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

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

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

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

Heidi M. Snell and Chantal Blanton

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

By: Robert C. Dowler and Darin S. Carroll

INTRODUCTION

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

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

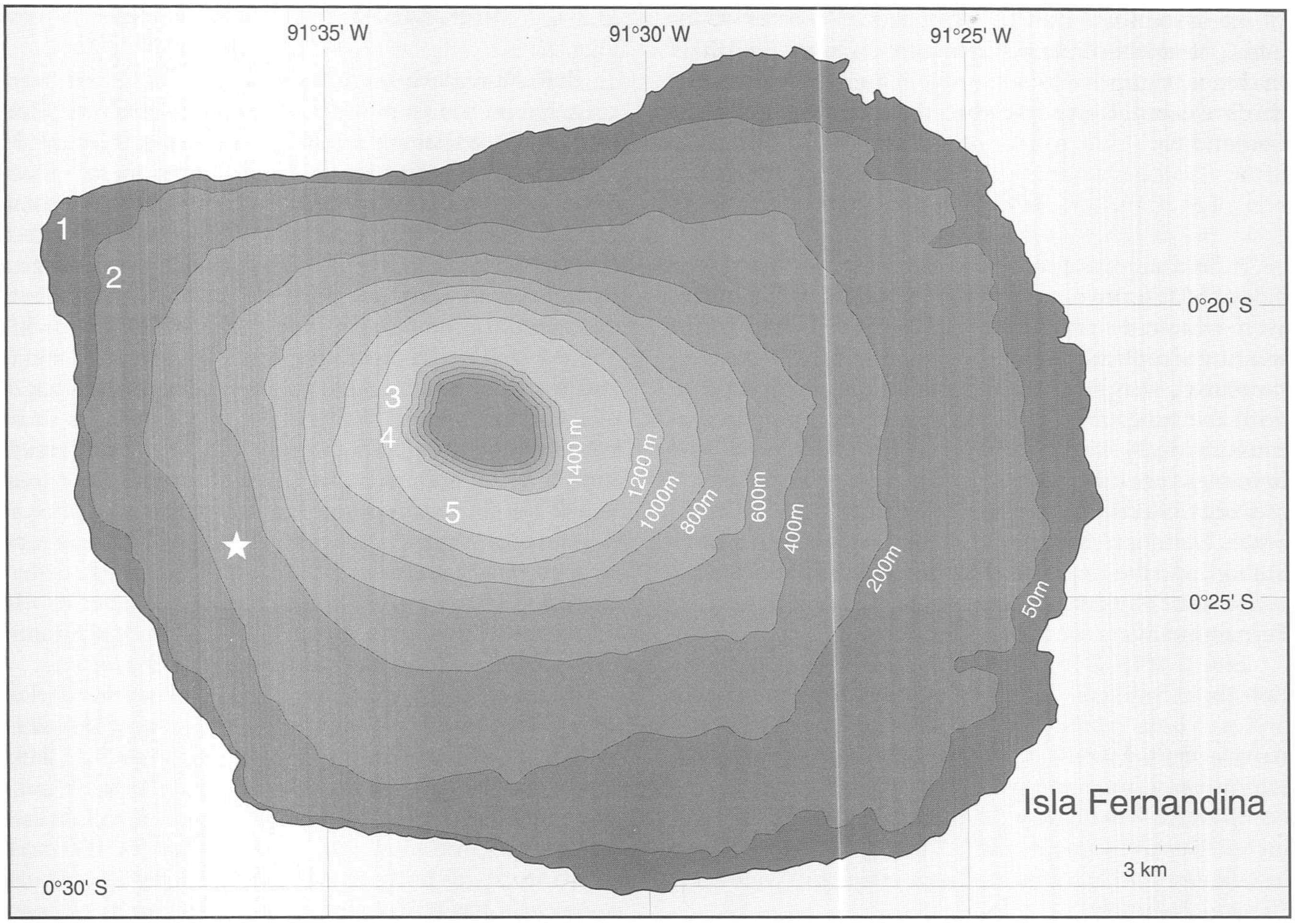

Figure 1. Map of Isla Fernandina. Numbers 1-5 designate the five collecting sites for *Nesoryzomys fernandinae* and *N. narboroughi*. The star represents the location where owl pellets containing the first reported skulls of *N. fernandinae* were collected (Hutterer and Hirsch, 1979).

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

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

This paper reports the results of field work conducted on Isla Fernandina during August, 1995. The objectives of our research were to: 1) determine if an extant population of the Fernandina mouse (*Nesoryzomys fernandinae*) exists; 2) to establish the status of the Galápagos rice rat (*N. narboroughi*); and 3) to determine if there is evidence for the invasion of any introduced species of rodents to Fernandina.

METHODS

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

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

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

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

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

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

RESULTS AND CONCLUSIONS

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

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

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

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

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

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

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

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

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

DISCUSSION

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

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

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

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

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

ACKNOWLEDGMENTS

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

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VOLCANIC HAZARDS AT SIERRA NEGRA

By: Robert W. Reynolds

INTRODUCTION

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

GEOLOGIC FEATURES OF VOLCÁN SIERRA NEGRA

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