied the impact of introduced plants on *Scalesia* & native plants.
- Hal Whitehead, Linda Weilgart & children arrived in their yacht *Balena*, with assistants Katherine Payne, Jenny Cristal, Sascha Hooker & Shannon Gowans, Dalhousie Univ. Canada to study sperm whale behavior. Graciela Monsalve, CDRS & Flip Nicklin, National Geographic, joined the 1st trip. The 2nd trip Godfrey Merlen captained, Francis Nicolaides, Nat. Fisheries Institute & Jimmy Peñaherrera, CDRS joined the group.
- Karen Rogers, Robin Rutledge, Robert Long, Scott Dummler, Stephen Kennedy & William Tidwell, Monsanto Co., evaluated results of "Round-Up" experiments on introduced plants. They also prepared a film on the use of herbicides for weed control.
- James Gibbs, Yale Univ., studied tortoise genetics.
- David Anderson, Wake Forest Univ. joined his Española field camp for studies of albatross & boobies.

May

- Edison Encalada volunteered in Protection.
- Nelson Zabala, Carlos Valle & students, Univ. San Francisco Quito, arrived for an ecology course.
- Scott Shouse, US Peace Corp, arrived for the Agroforestry Program on Isabela.
- Peter Glynn, Susan Theodosiou, Univ. Miami, Joshua Feingold, Univ. Nova, & Rafael Menoscal, Polytechnical School, studied El Niño effects on Galápagos corals.
- Cleveland Hickman, William Ober, Larry Hurd & 14 students, Univ. Wash. & Lee, censused littoral zone invertebrates & made a study of a sea cucumber systematics.
- The CDRS research vessel *Beagle* had repairs completed & made the first voyage of the year.
- Peter Hodum, Univ. of Dalhousie, joined Hal Whitehead.
- Carlos Beltrán volunteered in the Computer Center.
- Duncan Porter worked in the CDRS Herbarium.
- Craig MacFarland, President of CDF, visited CDRS.
- Heidi (Captain) & Howard Snell, Marco Altamirano & Eric Craig, Univ. New Mexico, arrived at Española aboard *Prima* after a 3-day sail from Salinas, Ecuador.
- Chantal Blanton attended meetings in Quito.
- Pádraig Whelan joined CDRS personel for Quarantine meetings on several islands.
- Napoleón Vargas, arrived to be the CDRS Manager.

June

- Adelaida Herrera ex-volunteer CDRS & Ron Sjostedt ex-Peace Corp, were married.
- Jennifer Grace, Univ. New Mexico arrived as a field assistant for the Snell's.
- Conley McMullen, W. Liberty College, WV photographed plants for a plant guidebook.
- Terry Naumann, Univ. Idaho & assistant Rommel Villagómez, Polytechnic School conducted a geologic study on Isabela.
- Napoleón Vargas became the CDRS Subdirector.
- Robert Miller, Univ. New Mexico joined the Snell's.

July

- Don Miles, Ohio State Univ., joined the Snell's to study speed & endurance of lava lizards.
- Dennis Geist, Jeff Standish & Robert Reynold, Univ. Idaho joined Terry Naumann for geological studies.
- Goats were found on top of Volcan Wolf, northern Isabela by Geist's geologic team.
- Gillian Key, Metropolitan Univ. Manchester, UK, discussed future plans for rodent studies.
- Kornelia Rassmann, Univ. N. Wales, UK, arrived to continue the genetic study of land & marine iguanas.
- Robert Dowler, Darin Carroll, Angelo State Univ., TX & assistant Diana Vinueza, Univ. Guayaquil, arrived to study endemic rats on Fernandina.
- María Soledad Luna, Univ. San Francisco, Quito, volunteered in Public Relations.
- Syuzo Itow, Univ. Nagasaki, & Ondina Landazuri, Central Univ. Quito, studied endemic & introduced plants.
- Fernando Ortiz, Fundacyt, gave information for scholarship students.
- Carla Abrams, US volunteer student began studies on Matazarno trees in the National Park.
- Alfredo Carrasco & Canadian Fund representatives visited.

August

- Ed Louis, Texas A&M & Joe Flannagan, Houston Zoo, arrived for the tortoise genetics study.
- Lázaro Roque volunteered as Museum Curator.
- Hernán Vargas became the CDRS Ornithologist.
- Monica Soria & Paola Buitrón volunteered at CDRS.
- Pool Segarra, Catholic Univ. Quito arrived as a volunteer for Monitoring.
- Chantal Blanton traveled to Quito for several days of CDF related meetings.
- Linda Cayot attended the wedding of her niece, Maryn McFarland to her student, Milton Yacelga.

September

- Goats were seen on Pinta, SPNG began eradication.
- CDRS access was blockaded & the SPNG offices on all islands were invaded for two weeks.
- Representatives of the American Consul in Guayaquil & Embassy, Quito arrived to assess the local situation.
- Long-time CDRS employee, Arnaldo Tupiza Chamaidan, died in an accident on Isabela.
- The new Tortoise Center on Isabela was officially named in honor of Arnaldo Tupiza Chamaidan.
- Martin Wikilski, Univ. Washington & Corina Thom, Jesko Partecke, Germany & Lorena Zambrano & Cristóbal Alarcon, Univ. Guayaquil arrived to continue the studies of marine iguanas on Santa Fe.
- US Ambassador to Ecuador, Peter Romero and group met briefly in Puerto Ayora & Villamil then circled Isabela with Priscilla Martinez, CDRS on the military launch *25 de Julio*.
- Maryn McFarland returns to CDRS as a volunteer.
- Jacinto Gordillo received the 1995 Ecuadorian Planeta Azul award.

October

- Friedeman Köster filmed on Plazas.
- The World Festival of Birds was celebrated in the islands promoted by the CDRS.
- María Soledad Luna became a volunteer for Public Relations.
- CDF meetings were held in Guayaquil.
- David Anderson, Ana Agreda, Tatiana Santander, Luis Vinueza, Leslie Clifford, and Kate Huyvaert began their studies on boobies, albatross and *Opuntia* on Española.
- David Steadman, Univ. Florida and Winter Vera CDRS, collected subfossial material from Floreana.
- A group from the Harbour Branch Institute arrived for marine prospecting and studies of deep water fish.

November

- Craig MacFarland, President CDF and Alfredo Carrasco, CDF Quito visited CDRS.
- Cynthia Palmer, US. Dept. of Energy, assessed the island's solid waste problems.
- María Elena Guerra began as Administrative Assistant.
- A group funded by USAID arrived for a consultancy on a potential Galápagos shipyard.
- Miguel Casares and Beatrix Scharman, Zurich Zoo began work on the reproductive cycle of tortoises.
- Evelyn Schulle, a Swiss volunteer began helping in Public Relations.
- Sacha Jalink arrived to volunteer for a month in Public Relations.

December

- Sabine Tebbich and Birgit Fessl, Austria began a Carpenter finch study on Santa Cruz.
- Diane Davies, Sara Thompson and Maria Clara Espinosa, Univ. Calif. Santa Cruz arrived with information panels.
- Peter and Rosemary Grant continued their studies on Darwin's finches.

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