THE SYSTEMATICS, BIOLOGY, AND CONSERVATION OF *SOLENODON*

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE
UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1991

To Nicole

To Alejandro

To Ana Daniela

ACKNOWLEDGEMENTS

With justice, this could be another chapter. I thank my professors, Dr. John F. Eisenberg, Chairman, Dr. Charles A. Woods, Dr. F. Wayne King, Dr. Robert W. Woodruff, Dr. Mel Sunquist, and Dr. Brian McNab, for their guidance, support and advice. For their assistance, I am thankful to the people of the Parque Zoologico Nacional of Santo Domingo, the Florida Museum of Natural History, the Department of Wildlife and Range Sciences, the Instituto de Ecología y Sistemática, Academia de Ciencias de Cuba, and the Museo Nacional de Historia Natural de Cuba. I thank the curators and staff of all of the natural history museums and zoological parks of North America, Europe and Caribbean that make specimens and information available to us.

For their friendship and support, I thank Kent Vliet, Kevin Jordan, Laurie Wilkins, Gary Morgan, Dick Franz, and Julian Duval. I also thank Alfonso Ferreira, Angelica Espinal, and Roberto María in Santo Domingo, and Rosendo Martinez, Oscar Arredondo, Jose Fernandez Milera and Jorge de la Cruz in La Habana. I am grateful to Missy Woods, Perran Ross, and John Eisenberg for their hospitality in Gainesville. I thank Kent Vliet for his invaluable help with the graphics figures, and Lisa Chandler for the

anatomical illustrations. For their wisdom and teachings, I thank the campesinos of the Dominican Republic.

My studies and conservation work in the Caribbean was possible with grants from Wildlife Conservation International, division of New York Zoological Society, the Nixon Griffis Foundation, and Brehm Funds for International Bird Conservation. During my stay in Gainesville, I was supported with grants to Dr. John F. Eisenberg, Dr. Charles A. Woods, and the Program for Studies in Tropical Conservation.

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the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

SYSTEMATICS, BIOLOGY AND CONSERVATION OF SOLENODON

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December 1991

Chairman: Dr. John F. Eisenberg
Major Department: Forest Resources and Conservation

An investigation of the geographic variation of Solenodon indicate that this Greater Antillean insectivore genus is represented by four species, two living, S. cubanus, S. paradoxus, and two extinct, S. marcanoi and a yet unnamed giant member from Cuba. The large fossil species from Cuba and a new geographic population of S. paradoxus from Hispaniola are described. The diagnosis of S. marcanoi is revised and some specimens of the original type series are re-assigned to S. paradoxus. S. marcanoi shares characters of both, S. paradoxus and S. cubanus, and is considered an intermediate lineage.

Surveys indicate that S. paradoxus is dispersed widely in the Dominican Republic. The discovery of new populations of the species in that country is presented. Extant populations are fragmented in distribution and low in numbers. In Haiti, the species appear to survive only in the southern Peninsula de Tiburon, yet it might exist in the Massif du Nord.

Observations on the biology of S. paradoxus were recorded in the wild and in captivity. Males and females show reduced secondary sexual dimorphism in external morphology, and in cranial and post-cranial skeleton, though females are on average slightly larger and heavier. The permanent dentition emerges completely by 4-5 months of age. Males and females attain adult size before eight months and might reach sexual maturity soon after one year of age. Age at first reproduction is probably around 18 months. Gestation lasts for about three months, and litter size is one.

Body temperature is low, ranging from an average 33°C during daytime to a peak of 36°C during nocturnal foraging. Limitations in thermoregulatory ability might be compensated by the microclimatic stability of the burrow. Diel activity patterns show a sleeping-resting phase throughout the day, which ends with a sudden start of activity at or after 1800 h. Nocturnal activity is characterized by successive foraging trips at variable intervals, with peaks between 2000-2400 h. Crepuscular activity is less frequent.

The residual populations of S. cubanus in eastern Cuba appear to be critical. Systematic efforts and direct conservation action would be required to ensure their survival.

CHAPTER I

INTRODUCTION

The West Indian insectivores, _Solenodon_ and _Nesophontes_, are endemic to the Greater Antilles and the most ancient members of the West Indian mammalian fauna. The genus _Solenodon_ is restricted to the islands of Cuba and Hispaniola and contains the only surviving members of the Insectivora in the region. The closely related _Nesophontes_ comprises eight extinct species known from the Holocene and Late Pleistocene of Cuba, Hispaniola, the Cayman Islands and Puerto Rico (Fig. I-1). The Puerto Rican species, _N. edithae_, which is intermediate in size between the larger _Solenodon_ and the much smaller remaining species of _Nesophontes_, has been recently discovered in a kitchen midden in Vieques Island (Morgan and Woods 1986, E. Wing pers. comm.).

Though they have fared better than other groups such as edentates and primates, insectivores have also suffered the high extinction rates recorded among other West Indian mammals (Morgan and Woods 1986, Woods 1989, 1990). Two of twelve species of insectivores have survived until today. Pleistocene climatic events, human exploitation and predation pressure from exotics have been indicated as major causes of extinction of the Antillean vertebrate fauna. Increasing support for the latter two factors have been presented (Steadman et al. 1984, Woods et al. 1986, Woods 1989). Most West Indian mammals were still extant at the time Amerindians arrived on the islands (Morgan and Woods 1986). In fact, all three species of Hispaniolan Nesophontes might have survived to the beginning of this century (Miller 1929). Both Nesophontes and Solenodon have been found in archaeological sites throughout their historical range. Their presence in archaeological deposits is, however, virtually insignificant compared to the abundance of other groups, and they do not seem to have represented an important source of human food. Evidence from cave deposits and owl pellet accumulations indicate that Nesophontes were clearly very abundant, but no Solenodon. Therefore, Nesophontes were undoubfully neglected as food by the Amerindians because of their small body size. Although Solenodon species were much larger, they do not seem to be more common in archaeological sites, and they are infrequent in cave deposits. Predation from exotics appears to be the single most important cause of their extirpation. Today, Cuban and Hispaniolan Solenodon are among the few native West Indian land mammals that still survive. They are considered among the most endangered mammals, and probably are the most threatened of all insectivores (Thornback 1983; Thornback and Jenkins 1982).

Evolutionary Relationships of West Indian Insectivores

The early evolutionary history of the group, was comprehensively summarized by McDowell (1958). The relationships of Solenodon and Nesophontes, among themselves and within the Insectivora, are not yet well understood. In part, this is a reflection of the continuing problems of insectivoran classification. The Order Insectivora has been an assemblage classically regarded as stem eutherians. In fact, this group was long considered to include tree shrews (Tupaiidae), elephant shrews (Macroscelididae), many early Tertiary mammals (Gregory 1910), and to be related to primates (Szalay 1975, Novacek 1982). These conclusions were mainly due to a shared primitive resemblance, for which the Insectivora was regarded as a "taxonomic wastebasket" by McKenna (1975) and "Eutheria incertae sedis" by Novacek (1990). Following the exclusion of the Menotyphla (Butler 1972, McKenna 1975, Novacek et al. 1983), the Insectivora was restricted to the Lipotyphla or Recent insectivores.

The separation of lipotyphlans (Insectivora sensu stricto) from tupaiid insectivores (Scandentia) has been supported by molecular evidence (Miyamoto and Goodman 1986). Thus, the Lipotyphla is a monophyletic clade comprising two sister groups, the Erinaceomorpha (Erinaceidae) and the Soricomorpha (Saban 1954, Butler 1956, 1972; McKenna 1975). They share, among other non-primitive features, the loss of caecum of the gut, reduction or loss of the jugal bone, expansion of the maxillary bone in the orbital wall, loss of the medial branch of the carotid artery, reduction of the pubic symphysis, retention of a mobile snout or proboscis, and reduced eyes.

Butler (1956) and McDowell (1958) included Solenodon and Nesophontes in the Soricomorpha, together with the living shrews (Soricidae), moles (Talpidae), tenrecs (Tenrecidae), and chrysochlorids (Chrysochloridae), as well as several fossil taxa, such as apternodontids (Apternodontidae) and geolabidids (Geolabididae). As such, Nesophontes and Solenodon are often considered to represent a monophyletic group derived from Eocene or Oligocene North American soricomorphs belonging to either the Apternodontidae or the Geolabididae (Matthew 1910, 1918; Schlaikjer 1934; Van Valen 1967; Butler 1972; McKenna 1975; McFadden 1980; Lillegraven et al. 1981). They may have reached the Greater Antilles in the Early Tertiary, either through vicariance by way of a proto-Antillean archipelago (McFadden 1980) or by dispersal from nuclear Central America. Van Valen (1967) considered the apternodontids as possibly ancestral to all of the extant zalambdodont lipotyphlans: solenodons, tenrecids and chrysochlorids. However, whether the zalambdodont condition of the dentition (triangular upper molar teeth with V-shaped cusps and prominent outer styles) in these groups is homologous or convergent is a problem that yet remains unsolved.

McDowell (1958) rejected any special relationships between Antillean insectivores and apternodontids, and on the basis of cranial similarities, suggested closer affinity between Solenodon and Nesophontes within the Soricidae than to any other soricomorph insectivore. He concluded this, in spite of the fact that Nesophontes has a fully dilambdodont dentition (upper molar teeth with W-shaped cusps). However, Van Valen (1966) have suggested the possibility that Nesophontes may be secondarily dilambdodont. In the opinion of McKenna (1975), McDowell's conclusions reflected a small sample and poor preservation of the material then available. Although unable to separate ancestral from derived characters, McDowell's work represents to date the most serious attempt to clarify the affinities of the West Indian insectivores.

More recently, Butler (1988) suggested the possibility that Centetodon (Geolabididae), Solenodon, and Nesophontes had a common ancestor, and that Solenodon is probably not especially related to either Apternodus or to the Soricidae. Solenodon may be the only survivor of a North American branch that includes Centetodon, Nesophontes, and possibly Apternodus.

In short, one, Solenodontidae (McDowell 1958, Findley 1967, Yates 1984), or two families, Solenodontidae and Nesophontidae (Hall 1981, Honacki et al. 1982), have been recognized. I follow the latter arrangement in this discussion, and treat West Indian insectivores in two distinct families.

Evolution of the Solenodontidae

The genus Solenodon was described in 1833 by Brandt from a single Hispaniolan specimen with an incomplete skull. Although the existence of a solenodontid in Cuba was discovered in 1836 (Poey 1851), the animal was considered conspecific with the type from Hispaniola, S. paradoxus (Poey 1851), until it was finally named (Peters 1861) and critically described as a distinct species, S. cubanus, 27 years later (Peters 1863). Whereas Peter's separation of the two species in the same genus was generally adopted (Gundlach 1866-67, 1872, 1877, 1895; Dobson 1884, True [1884] 1885; Flower and Lydekker 1891; Elliot 1905; Leche 1907, Beddard 1909; Gregory 1910, Allen 1908, Allen 1911, Miller 1924, Webber 1928), Dobson (1882) considered both species to represent geographic forms of one species. Disagreement concerning their generic status arose thereafter. Allen (1908) pointed out that certain characters were different enough to justify subgeneric condition, whereas Cabrera (1925) created the genus Atopogale for the Cuban species.

With few exceptions (Miller and Kellogg 1955, Hall and Kelson 1959, Findley 1967), most authors disregarded Cabrera's criteria, recognizing but a single genus for the two species, and either relegating Atopogale to subgenus (Aguayo 1950, Arredondo 1955, Moreno 1966, Cave 1968, Varona 1974, Hall 1981, Novak and Paradiso 1983) or simply considering it a synonym of Solenodon (Winge 1941, Allen 1942, Simpson 1945, Westermann 1953, Simpson 1956, Vrydagh 1954, Eisenberg and Gould 1966, Eisenberg 1975, Walker 1975, Kowalski 1976, Paula Couto 1979, Lawlor 1979, Corbet and Hill 1980, Honacki et al. 1982, Yates 1984). The validity of Atopogale was discussed by Podushcka and Podushcka (1983). Essentially, their conclusions agree with the placement of the Cuban form under Solenodon as used by most authors since the description of cubanus last century. In their evaluation of Cabrera's characters, these authors also expressed serious doubts concerning the consistency of most characters accepted until now to distinguish Cuban from Hispaniolan solenodons.

A second form of Solenodon from the northeastern mountainous region of Cuba, S. poeyanus (Barbour 1944), was described exclusively on the basis of external characters (coloration and claw length) of a single specimen. Aguayo (1950) suggested that at best this proposed form be considered as a subspecies. B. Patterson (in Arredondo 1970) expressed doubts of the validity of poeyanus, whereas Varona (1974) has stated that this proposed form cannot be separated from cubanus even at subspecific level. However, Hall (1981) has retained poeyanus as a distinct geographic population following Aguayo.

A new genus and species of a somewhat smaller solenodontid, *Antillogale marcanoi*, was described from Late Pleistocene to Recent fossil deposits of the Dominican Republic (Patterson 1962). But the generic validity of *Antillogale* was questioned by Van Valen (1967) and relegated to subgenus by Varona (1974), who placed *marcanoi* under *Solenodon*. The existence of another extinct species of *Solenodon* was reported by Arredondo (1970), based on a femur from a Late Pleistocene fossil site in Cuba. This femur was illustrated and described in detail by Morgan *et al*. (1980). Although still unnamed, this new Cuban solenodontid is certainly much larger than any of the species described for the genus, living or extinct.

Despite the disagreement on the taxonomic status of the different nominate forms and genera in the literature, the group has not been the subject of systematic revision. In part, taxonomic studies might have been prevented in the past due to the paucity of *Solenodon* material in collections. Furthermore, the majority of the specimens available until now were collected in the beginning of the century and lack adequate collecting data.

During this investigation, new Hispaniolan material was obtained from the Dominican Republic, including the fresh remains of several specimens of very small body size. These specimens are smaller than the known extant Hispaniolan species, *S. paradoxus*, and in fact, resemble in size the animal described by Patterson (1962) as *Antillogale* marcanoi. This has led some authors (Woods and Eisenberg 1989) to suggest that A. marcanoi, so far assumed to be extinct, appears to be alive. During the past 15 years, a number of Hispaniolan specimens have also been secured from the Massif de la Hotte, in the southwestern end of Haiti (Woods 1986). Both fossil and Recent Solenodon specimens are represented in this material, including four skulls of S. marcanoi, until now known only from partial mandibles and limb bones. Unknown material of the giant animal from Cuba, including a partial skull and complete femur, have also been recently collected, which would allow its comparison with the other known members of the genus.

Biology of Solenodon

Because of its conservative traits, Solenodon has been an attractive study subject for descriptive, functional, and comparative anatomy. A fairly extensive amount of literature dealing with their morphology is available: skeleton and dentition (Brandt 1833, Peters 1863, Mivart 1878, Leche 1907, Gregory 1910, McDowell 1958); general anatomy (Dobson 1882, Allen 1908, Allen 1910); functional occlusion of teeth (Mills 1966); deltoid musculature (Shrivastava 1963); hyoid arch (Cave 1968); bulla and auditory region (Segall 1970, MacPhee 1981); palatine rugae (Eisentraut 1976); morphology of nasal region (Menzel 1979). There is little known about the physiology of Solenodon.

The toxicity of the salivary glands was investigated by Rabb (1959).

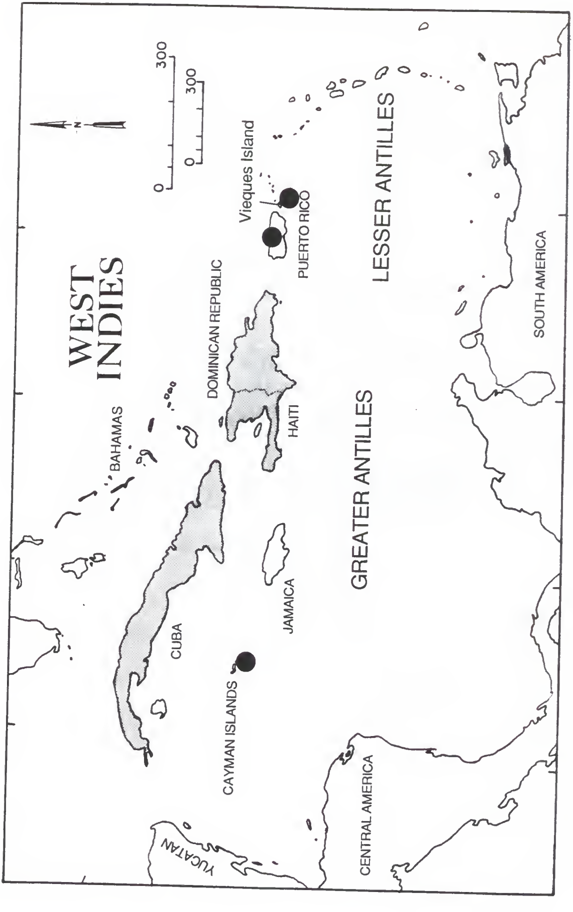
However, information about their natural history is less available, because observations in the wild have been precluded by the rarity of the animals. Opportunities for the study of *Solenodon* traditionally have been offered by captive specimens, but limited access to live animals has even restricted their study in captivity. Nevertheless, the behavior of *S. paradoxus* has been extensively described by Eisenberg and Gould (1966). Additional behavioral observations are given by Eisenberg and Leyhausen (1972), Eisenberg (1975, 1981), Mohr (1936-38), Poduschka (1977), and Poduschka and Wemmer (1986). Reproduction and ontogeny in *S. paradoxus* have been discussed by Eisenberg (1975) and Mohr (1936-38). Wislocki (1940) described the placentation of *S. paradoxus*, and R. Aulisio (*in* Eisenberg 1975) determined oestrous duration and interval. Peña (1977) discussed some aspects of its natural history, and Ottenwalder (1985) described the distribution and habitat selection of *S. paradoxus* in the Dominican Republic.

The biology of *S. cubanus* is poorly known. Recent contributions of Varona (1983), Eisenberg and Gonzalez (1985), and Abreu *et al*. (1990), represent the best syntheses of available information on the natural history and ecology of the Cuban species.

No previous attempt has been made to study the systematics of living and extinct *Solenodon*. Furthermore, their natural history is insufficiently known. Accordingly, the objectives of the present study are a) to investigate the amount of geographic and non-geographic variation among and between *Solenodon* populations from Cuba, Dominican Republic and Haiti; b) to establish the Late Pleistocene-Holocene and Recent distribution of the different species of *Solenodon*; and c) to document aspects of the ecology and conservation biology of the extant species.

FIG. I-1

Map of the West Indies showing distribution of Greater Antillean insectivores. Shaded areas-*Solenodon* and *Nesophontes*; closed circles-*Nesophontes*.


WEST INDIES
N
0 300
0 300
BAHAMAS
CUBA
CAYMAN ISLANDS
JAMAICA
HAITI
DOMINICAN REPUBLIC
PUERTO RICO
Vieques Island
GREATER ANTILLES
LESSER ANTILLES
YUCATAN
CENTRAL AMERICA
SOUTH AMERICA

CHAPTER II

SYSTEMATICS OF THE GENUS SOLENODON

Materials and Methods

A total of 247 Recent specimens was examined. Specimens were conventional museum specimens preserved as skins, skulls, skeletons, fluid and/or taxidermy mounted specimens. These specimens are housed in the following collections of Recent mammals: American Museum of Natural History, New York (AMNH); Carnegie Museum of Natural History, Pittsburgh (CM); Field Museum of Natural History, Chicago (FMNH); Florida Museum of Natural History, University of Florida, Gainesville (UF); Instituto de Ecología y Sistemática, Academia de Ciencias de Cuba, La Habana (IES/ACC); Institut Royal des Sciences Naturelles de Belgique, Brussels (IRSB); Jose A. Ottenwalder, private field collections, Santo Domingo, (JAO); National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM); Museo Nacional de Historia Natural, La Habana, (MNHNC); Museum of Comparative Zoology, Harvard University, Cambridge (MCZ); Peabody Museum, Osteological Collection, Yale University (YPM); Puget Sound Museum of Natural History, University of Puget Sound, Tacoma (PSM); Rijksmuseum van Natuurlijke Historie, Leiden (RMNH);

Zoologisches Institut und Zoologisches Museum, Universität Hamburg (ZMUH). In the text, specimens will be referred to by their collection acronyms.

All specimens were assigned to three age classes; Age I, juvenile; Age II, subadult; and Age III, adult. Age was established on tooth wear and the following criteria. Juvenile-last cheektooth is not fully erupted; temporal ridges not joined to form a sagittal crest; lambdoidal crest is not well defined; basioccipital and basisphenoid are not fused. Subadult-all cheekteeth are fully erupted; temporal ridges are joined to form a weakly developed sagittal crest; lambdoidal crest is not well developed; basioccipital and basisphenoid are not completely fused; maxilla and pre-maxilla are not completely fused. Adult-all cheekteeth are fully erupted; sagittal and lambdoidal crests are well defined; basioccipital and basisphenoid are completely fused; maxilla and pre-maxilla are completely fused; traces of labial reentrant angles are usually gone. Older adults often have a more massive cranium, with more pronounced sagittal and lambdoidal crests, interorbital region, and occipital region.

Five external measurements (total length, TL; head-body length, HBL; tail length, TL; ear length, EA; and hindfoot length, HF) were taken directly from live animals (Dominican Republic only) and museum specimens preserved in fluid. External measurements were also obtained from labels of specimens preserved as standard museum skins, and, in the case of missing types or otherwise unavailable critical specimens, from the literature. Fifty-eight (58) cranial, dental, and post-cranial measurements divided into lengths (L), breadths or widths (B) and heights or depths (H) were taken. All internal measurements were taken with dial calipers to the nearest 0.05 mm. Needle point dial calipers were utilized in dental measurements. There is disagreement concerning the missing premolar of Solenodon; whether it is the P3/3 or the P4/4. The criteria of McDowell (1958), who tentatively regarded the missing premolar as the P3/3, is followed here. All measurements are given in millimeters. Definitions of internal measurements and their abbreviations are given below.

GLS - Greatest length of skull.-greatest distance between the posteriormost part of the skull above the foramen magnum (supraoccipital processes) and the anteriormost part of the premaxilla.

CBL - Condylobasal length.-greatest distance from the posteriormost part of the exoccipital condyles to the anteriormost part of the premaxillary.

PL - Palatilar length.-greatest distance from the anteriormost point on the border of the palate to a line connecting the posteriormost margins of the alveoli of the upper incisors.

PPL - Postpalatal length.-greatest distance from the anteriormost margin of the foramen magnum to the posterior border of the palate.

AMTR - Alveolar length of upper molar toothrow.-least distance from posterior point of alveolar margin of last molar to anterior point of alveolar margin of first molar.

MMTR - Length of upper molar toothrow.-least distance measured at the crowns.

LMTR - Length of maxillary toothrow.-least distance between the anteriormost and posteriormost margins of the alveoli of the maxillary teeth (C^1-M^3).

MTRW - Breadth across maxillary toothrow.-least width of palate (from M^1M^2 to M^1M^2) taken at the labial margins of each toothrow.

AC - Anteorbital constriction.-least distance between lower anteriormost part of the fossae, taken over the opening of the canale infraorbitale.

ZB - Zygomatic breadth.-greatest width across zygomatic arches, measured at right angles to the longitudinal angles of cranium.

IC - Interorbital constriction.-least width across postorbital constriction, measured between the orbits at right angles to the long axis of the cranium.

SB - Squamosal breadth.-least width across the lateral margins of the squamosal bones, measured at right angles to the long axis of the cranium.

MB - Mastoid breadth.-greatest width across the mastoid processes, measured at right angles to the long axis of the cranium.

BB - Breadth of the braincase.-greatest width across braincase, measured at right angles to the long axis of the cranium.

CB - Condylar breadth.-greatest width across external margin of occipital condyle.

SH - Skull height.-perpendicular distance from a plane going through the most inferior part of the post-glenoid processes, to the highest point on cranium.

LC^1 - Maximum length of C^1.

WC^1 - Maximum width of C^1.

LP^1 - Maximum length of P^1.

WP^1 - Maximum width of P^1.

LP^2 - Maximum length of P^2.

WP^2 - Maximum width of P^2.

LP^4 - Maximum length of P^4.

WP^4 - Maximum width of P^4.

LM^1 - Maximum length of M^1.

WM^1 - Maximum width of M^1.

LM^2 - Maximum length of M^2.

WM^2 - Maximum width of M^2.

LM^3 - Maximum length of M^3.

WM^3 - Maximum width of M^3.

GML - Greatest mandible length.-least distance from most posterior part of condyle to anterior (lowest) point of the first incisor at its alveolus (=tip of the dentary).

MTR - Mandibular toothrow.-length from anterior edge of alveolus of canine to posterior edge of alveolus of last molar.

P_4-M_3 - Alveolar length of P_4-M_3.-posterior point of alveolar margin of last molar to anterior point of alveolar margin of last premolar.

DCP - Depth through coronoid process.-least vertical height between tip of coronoid process to highest edge of lunate notch.

ACH - Angular-condylar height.-least distance from lowest point on angular process to highest point on condyle.

LC_1 - Maximum length of C_1.

WC_1 - Maximum width of C_1.

LP_1 - Maximum length of P_1.

WP_1 - Maximum width of P_1.

LP_2 - Maximum length of P_2.

WP_2 - Maximum width of P_2.

LP_4 - Maximum length of P_4.

WP_4 - Maximum width of P_4.

LM_1 - Maximum length of M_1.

WM_1 - Maximum width of M_1.

LM_2 - Maximum length of M_2.

WM_2 - Maximum width of M_2.

LM_3 - Maximum length of M_3.

WM_3 - Maximum width of M_3.

LF - Maximum length of femur.

MWF - Maximum width of femur.-at proximal end.

FMW - Minimum shaft width of femur.

LH - Maximum length of humerus.

MWH - Maximum width of humerus.-at distal end.

HMW - Minimum shaft width of humerus.

LU - Maximum length of ulna.

MWU - Maximum width of ulna.-at olecranon.

UMW - Minimum shaft width of ulna.-at lower section of diaphisis.

Specimens of Recent Solenodon were grouped into seven reference samples throughout the geographic range of the genus (Fig. II-1) as follows:

1) Peninsula de Samana-Promontorio de Cabrera, northeastern Dominican Republic (North Hispaniola).
2) Los Haitises-Sierra de Seibo-Caribbean Coastal Plain, eastern Dominican Republic (North Hispaniola).
3) Cordillera Central-Cibao Occidental Valley, central north-central Dominican Republic (North Hispaniola).
4) Peninsula de Barahona, southwestern Dominican Republic (South Hispaniola)
5) Sierra de Baoruco, southwestern Dominican Republic (South Hispaniola).
6) Massif de la Hotte, southwestern Haiti (South Hispaniola)

7) Eastern Cuba, including both the southern (Sierra
   Maestra) and northern ranges (Sierra de Nipe, Sierra
   del Cristal, Cuchillas de Moa, Toa, and Baracoa).

A total of 110 specimens of the Late Pleistocene, Early Holocene and Amerindian times from Cuba, Dominican Republic and Haiti were examined. These fossil, subfossil and kitchenmidden specimens are housed at the following collections: Carnegie Museum of Natural History, Pittsburgh (CM); Florida Museum of Natural History, University of Florida (UF); Instituto de Ecología y Sistemática, Academia de Ciencias de Cuba, La Habana (IES/ACC); Museo Nacional Historia Natural, La Habana, Cuba (MNHNC); Museum of Comparative Zoology, Harvard University (MCZ); National Museum of Natural History, Smithsonian Institution (USNM); Oscar Arredondo private collection, La Habana, Cuba (OA).

The sites from which these specimens were recovered are discussed and illustrated in Chapter 3 (Distribution).

Statistical analyses were performed using the NCSS Statistical System (Version 5.0), and the Statistical Analysis System (SAS Institute 1985). Descriptive statistics (mean, range, standard deviation, standard error, variance and coefficient of variation) were calculated with the MEANS routine. Univariate analyses of variation with age, individual variation, secondary sexual variation, and geographic variation were performed using a single classification analysis of variance (ANOVA). The specimens from central Hispaniola, the largest sample available, was selected to study the influence of variation of age and sex on the populations. Although small, the sample from Eastern Cuba was also tested for secondary sexual variation, but analysis of variation with age in this population was prevented by insufficient sample size. The General Linear Model (GLM-ANOVA) was used to test for significant differences among or between means for each character. Subsequently, a Duncan's Multiple Range Test was used to determine maximally nonsignificant subsets, if means were found to be significantly different. Because solenodons are very rare in collections and endangered in the wild, samples of Recent specimens available for examination are limited in number. Furthermore, most subfossil specimens had missing measurements. To maximize sample size, characters were analyzed separately in three data sets (cranial, mandibular and limb bones) to assess multivariate relationships. The multivariate technique used was descriminant function analysis. Stepwise descriminant analysis performs a multiple discriminant analysis in a stepwise manner, selecting the variable entered by finding the variable with the greatest F value. The F value for inclusion was set at 0.01, and the F value for deletion was set at 0.05. The program also classifies individuals, placing them with the group to which they are nearest on the discriminant functions.

The weight of five cranial characters was evaluated for diagnostic consistency in separating _S_. _paradoxus_ from _S_. _cubanus_, and for usefulness in assessing specific relationships among and between known _Solenodon_ species. A total of 115 specimens of living and extinct _Solenodon_ representing all three nominated taxa plus the undescribed skull of a suspected distinct species were individually examined. Characters were not polarized but treated as having equal weight. The following characters states were evaluated for analysis:

Character 1. Para-nasal (=Os proboscis) bone support

0 = absent

1 = present

Character 2. Diastema I^3-C^1

0 = absent

1 = present

Character 3. Accessory cusp C^1

0 = absent

1 = present

2 = vestigial

Character 4. -Shape P^2

0 = triangular

1 = simple, oval or conical

2 = intermediate

Character 5. Mesopterygoig fossa

0 = wider posteriorly than anteriorly

1 = wider anteriorly than posteriorly

2 = parallel

Cranial measurements, collecting data, or photographs of 53 additional specimens also were examined. These data were not included in the statistical analysis. These specimens are found in the following mammal collections: Museum of Zoology, University of Michigan (UMMZ); British Museum (Natural History), London (BMNH); Forschungsinstitut und Natur-Museum Senckemberg, Frankfurt (SMF); Max-Planck-Institute Für Hirnforschung, Frankfurt (MPIH); Naturhistorisches Museum Wien, Wien (NMW); Naturhistoriska Riksmusset, Swedish Museum of Natural History, Stockholm (NRM); University Museum of Zoology, University of Cambridge, UK (UMZC); Zoological Museum, Institute of Taxonomic Zoology, University of Amsterdam, Amsterdam (ZMA).

Results

NonGeographic Variation

Three kinds of non-geographic variation were investigated: variation with age, secondary sexual variation, and individual variation.

Variation with age

Age categories used in this study are referred to as Age I, adults; Age II, subadults; and Age III, juveniles. These categories are based on the criteria described above (see Materials and Methods) and on dental wear, and do not reflect reproductive age. The influence of age ws tested using GLM-ANOVA. Because of insufficient sample, the Cuban population was not tested for age variation. In the sample from Hispaniola, adults, subadults, and juveniles form non-overlapping subsets in only 3 out of 41 measurements (zygomatic breadth, maximum width of P_4, minimum shaft width of humerus). Adults and subadults form an overlapping subset that differs significantly from the juvenile subset in 30 measurements. Adults averaged the largest in most measurements, except in sixteen, in which subadults were slightly larger. Nevertheless, only adult specimens were used in subsequent analyses. Variation with age is discussed in more detail in Chapter IV.

Secondary sexual variation

Forty-one cranial and post-cranial measurements of adult males of two samples (eastern Cuba and Central Hispaniola) were tested against those of adult females, utilizing GLM-ANOVA to establish the existence of any significant differences in size between the sexes. The results are shown in Table II-1.

Although females averaged larger than males in most measurements, no significant ($p<0.05$) differences were observed between males and females of S. cubanus in any of the internal and most external measurements tested. Only in hindfoot length were females different from males in the

Cuban sample. In the sample from the Cordillera Central-Cibao Occidental Valley region, in central Dominican Republic, females proved significantly larger than males in only two measurements (breadth across maxillary toothrow and anteorbital constriction). As in the Cuban solenodon sample, females from Hispaniola were also somewhat larger than males in most measurements, but again, variation in size between the sexes was only slightly different. For instance, all measurements of the lower dentition were identical for males and females from Hispaniola. Measurements of the upper teeth were also very close for both sexes, including that of the canines, often an important character in secondary sexual dimorphism in mammals. Males were then tested against females from the Dominican Republic (as one sample), and no significant differences were observed between males and females in any of the measurements. Considering these results, males and females were not treated separately in subsequent analyses.

Individual variation

The majority of the internal measurements examined revealed a relatively low degree of individual variation as expressed by the coefficient of variation (Tables II-1, II-2, II-3). Cranial and mandibular measurements in all populations usually had coefficients of variation of less than 5, whereas dental and limb bone measurements ranged mostly between 2 and 15. All external measurements, except hindfoot length and body weight, had higher coefficients of variation, and therefore were excluded from geographic variation analysis.

Specific Relationships (Geographic Variation)

To establish the specific relationships of the *Solenodon* populations from Cuba, Dominican Republic and Haiti, univariate and multivariate analyses were utilized to compare the geographical samples.

Univariate Analyses

Standard statistics for each geographical sample of living solenodons and the results of Duncan's multiple range test for determination of the maximally non-significant subsets of 41 variables are given in Table II-2. The GLM-ANOVA analysis yielded highly significant differences between the seven geographic samples in all measurements with the exception of one (interorbital constriction). Results of the Duncan's test revealed geographic samples from North Hispaniola (samples 1, 2, 3) grouped alone in one subset, differed significantly from all other samples in the following eight measurements: greatest length of skull, condylobasal length, palatal length, length of maxillary toothrow, length of mandibular toothrow, alveolar length of P_4-M_3, maximum length of P_4, and total length of humerus.

The samples from North Hispaniola also assembled separately, differed significantly from the rest of the samples in two non-overlapping subsets for two measurements (maximum width of M^3 and angular-condylar height) and in two overlapping subsets for one measurement (greatest mandible length). Furthermore, the three samples from North Hispaniola grouped together with the sample from southwestern Haiti (sample 6, South Hispaniola) in a single subset, differing significantly from all other samples in the following eight measurements (length of upper molar toothrow, breadth across maxillary toothrow, maximum width of C^1, maximum width of P_4, maximum length of M_1, maximum width of M_1, maximum width of M_2, maximum width of M_3).

The samples from South Hispaniola (samples 4, 5, 6) grouped together in 11 measurements with the Cuban population (7) differed significantly from North Hispaniolan samples, in one (angular-condylar height, maximum length of P_4, total length of humerus) or in two or more overlapping subsets (greatest length of skull, condylobasal length, palatal length, length of maxillary toothrow, greatest mandible length, length of mandibular toothrow, maximum width of femur, total length of humerus). All three South Hispaniolan samples also clustered in one subset in three measurements (maximum width of M^3, maximum width of P_4, and total length of femur), and in two significantly different subsets in one (alveolar length of P_4M_3). Whereas the Haitian sample showed an intermediate position between the North and Dominican Republic south samples (4, 5) in eight measurements, the latter populations differed significantly from all other samples in length of upper molar toothrow, maximum width of C^1, maximum length of M_1. These two samples also separated from the others with the Cuban population in breadth across maxillary toothrow (in one subset), and in maximum width of M_1, maximum width of M_2, and maximum width of M_3 (in two subsets). The sample from Sierra de Baoruco (5) isolated from all other samples in one subset in P_4-M_3 and maximum length of M_2.

The Cuban sample differed significantly from all other samples in 13 measurements (PPL, AMTR, MMTR, AC, WC^1, WM^3, P_4-M_3, LM_1, LM_2, LM_3, FMW, MWH, HMW). Eastern Cuba clustered, in one overlapping subset, with North Hispaniolan samples in four measurements (skull height, maximum length of C^1, maximum width of P_4, total length of femur), and with South Hispaniolan in 15 measurements (greatest length of skull, condylobasal length, palatal length, length of maxillary toothrow, breadth across maxillary toothrow, greatest mandible length, length of mandibular toothrow, angular-condylar height, maximum length of P_4, maximum width of M_1, maximum width of M_2, maximum width of M_3, total length of humerus, maximum width of femur, total length of humerus).

All samples assembled in two or more overlapping subsets in the following measurements: zygomatic breadth, interorbital constriction, squamosal breadth, mastoid breadth, breadth of braincase, condylar breadth, skull height, depth coronoid process, length of ulna, maximum width of ulna, and minimum shaft width of ulna.

The three samples of Recent Solenodon were tested against and between samples of fossil to sub-Recent material of the genus from cave deposits and archaeological sites of Cuba and Hispaniola. The results of the univariate analysis and Duncan's test are shown in Table II-3. The unnamed Cuban Solenodon is significantly larger than all other population samples in 15 of the 29 measurements available for its own sample. The Haitian sample of S. marcanoi (F) differed significantly from the rest of the samples, including the S. marcanoi sample from Rancho la Guardia (G), in 41 measurements and averaged smaller in 53 of the characters. Although averaging larger than Recent S. cubanus in most measurements, the fossil-sub-Recent sample from Cuba (B) nested in one subset with the Recent sample of Cuba or overlapped with Cuban and Hispaniolan Recent samples in most cranial measurements, differing only in anteorbital constriction. However, it differed significantly in mandibular and lower tooth measurements from the other samples either alone (GML, P_4M_3, LC_1, WC_1, LP_1, WP_1, WP_2), or sharing a subset with the larger North Hispaniola sample (MTR, DCP, ACH, LP_4).

Multivariate Analyses

To maximize sample size, discriminant function analyses were run separately for three data sets, cranial, mandibular and limb bone characters. In Table II-4, characters used for the analysis in each data set are listed from the most useful to the least useful in discriminating groups. A similar arrangement of the geographical relationships of the samples, offered by the univariate analysis, is suggested by the discriminant function analysis. Examination of the distribution of individuals by the classification matrixes reveal three groups: Cuba, North Hispaniola and South Hispaniola (Table II-5). All individuals in the sample from Cuba classified with their proper group in each matrix. In the matrix for cranial characters all individuals from North Hispaniola are classified in their own groups. Of three misclassified individuals from South Hispaniolan samples, two classified with other groups within the South (one from sample 4 is classified with sample 5, and one from sample 6 is classified with sample 4), whereas one individual from sample 5 is misclassified with the northern sample 1.

In mandibular characters, the matrix shows 14 individuals from North Hispaniola misclassified with groups within the north (one from 1 in 3; one from 2 in 1; two from 2 in 3; seven from 3 in 1; and four from 3 in 2), whereas only four are misclassified with the South samples (three from 2 in 6; one from 3 in 5). Six individuals from South Hispaniola are misclassified with groups within the South (three from 4 in 5; two from 5 in 4; one from 6 in 5), and two with samples from the north (one from 4 in 3; one from 5 in 2).

In the long bone matrix, North Hispaniolan samples misclassified 7 individuals within other north groups (one from 1 in 2; one from 2 in 1; one from 2 in 3; three from 3 in 2; one from 3 in one), and three with South samples (one from 2 in 4; one from 2 in 5; and one from 3 in 4). Two South sample individuals are misclassified, one from 4 with sample 2, and one from 5 with sample 4. In an additional analysis, using all cranial and mandibular characters together, all individuals in each sample classified with their own group. Both cranial and overall classification matrices indicated that 100 percent of the Cuban and Hispaniolan populations could be accurately identified using only two characters: length of upper molar toothrow and width of upper canine. To assess the range of variation among geographic populations of extant Solenodon a bivariate plot was prepared using these two characters. The plot shows the Cuban and Hispaniolan populations well separated in two diagonally opposed clusters (Fig. II-2). On the left upper corner, the two Hispaniolan populations are distinguishable but overlap. Because of its reduced and fragmented condition, the fossil and sub-Recent sample could not be analyzed using multivariate techniques. When plotted, using the same two characters, both extinct species are clearly separated from the clusters of the two extant populations (Fig. II-3).

Variation in cranial morphology

In their comparisons of S. cubanus with S. paradoxus, Poduschka and Poduschka (1983) argued strongly against the consistency of the diagnostic characters proposed by previous authors (Peters 1863, Dobson 1882, Allen 1910, Leche 1907) to separate both species, but particulary those used by Cabrera (1925) to create Atopogale. Differences between the two species in cranial characters were attributed by Poduschka and Poduschka either to variation in age or to individual variation. I do agree with most authors in considering Atopogale congeneric with Solenodon, and with Poduschka and Poduschka in considering that Cabrera's set of characters did not have enough generic weight. However, the following analyses show that the characters tested are consistent despite the effect of age and individual variation, and provide a reliable diagnosis when used in combination.

My observations are based on the examination of the skulls of a sample of 91 S. paradoxus and 14 S. cubanus, which is comparable to the sample of 71 and 16 (?), respectively, reportedly examined by Poduschka and Poduschka. Upon examination of the Cuban solenodon material in collections, including most of those studied by Poduschka and Poduschka, I have found that four of the specimens reported by them as S. cubanus, either do not seem to exist or are actually S. paradoxus. Poduschka and Poduschka listed two FMNH skeletal specimens among the S. cubanus material studied. I have examined all four specimens catalogued as *S. cubanus* in the FMNH collection and my conclusion is that only FMNH 134, a mounted skin, represents *S. cubanus*. FNMH 66889 and 72809, alcoholic body and alcoholic head-only respectively, are without doubt *S. paradoxus*. FMNH 66890 is only an axial skeleton, with no skin, no skull, no limb bones, and, therefore, it is uncertain as to which species it might represent. Furthermore, Poduschka and Poduschka listed one skeletal *S. cubanus* specimen each from Cambridge (UMZC), and Paris (MNHN). I have not seen any of these, but have examined both photographs and measurements of the UMZC specimens and believe all three are clearly *S. paradoxus*. To my knowledge (M. Tranier, pers. comm.) all three *Solenodon* in Paris are mounted specimens, without skull, skeleton, or fluid preserved parts. In addition to the above mentioned Recent specimens, I examined fossil material of 4 *S. marcanoi* and 1 *Solenodon* sp.

Characters of the external anatomy (hair, claws) have been debated previously by many authors (Dobson 1882, Allen 1908, Allen 1910) and need no further discussion. Morphometric characters, for which an answer might have been given already in any of the several tables presented here testing the effect of age, sex and individual variation on size, need no further discussion. *S. paradoxus* is, in fact, larger than *S. cubanus* in overall body size, weight, and most cranial and dental measurements, despite individual variability. Five qualitative characters in Cabrera's criteria were investigated:

a) Prenasal or paranasal or "os proboscis" bone present in S. paradoxus, but missing in S. cubanus. All previous authors agree that this bone is absent in every known skull of the Cuban species. The bone was not detected by x-ray examination of the only complete alcoholic-preserved specimen known of S. cubanus (Eisenberg and Gonzales 1985). According to Poduschka and Poduschka, this bone develops only with advancing age, and its absence in the x-rayed animal is not valid evidence because the age of the specimen is unknown. Furthermore, they concluded that all specimens of S. cubanus examined by them may have been young animals. I have examined the same specimens these authors studied, plus most of the specimens in Cuban collections. To my knowledge, and using, as did Poduschka and Poduschka, the maxillary suture as a criteria, only two specimens appear to be subadults; one in the Instituto de Ecología y Sistemática of the Cuban Academy of Science (IES 1.480), the other is, according to Poduschka and Poduschka, the type used by Peters. Their measurements suggest that both specimens have already attained adult size. The alcoholic specimen examined by Eisenberg and Gonzales (USNM 15527) and a presumed S. cubanus in London (BMNH 98.1.20.3, skin and skull) are the only juvenile-subadult specimens. In my opinion the rest of the specimens are adults or at least young adults, and all of them lack the prenasal or os proboscis bone. In contrast, this bone is present in adult, subadult and juvenile specimens of S. paradoxus. All Hispaniola animals either possess the bone or, if it was lost in preparation, its articular socket in front of the premaxilla is evident. In S. cubanus this portion of the premaxilla differs from S. paradoxus in being square-shaped and slightly projected forward, whereas in the Hispaniolan species the anterior part of the premaxilla above the I^1 is invaginated to receive the os proboscis bone. The presence of the prenasal in seven skulls with deciduous dentition and five immature alcoholic specimens of S. paradoxus (4-weeks to 5 months old), suggest that this bone, at least in this species, develops at a very early age.

b) Mesopterygoid fossa wider anteriorly than posteriorly in S. paradoxus, and the inverse in S. cubanus. This character was considered by Poduschka and Poduschka "a trifling quantitative feature". There is indeed slight variability in the shape of the mesopterygoid fossa. However, the condition described for S. cubanus is consistent in 100 percent of the specimens examined. In S. paradoxus, 96 percent of the specimens meet the species criteria, while the remaining skulls exhibit an equal width in the anterior and posterior ends of the fossa, but none approach the condition in S. cubanus. In addition, the pterygoid processes are more expanded posteroventrally in S. cubanus.

c) Presence of a diastema between I^3 and C^1 in S. cubanus, while I^3 is in contact with C^1 in S. paradoxus. Poduschka and Poduschka agreed on this difference, but pointed out that some S. paradoxus have the diastema. My analysis indicates that 77 percent of the S. paradoxus sample lack the diastema, whereas the remaining 33 percent show a slightly variable but, on the average, much reduced diastema. In S. cubanus the I^3-C^1 diastema is constant and much larger. In addition, S. cubanus also exhibits smaller but distinct diastemata between I^2-I^3 and often between C^1-P^1, which are lacking in S. paradoxus. The presence of the diastema in S. paradoxus appears to be more related to geographic region than to individual variation. This is suggested by the fact that this tendency was most noticeable in specimens from South Hispaniola, and from the eastern portion of the Dominican Republic (Los Haitises, Nisibón, Sierra del Seibo-Hato Mayor, Boca de Yuma).

d) C^1 with anterior accessory cusp in S. paradoxus; accessory cusp lacking in C^1 of S. cubanus. All specimens can be accurately identified with this character, perhaps the best diagnostic feature distinguishing Hispaniolan from Cuban solenodons.

e) P^2 simple, oval or conical in S. paradoxus, triangular in S. cubanus. This feature exhibits the higher variability in

S. paradoxus, and I agree with Poduschka and Poduschka in the existence of both conditions in either side of the maxilla of several specimens. Except for one specimen, both left and right P^2's in *S. cubanus* are strongly triangular in shape and much wider than in *S. paradoxus*. Both lower and upper premolars, but the last (P4's), are appreciably wider in *S. cubanus* than in *S. paradoxus*.

In the large fossil skull from Cuba, these characters match the conditions of *S. cubanus* as could be expected from geographic affinity. This is not the case, however, between *S. marcanoi* and *S. paradoxus*. Examination of four *S. marcanoi* skulls indicate that this extinct species shares Cuban and Hispaniolan features. As in *S. paradoxus*, the mesopterygoid fossa is wider anteriorly than posteriorly, the pterygoid plate is projected medially, and the anterior invagination in front of the lower premaxilla resembles the socket where the paranasal bone articulates in *S. paradoxus*. As in *S. cubanus*, a relatively large diastema between I^3-C^1, and smaller diastemata between I^2-I^3 and C^1-P^1 are obvious. In the only two existing specimens of *S. marcanoi* with upper canines, the accessory cusps are lacking in one and are virtually vestigial in the other. Furthermore, the second upper premolar is triangular in shape, though reduced and laterally compressed.

Taxonomic conclusions

I interpret the univariate and multivariate analyses as confirming that the genus Solenodon is represented by two living species, S. cubanus from Cuba, and S. paradoxus from Hispaniola, and two extinct species. The proposed extinct giant form from Cuba, and the nominate S. marcanoi are clearly distinct species. These analyses also reveal the existence of two distinct extant Solenodon populations in Hispaniola, one from North Hispaniola (Peninsula de Samana-Cabrera Promontory, Los Haitises-Sierra del Seibo-Boca de Yuma-Caribbean Coastal Plain and Cordillera Central in the Dominican Republic), and another from South Hispaniola (Peninsula de Barahona and Sierra de Baoruco in the Dominican Republic, and Massif de la Hotte in Haiti). Although these data suggest that the Haitian sample seems to represent an intermediate population between the North and South populations, I believe it is more closely related to the Barahona and Baoruco samples in southwestern Dominican Republic.

This biogeographical trend is suggestive of an Hispaniola paleoisland distribution of Solenodon. The concept of north and south island faunas in Hispaniola, first envisioned by Mertens (1939) and later developed by Williams (1961), has been discussed in detail by Schwartz (1980) in his analysis of the distributional patterns of the Hispanolan herpetofauna, and referred to by many authors since. The present island of Hispaniola is derived from the fusion of two paleoislands along a relatively narrow (ca. 25 km) marine strait that is now the Cul de Sac-Valle de Neiba plain; the former portion of this plain lies in Haiti and the latter in the Dominican Republic (Fig. II-1).

The South island, the smaller of the two (9,550 km^2), is a composite of three major mountain ranges, the Massif de la Hotte, the Massif de la Selle and the Sierra de Baoruco, and of the Península de Barahona, a xeric extension (85 km) to the south of the Baoruco mountains. The larger (67,700 km^2) and more physiographically diverse north island comprises most of Hispaniola. Despite the higher complexity of its relief, _Solenodon_ is unknown on the Haitian portion of the North island. This region is, therefore, irrelevant to the present discussion. The Dominican portion includes the Cordillera Central, the largest mountain range of Hispaniola, and several less extensive ranges. It also contains the largest number of _Solenodon_ populations still surviving on Hispaniola (Ottenwalder 1985).

A third "island mass" (the northern portion of Dominican Republic north of the Cibao Valley to the coast, and extending from Manzanillo Bay in the northwest to Samana Bay in the northeast) is also generally accepted as part of the make up of present day Hispaniola. This additional segment however, does not embody a significant zoogeographical identity, and in this sense, is generally conceived as an intrinsic part of the north-island of Hispaniola. In addition to the Cordillera Septentrional, the third "island segment" of Hispaniola includes the Cabrera Promontory and the Samana Peninsula. My analysis indicates that the *Solenodon* sample from these two latter regions (sample 1) of the Dominican Republic does not differ significantly from the other two North Hispaniolan samples, which therefore appear to support the notion of reduced zoogeographical importance of this third Hispaniolan division.

The three samples of Recent *Solenodon* were also tested against and between samples of fossil to sub-Recent material of the genus from cave deposits and Amerindian sites of Cuba and Hispaniola. This material, mostly single bone specimens of Late Pleistocene age, represent at least 90 percent of the Late Quaternary *Solenodon* known to have been collected until now. It includes: a) the limb bones reported by Arredondo (1970) and Morgan *et al*. (1980) to belong to a new giant *Solenodon* from Cuba, plus new material referrable to this yet unnamed form ; b) material collected in Cuba since 1949, which has been mentioned in the literature either as *S*. cf. *S*. *cubanus* or as a possible new species (Allen 1918, Aguayo 1950; Arredondo 1951, 1955, 1970; Koopman and Ruibal, 1955; Varona and Arredondo 1979) plus additional new material; and c) the material used by Patterson (1962) in the description of *Antillogale marcanoi*, plus previously unknown material from the type locality (Rancho la Guardia), and from southwestern and southeastern Haiti, both attributable to this presumably extinct species.

Comparison of the three geographic samples of Recent Solenodon with four Late Quaternary samples of the genus, using univariate analysis, indicate the existence in Cuba and Hispaniola of two species in each island, one large and one small. Of the four Solenodon taxa, the two species on the extremes of the size range of the genus, the giant Cuban animal and the small Hispaniolan S. marcanoi, are extinct, whereas the two species of intermediate size are extant.

Systematic Accounts

Order Insectivora Bowdich, 1821
Suborder Soricomorpha Saban, 1954
Family Solenodontidae Dobson, 1882
Genus Solenodon Brandt, 1833

Solenodon Brandt, 1833. Mem. Acad. Imp. Sci., St. Petersbourg, ser. 6, Sci. Math. Phys. Nat., 2:459.

Type species. Solenodon paradoxus Brandt

Definition. Diagnosis and general characters as for the family. General form of body that of a large shrew; snout elongate, tip bare, nostrils opening laterally; eyes small; ears small but visible above pelage; pelage coarse; tail long, only sparsely haired, nearly naked; pinna present, well developed; ventral and cranial glands; one pair of inguinal mammae; penis retractable, testes abdominal; skull elongate, rostrum somewhat tubular;

zygomatic arch present but incomplete, with only maxillary and squamosal roots present; auditory bulla absent; lacrimal foramen large, extending above dorsal extremity of occipital condyle; alisphenoid and transverse canals present; lambdoidal and, to a less extend, sagittal crests pronounced; I^1 and I_2 greatly enlarged, I^1 directed slightly backwards, I_2 with a deep lingual groove; upper molars zalambdodont, tritubercular, with high paracone, and low internal paracone and hypocone, metacone absent; milk dentition calcified, functional; pubic bones united in short symphysis. Dentition I 3/3, C 1/1, P 3/3, M 3/3=40.

Solenodon paradoxus Brandt 1833

Distribution. This species occurs only in the Dominican Republic and Haiti (Hispaniola).

Diagnosis. S. paradoxus can be distinguished from the S. cubanus both by size and morphology. S. paradoxus differs from the S. "new species A" and from S. cubanus in the presence of a small, rounded bony structure (os proboscis) placed horizontally in front of the premaxilla for the support of the proboscis; skull almost cylindrical in shape; mesopterygoid fossa wider anteriorly than posteriorly; lack of diastema between I^3 and C^1 and between C^1 and P^1; presence of accessory cusp in C^1. P^2 simple with oval, conical, or infrequently, triangular base; first two upper and lower premolars more laterally compressed. As for S. cubanus, it differs from S. marcanoi in the absence of distinct diastema between I^3 and C^1 and between C^1 and P^1; presence of accessory cusps on C^1, P^1 and P^2; P^2 primarily simple, oval or conical.

Comparisons. In overall size, S. paradoxus is larger than S. cubanus and S. marcanoi, and only smaller than Solenodon "new species A" (Fig. II-4). S. paradoxus is larger than S. cubanus in most cranial (GLS, CBL, PL, PPL, AMTR, MMTR, LMTR, MTRW, ZB, MB, CB, WM^3), mandibular (GML, MTR, P_4M_3, DCP, ACH, LP_4, LM_1, WM_1, LM_2, WM_2, LM_3, WM_3) and long bone (MWF, FMW, LH, MWH, HMW, LU, MWU, UMW) measurements studied (Tables II-1, II-2, II-3). Both overlap in squamosal breadth, skull height, length of C^1, width of P_4, and femur length. In anteorbital constriction, interorbital constriction, breadth of braincase, and width of C^1, S. cubanus is larger, or at least slightly larger, than S. paradoxus. The differences in pelage and coloration between the two living species have been discussed in detail previously (Peters 1863; Gundlach 1877; Dobson 1882; Allen 1908).

Of the two extinct species, Solenodon "new species A" from Cuba is significantly larger than S. paradoxus in sixteen (palatal length, length of maxillary toothrow, anteorbital constriction, zygomatic breadth, squamosal breadth, condylar breadth, maximum length of C^1, maximum width of C^1, maximum width of P^1, maximum length of P^2, maximum width of P^2, total length of femur, maximum width of femur, minimum shaft width of femur, total length of humerus, and maximum width of humerus) of the 29 measurements available for its sample (Table II-3). It overlaps with S. paradoxus in alveolar length of upper molar toothrow, breadth across maxillary molar toothrow, interorbital constriction, maximum length of P^1, maximum length of M^1, maximum width of M^1, maximum width of M^2, minimum shaft width of humerus, and minimum shaft width of ulna. S. paradoxus is significantly larger than the giant Cuban form in maximum length of M^3 and maximum width of M^3, and averages larger in length of upper molar toothrow and maximum length of M^2.

S. paradoxus is significantly larger than S. marcanoi in 41 cranial, mandibular, dental, and limb bone measurements (Table II-3). It also averages larger than S. marconoi in 12 additional measurements, with only minor overlap in condylar breadth, maximum length of P^2, maximum length of P_1, maximum length of P_2, maximum length of P_4, maximum width of femur, mastoid breadth, maximum length of M^1, minimum shaft width of ulna).

Geographic variation. Standard statistics for the North and South Hispaniolan samples are given in Table II-2 (for 41 characters) and Table II-3 (for 58 characters). Univariate analysis and the results of the Duncan's test of 41 measurements of extant Solenodon (Table II-2) revealed a geographic pattern in which samples from North Hispaniola differed significantly from South Hispaniolan samples in 12 measurements: greatest length of skull, condylobasal length, palatal length, length of maxillary toothrow, maximum width of M^3, greatest mandible length, length of mandibular toothrow, alveolar length of P_4-M_3, angular condylar height, maximum length of P_4, maximum width of femur and total length of humerus. The three samples from North Hispaniola also grouped in a single subset with the sample from Haiti (South Hispaniola), differing significantly from all other samples in eight measurements (length of upper molar toothrow, breadth across maxillary toothrow, maximum width of C^1, maximum width of P_4m, maximum length of M_1, maximum width of M_1, maximum width of M_2, maximum width of M_3).

The samples from South Hispaniola grouped together in 11 measurements with the Cuban population, differing significantly from North Hispaniolan samples in angular-condylar height, maximum length of P_4, greatest length of skull, condylobasal length, palatal length, length of maxillary toothrow, greatest mandible length, length of mandibular toothrow, maximum width of femur, total length of humerus. All three South Hispaniolan samples also clustered alone in one or two subsets in four measurements (maximum width of M^3, maximum width of P_4, total length of femur, alveolar length of P_4M_3). Whereas the Haitian sample showed an intermediate position between the North and Dominican Republic south samples in eight measurements, the latter populations differed significantly from all other samples in length of upper molar toothrow, maximum width of C^1, and maximum length of M_1. These two latter samples also separated from the others with the Cuban population in breadth across maxillary toothrow, maximum width of M_1, maximum width of M_2, and maximum width of M_3. The sample from Sierra de Baoruco isolated from all other samples in one subset in P_4-M_3 and maximum length of M_2.

Univariate analysis among and between all living and extinct samples of Solenodon (58 characters) shows the north and South populations differing significantly in 28 measurements, grouped in non-overlapping subsets in 8 additional measurements, and overlapping in 22 characters. Furthermore, univariate analysis of 41 characters for the six Hispaniolan samples alone revealed highly significant ($P < 0.01$) differences among and between the two populations in all but two measurements (interorbital constriction and minimum shaft width of humerus). Both populations were clearly separated in 17 measurements. The population from Haiti grouped with the North in all eight upper molar and canine characters, differing significantly from the other south populations.

Multivariate analysis of the S. paradoxus populations, using discriminant function analysis of 45 characters, reveal similar patterns of geographic variation. The classification matrix indicated that 100 percent of the individuals could be correctly identify using two characters, width of the P_4 and angular-condylar height of the mandible. A bivariate plot of these two measurements of the Hispaniolan populations is presented in Fig. II-5. The

South populations are found on the lower left and the north populations on the upper right of the horizontal variate.

Separate analyses of sets of cranial, mandibular, and limb bone characters using discriminant functions (Table II-6) and classification matrices (Table II-7) indicate that North and South populations might not be accurately distinguished using mandibles and limb bones alone.

Taxonomic conclusions. The S. paradoxus population from the north is larger than the population from the South in most cranial, mandibular, dental and limb bone measurements investigated. The Haitian population has the cranial, mandibular, and limb bone dimensions of the southern S. paradoxus population from Dominican Republic, but the size of the upper molars and canine are similar to the North Hispaniola animals. The population from the southern Dominican Republic is certainly the smallest population of S. paradoxus, with some specimens approaching the skull dimensions of S. marcanoi. The Haitian population seems more closely related to these two latter populations, though their differences indicate that the south Haiti and south Dominican Republic populations have been isolated for a long time in the past. This is expected because most surviving populations in Hispaniola occur at, or in the proximity of, relevant mountain ranges. The same could be said of S. cubanus, which is suggestive of an island refugia phenomena. Based of the results of these analysis, I believe the Solenodon populations from South and North

Hispaniola represent different geographic forms. The possibility also exists that the Haitian sample might represent a phenetically identifiable population from those of North Hispaniola (samples 1, 2 and 3) and south Dominican Republic (samples 4 and 5), and therefore a separately evolving lineage. However, because my data are inconclusive, and considering the lack of genetic information, I have chosen not to recognize the Haitian animals as a separate population for the time being. Therefore, I include the population from Haiti with those from south Dominican Republic in the new subspecies of _S. paradoxus_ from South Hispaniola.

Solenodon paradoxus paradoxus Brandt 1833

Solenodon paradoxus Brandt, 1833. Mem. Acad. Imp. Sci., St. Petersbourg, ser. 6, Sci. Math. Phys. Nat., 2:459.

Holotype. Skin and incomplete skull of subadult male from "Hispaniola", Zoological Museum of the Academy of Sciences of St. Petersburg, obtained by Jaegerus.

Measurements of the holotype. The type was not available for examination. The following external measurements are taken from Brandt (factor from inches, 2.54): total length, 520; head-body length, 292; tail length, 229; ear length, 25; hind foot, 50. Cranial measurements are from Peters (1863) as given by Allen

(1908): basal length, 74.3; palatal length, 44; breadth at zygomatic process of maxilla, 31.5; breadth at zygomatic process of squamosal, 30.3; interorbital breadth, 17.7; breadth of rostrum at anterior border of canines, 8.7; breadth across maxillary toothrow, 23; length of upper toothrow, 39; length of P^4-M^3 (given as P^3-M^3), 15.3; mandibular height at coronoid, 25.5; length of lower toothrow, 33; length of P_4-M_3 (given as P_3-M_3), 17. Not all these are comparable with the measurements used here.

Distribution. Known from the Dominican Republic, north of the Neiba Valley. Apparently a recent invader to the south-island of Hispaniola (sensu Schwartz 1980).

Comparisons. The nominate subspecies, S. p. paradoxus, can be distinguished from the new geographic form from South Hispaniola by its larger overall size (Figs. II-6, II-7). See Comparisons and Geographic variation under S. paradoxus. See also Comparisons for S. paradoxus subspecies B.

Remarks. In his description, Brandt gave Hispaniola as the origin of the type specimen. Why later authors (Peters 1863; Leche 1907; Allen 1908) referred to it as coming from Haiti, was probably due to the fact that the name Haiti was also used around the turn of the century to include the whole island of Hispaniola. The specimen must have been obtained by the donor on, or prior to, 1832, as Brandt first presented the specimen to the Academy of St. Petersburg in December of that year. The maxillar-premaxillar suture of the type was still unfused (Peters 1863, Podushcka and

Podushcka 1983), which indicates that it is not a full grown animal, and therefore presumably a subadult. Lacking further pertinent information, and on the basis of available evidence (namely external and cranial measurements and approximate age), I believe the North Hispaniola population is better represented by the type specimen of Solenodon paradoxus. The possibility exists that the type has been lost.

Specimens examined. (128). DOMINICAN REPUBLIC: Rio Limpio, Loma de Cabrera, Dajabón Province, 1 (JAO); Arroyo de Agua, Mata Grande, Cacique, Monción, Santiago Rodriguez Province, 2 (JAO); Jaiqui Picado, San Jose de las Matas, Santiago Province, 13 (JAO); La Cuesta, San Jose de las Matas, Santiago Province, 8 (7 PSM, 1 ZMUH); near Santiago, Santiago Province, 2 (USNM); La Vega, La Vega Province, 64 (1 UF, 46 MCZ, 4 FMNH, 7 USNM, 1 CM(NH), 1 RMNH, 4 IRSNB); El Mogote, Jarabacoa, La Vega Province, 1 (JAO); Cordillera Central, 4 (AMNH); Loma Alta, Cabrera, María Trinidad Sanchez Province, 2 (JAO); Los Hoyos, SW Cabrera, María Trinidad Sanchez Province, 1 (JAO); La Confluencia, Cabrera, María Trinidad Sanchez Province, 1 (JAO); Rio Guaraguao headwaters, Arenoso, Duarte Province, 1 (JAO); El Naranjito, N Sanchez, Samana Province, 1 (JAO); Rio San Juan, Samana Province, 1 (USNM); Laguna, Samana Province, 1 (USNM); San Lorenzo, Samana Province, 1 (AMNH); Hidalgo, Los Haitises, San Cristobal Province, 1 (JAO); Monte Bonito, Los Haitises, San Cristobal Province, 2 (JAO); San Cristobal, 1 (AMNH); El

Centro, SW Sabana de la Mar, El Seibo Province, 3 (MCZ); Loma El Cavao, S. El Valle, Sabana de la Mar, El Seibo Province, 1 (JAO); Sabana de la Mar, El Seibo Province, 1 (ZMUH); Guamira, Machado, NW Hato Mayor, El Seibo Province, 1 (JAO); near Hato Mayor, El Seibo Province, 3 (PSM); S. Miches, El Seibo Province, 3 (PSM); Candelaria, NW El Seibo, El Seibo Province, 1 (JAO); El Seibo Province, 3 (AMNH); Las Cañas, Nisibón, La Altagracia Province, 2 (JAO); Boca de Yuma, La Altagracia Province, 1 (JAO); Punta Caletón Hondo, Granchorra, La Altagracia Province, 1 (JAO); Las Cañas-La Ureña, E Santo Domingo, Distrito Nacional, 1 (JAO).

Solenodon paradoxus "new subspecies B"

Holotype. Adult male, skin, skull and skeleton, JAO 462; from Bucan de Tuí, S. Oviedo, Península de Barahona, Provincia Pedernales, Dominican Republic. Obtained March 1977.

Measurements. External, cranial and post-cranial measurements of the holotype are as follows: TL, 502; TA, 219; HF, 57; EA, 25; GLS, 79.9; CBL, 74.2; PL, 33.2; PPL, 28.5; AMTR, 7.9; MMTR, 10.3; LMTR, 23.5; MTRW, 22.7; AC, 13.5; ZB, 33.5; IC, 14.5; SB, 31.3; MB, 23.8; BB, 23.9; CB, 15.6; SH, 17.7; LC^1, 3.7; WC^1, 2.1; WM^3, 4.8; GML, 49.3; MTR, 24.7; P_4-M_3, 15.7; DCP, 22.9; ACH, 12.3; LP_4, 3.9; WP_4, 2.6; LM_1, 4.3; WM_1, 3.7; LM_2, 4.7; WM_2 3.7; LM_3, 4.9; WM_3,

3.0; LF, 41.4; MWF, 12.6; FMW, 4.9; LH, 42.8; MWH, 16.6; HMW, 5.4. Body weight, 795 g.

Distribution. South Hispaniola; including Peninsula de Barahona and Sierra de Baoruco in the Dominican Republic, and Peninsula de Tiburon (Dept. du Sud and Dept. de l'Ouest) in Haiti. A possible invader of the north-island in the Dominican Republic.

Comparisons. *S. paradoxus* new subspecies B (Figs. II-6, II-7) is distinguished from *Solenodon paradoxus paradoxus* by its smaller cranial, mandibular and post-cranial size (Tables II-2 and II-3). It is particularly smaller than the nominate form in greatest length of skull, condylobasal length, palatal length, length of maxillary toothrow, maximum width of M^3, greatest mandible length, length of mandibular toothrow, alveolar length of P_4-M_3, angular condylar height, maximum length of P_4, maximum width of femur and total length of humerus. In size, the southern Hispaniola solenodon is similar to *S. cubanus*, both differing significantly from North Hispaniolan populations, in the same measurements separating the two Hispaniolan subspecies.

All three South Hispaniolan populations show little overlap with other populations in maximum width of M^3, maximum width of P_4, total length of femur, alveolar length of P_4M_3. Within South Hispaniola, the two populations from southwestern Dominican Republic are smaller than any other living population and more closely related to each other, whereas the Haitian population is slightly larger, and resembles the north island S. paradoxus in some upper dentition characters. The populations from Sierra de Baoruco and Peninsula de Barahona show little overlap with the other samples and are the smallest in length of upper molar toothrow, maximum width of C^1, and maximum length of M_1. These two latter populations are only close to S. cubanus in breadth across maxillary toothrow, maximum width of M_1, maximum width of M_2, and maximum width of M_3. The population from Sierra de Baoruco is also noticeably smaller than all other populations in P_4-M_3 and maximum length of M_2. The population from southern Haiti is closer to the north population in length of upper molar toothrow, breadth across maxillary toothrow, maximum width of C^1, maximum width of P_4m, maximum length of M_1, maximum width of M_1, maximum width of M_2, maximum width of M_3.

Remarks. Differences in size between the populations of the two geographic divisions have been demonstrated. However, the presence of some South Hispaniolan-sized individuals in North Hispaniola, and vice versa, might raise some questions as to whether, large and small S. paradoxus merely represent ecomorphs. This would lead to further questions concerning the geographical, and therefore reproductive, isolation of the two proposed forms. Unfortunately there are no data on genetic variability of Solenodon.

Conservative mammalian insectivores are known to exhibit a marked degree of within-group morphological variation. Individual variability in the ontogeny of tooth replacement and growth rates are associated with an inflated number of species of shrew tenrecs of the genus Microgale (MacPhee 1987). This is not the case with Solenodon, since sex and age factors have been evaluated, and no individuals but geographic populations have been tested here. Furthermore, the differences detected between the two populations are based on an adequate sample (considering the rarity of Solenodon). Steps were also taken to minimize the chances of introducing artificial variability in the data. For instance, only measurements taken by me were used in the analyses, even at the expense of excluding invaluable data (i.e., measurements taken by others) from important specimens that I could not measure. Because of their rarity, several European museums were reluctant to send their Solenodon material on loan, which includes some of the few putative specimens of S. cubanus in collections anywhere.

Specimens examined (65). DOMINICAN REPUBLIC: El Narajo, S Cabral, Barahona Province, 1 (JAO); Bucán de Isidro, S Oviedo, Pedernales Province, 5 (JAO); Bucán de Tuí, S Oviedo, Pedernales Province, 3 (JAO); near Laguna La Rabiza, S Oviedo, Pedernales Province, 4 (JAO); Sabana de Sanson, 8 km SW Oviedo, Pedernales Province, 1 (JAO); El

Acetillar, 30 km N Cabo Rojo, Pedernales Province, 1 (JAO); Las Mercedes, NE Pedernales, Pedernales Province, 4 (JAO); La Azucena, S Pedernales, Pedernales Province, 1 (JAO); Avila, N Pedernales, Pedernales Province, 2 (JAO); 2 km N El Manguito, Avila, N Pedernales, Pedernales Province, 3 (JAO); Mencía (=La Colonia), N Pedernales, Pedernales Province, 5 (JAO); El Aguacate, 5 km O Las Cruces, Sierra de Baoruco, Independencia Province, 1 (JAO); Trujín (=Oviedo) 2 (USNM). HAITI: 2 mi E Duchity, east of River Glace, Dept. du Sud, 2 (UF); LaCanal, 2 mi NW Duchity, Dept. du Sud, 2 (UF); Nan Rete, 3 mi SW Duchity, Dept. du Sud, 2 (UF); Vete Shalme, near River Glace, 1 mi SE Duchity, Dept. du Sud, 1 (UF); near River Glace, 3 mi SE Duchity, Dept. du Sud, 1 (UF); Cadey, 4 km WSW Duchity, Dept. du Sud, 1 (UF); La Fiere, 2.5 km SSE Duchity, Dept. du Sud, 1 (UF); Ambaso, W Catiche, 3.2 km S Duchity, Dept. du Sud, 2 (UF); Duchity, Dept. du Sud, 17 (UF); Catiche, Dept. du Sud, 1 (UF); 27 km NW Les Cayes, Dept. du Sud, 2 (UF).

Late Quaternary material of S. paradoxus from cave deposits in southwestern Haiti is tentatively assigned to this geographic form, which includes one skull fragment (UF 125176); 3 proximal femur and sacral vertebrae (UF unnumbered) all from Sa Wo; and one R proximal humerus missing distal end (UF 128963) from Trouing Marassa. However, three ulna from Trouing Jeremy #1 (UF 128173-128175, 1 complete, 2 proximal) seem larger than those of Recent specimens. UF 128173 is actually above the size range of the North population in total length (54.9). Most of the material collected during the FMNH paleontological expedition to Haiti is still unsorted and uncataloged. An undetermined amount of fossil or subfossil Solenodon material (not yet examined) is in these collections.

Solenodon cubanus Peters 1861

Distribution. This species occurs only on the island of Cuba. No records are known elsewhere in the Cuban Archipelago outside the mainland.

Diagnosis. S. cubanus can be distinguished from the Hispaniolan solenodons, S. paradoxus and S. marcanoi, primarily by morphology, as well as by size (Tables II-1, II-2, II-3). From Solenodon "new species A", S. cubanus can be separated essentially by size (Table II-3; Figs. II-8, II-9). It differs from S. paradoxus and S. marcanoi in the more constricted internal narial opening and anterior portion of pterygoid fossa, much larger posteroventrally expanded pterygoid processes, relatively broader frontals at the anterior edge of the orbits, much broader frontal region, greatly enlarged and inflated upper canines, strong lingual expansion of first two upper premolars, and somewhat larger first two lower premolars and lower canines. From S. paradoxus, it can be distinguished by the presence of a diastema between I^3 and C^1 as well as smaller diastemas between I^2-I^3 and C^1-P^1, and lack of accessory cusps on C^1, P^1, and P^2. From the extinct Hispaniolan S. marcanoi, which in some characters shows an intermediate condition between S. cubanus and S. paradoxus (see account for S. marcanoi), S. cubanus can be clearly differentiated by its much larger size (Table II-3). S. cubanus is considerable smaller than the new fossil Solenodon from Cuba (see account for S. "new species A").

Comparisons. In addition to morphology, the two living species, which occur allopatrically, can be readily distinguished by size and by coloration. S. cubanus (Figs. II-4) is smaller than the North Hispaniola Solenodon in most cranial (GLS, CBL, PL, PPL, AMTR, MMTR, LMTR, MTRW, ZB, MB, CB, WM^3), mandibular (GML, MTR, P_4M_3, DCP, ACH, LP_4, LM_1, WM_1, LM_2, WM_2, LM_3, WM_3) and long bone (MWF, FMW, LH, MWH, HMW, LU, MWU, UMW) measurements studied (Tables II-1, II-2, II-3). Both overlap in squamosal breadth, skull height, length of C^1, width of P_4, and femur length. Although closer in size, S. cubanus is also significantly smaller than the South Hispaniola Solenodon in postpalatal length, alveolar length of upper molar toothrow, length of upper molar toothrow, width of M^3, alveolar length of P_4-M_3, length of M_1, length of M_2, length of M_3, minimum shaft width of femur, maximum width of humerus and minimum shaft width of humerus. The South Hispaniolan Solenodon either overlap or are slightly larger than S. cubanus in most measurements (GLS, CBL, PL, LMTR, MTRW, ZB, MB, CB, GML, MTR, DCP, ACH, LP_4, WM_1, WM_2, WM_3, MWF, LH, LU, MWU, UMW). In anteorbital constriction, interorbital constriction, breadth of braincase, and width of C^1, S. cubanus is larger, or at least slightly larger, than both northern and southern Hispaniola Solenodon. The Cuban species is also larger than the South Hispaniola populations in squamosal breadth, skull height, length of C^1, width of P_4, and femur length. The differences in pelage and coloration between the two living species have been described in detail previously (e.g. Peters 1863; Gundlach 1877; Dobson 1882; Allen 1908; Allen 1910).

Geographic variation. Standard statistics for the Recent Cuban sample are given in Tables II-1, II-2, II-3, and for the Late Quaternary sample in Table II-3. Recent S. cubanus is known only from the eastern portion of Cuba. The sample available was analyzed for geographic differences between northeastern and southeastern populations. Univariate analysis yielded no significant results. Because of missing data and consequent small or non-existing samples, the Late Quaternary sample was rejected for multivariate analysis.

Taxonomic conclusions. Only one adult specimen from Sierra Maestra (adult female USNM 37983/15526) was available for comparison with the north population of eastern Cuba, including the type specimen of S. poeyanus. I found no differences between the specimens of the two geographic regions of eastern Cuba, not even to justify subspecific distinction. Among the samples of S. cubanus I was able to examine in both American and Cuban collections, three adult specimens (USNM 300634, adult male from La Iberia, Baracoa; IES/ACC 1478, adult female from Mayarí, Holguín; and MCZ 46306, adult, unknown) are noticeably larger than the rest of the Cuban material. Of these, at least the first two are from the northeastern region. The single adult specimen from Sierra Maestra is certainly smaller than these two, and so are the type of S. poeyanus (adult female from near Nipe Bay), and all three known additional northeastern specimens. Measurements of the S. poeyanus and of the Sierra Maestra specimens, are respectively: GLS, (78.7), 77.4; CBL, (74.2), 74.1; PL, 35.6, 34.5; PPL, (27.1), 27.5; AMTR, 8.1, 7.9; MMTR, 8.5, 8.3 ; LMTR, 24.4, 23.3; MTRW, 21.4, 20.7; AC, 15.2, 14.7; ZB, 33.4, 32.2; IC, 15.0, 15.3; SB, (30.9), 30.8; MB, (24.6), 24.7; BB, (25.3), 24.5; CB, (16.0), 15.7; SH, (19.6), 19.6; LC^1, 4.8, 4.65,; WC^1, 3.05, 2.86; WM^3, 4.5, 4.4; GML, (49.4), 48.3; MTR, 26.2, 24.5; P4M3, 14.8, 13.8; DCP, 24.2, 22.3; ACH, (12.9), 13.3. The skull of S. poeyanus is not complete. Measurements in parenthesis represent good approximations. In Barbour's (1944) description, the specimen was erroneously identified as MCZ 6957. The correct collection number for the type of S. poeyanus is MCZ 6597.

The fossil/sub-Recent sample (B) is significantly larger than Recent S. cubanus in most mandibular and premolar measurements (GML, MTR, P_4M_3, DCP, ACH, LC_1, WC_1, LP_1, WP_1, WP_2, LP_4, LM_1), except one cranial measurement (anteorbital constriction). None of the lower maxillas examined approach the occlusion area of the skull of the new giant form. On the other hand, none of the five partial skulls in the late Quaternary sample match the size of the large mandibles, nor does any of the Recent specimens. These mandibles might either be very large S. cubanus, or small individuals of the new extinct Solenodon. The possibility also exist that such mandibles might represent an intermediate population. Considering the paucity of the material available, I have chosen not to assign the material in question to any of the taxa recognized here, and to maintain its taxonomic status, for the time being, as Solenodon cf. S. cubanus.

Solenodon cubanus Peters 1861

Solenodon cubanus Peters, 1861. Monatsb. Akad. Wiss. Berlin, p. 169.

Atopogale cubana Cabrera, 1925. Genera mammalium: Insectivora, Galiopithecia, Mus. Nac. Cien. Nat., Madrid, p. 177.

Solenodon cubanus Varona, 1974. Acad. Cien. Cuba. p. 7.

Holotype. Adult female from the mountains near Bayamo, Prov. Granma, Cuba; Berlin Academy of Sciences. Obtained by J. Gundlach.

Measurements of the holotype. The type was not available for examination in this study. The following measurements are from Peters (1863): head and body length, 280; length of tail 190; height of ear, 30; length of hindfoot, 56; occipito-nasal length, 87; basal length, 73.7; palatal length, 45; breadth at zygomatic process of maxilla, 34.7; breadth at zygomatic process of squamosal, 33.5; interorbital breadth, 19.6; length of upper toothrow, 39; length of P^4-M^3 (given as P^3-M^3), 12.2; mandible height at coronoid, 28; length of lower toothrow, 30.5; length of P_4-M_3, (given as P_3-M_3), 14. [With some exceptions, the above measurements are not useful for comparisons with those presented here as they differ from mine as described in Materials and Methods].

<u>Distribution</u>. The Recent distribution of this species is restricted to the eastern portion of Cuba. It is known from a number of Late Pleistocene-early Holocene and Amerindian sites throughout the western and eastern regions of Cuba. Its past existence in the central portion of the island is only confirmed from Sierra de Cubitas.

<u>Comparisons</u>. See Specific Relationships

<u>Specimens examined</u>. CUBA; Recent (19). Near Nipe Bay, Holguín Province, 1 (MCZ); Sierra La Boca, Mayarí, Holguín Province, 2 (IES/ACC); Cabezada Rio Nibujón, Cerra La Iran, Baracoa, Guantanamo Province, 1 (IES/ACC); La Iberia, Baracoa, Guantanamo Province, 3 (2 IES/ACC, 1 USNM); Baracoa, Guantanamo Province, 1 (IES/ACC); Sierra Maestra, Granma Province, 2 (USNM); Cuba, 10 (4 USNM, 3 MCZ, 2 NMNH, 1 FMNH). Late Quaternary( ). Referred material: OA 35,

partial skull with R P^1 and L P^4, Cueva de José Brea, Sierra Pan de Azucar, Pinar del Río Province. OA 83, mandibular fragment with P_2; OA 85, mandibular fragment (edentate); IES/ACC 208, partial L mandible with alveoli of P_4-M_3; IES/ACC 620, L femur; IES/ACC 2599-3678, L femur; IES/ACC 622, R humerus, missing proximal head; IES/ACC, R humerus, partial, missing proximal portion; IES/ACC 621, L humerus, complete; IES/ACC, 2325-3645, partial skull, rostrum and almost complete palate with R P^1, P^2 and M^1; all from Cueva Paredones, Ceiba de Agua, San Antonio de los Baños, La Habana Province. OA 8525, L mandible fragment (edentate), Residuario San Martín, Boca de Jaruco, La Habana Province. OA, L C^1, Reparto América, Calabazar, Ciudad Habana, La Habana Province. OA, partial skull (with R I^1, C^1-M^2 and L I^1, C^1, P^1, M^2) and associate R mandible (with I_1-I_3, P_1-M_3), from Cueva del Túnel, La Salud, La Habana Province. OA, partial L mandible with P_1-M_2, Cueva del Círculo, Sierra de Cubitas, Camaguey Province. MCZ 7054, R mandible with I_2 through M_1 but I_3, plus 6 isolated teeth, Cueva del Indio (Cueva #1), near Banao, Camaguey Province. OA, R mandible with P_1-P_2, Mayarí, Holguin Province; OA, L mandible (edentate), Cueva de los Panaderos, Gibara, Holguin Province. IES/ACC, partial skull with L P^1-P^2 and R P^1, M^1, from Los Negros, 25km S Baire, Santiago de Cuba Province. OA, partial L mandible with P_2, La Gloria, Santiago de Cuba Province. MCZ 10065, R mandible, Cueva San Lucas, Meseta (=Gran Sierra) de Maisi, Guantanamo Province.

Solenodon cf. S. cubanus

Referred material. OA 306E (+31), matched mandibles with L P_1-P_4 and R M_2, and associated proximal humerus, Caverna de Pío Domingo, Ensenada Pica -Pica, Sumidero, Pinar del Río Province. IES/ACC 1308-3677, partial R mandible, from alveoli I_1 to alveoli M_2, edentate; IES/ACC 228, R mandible missing tip from anterior edge of alveoli of I_3, edentate; IES/ACC, L mandible, edentate; IES/ACC 2598-3646, L mandible with I_1 and I_2; IES/ACC 2595, partial L mandible, edentate; all from Cueva Paredones, Ceiba de Agua, San Antonio de los Baños, La Habana Province. OA, L mandible with P_2, Cueva de Calero, Camarioca, Matanzas Province. OA 124-152, L mandible with P_1, P_2, and P_4, Caimanes III, 1.5 kilometros from bay shore, about 150 m. from Río Caimanes, Santiago de Cuba Province.

Remarks. Larger and more massive than average Recent S. cubanus. Measurements of selected specimens are given in Table II-8. IES/ACC 1308-3677, OA 306E, OA 124-152, all appear to be from adult animals and might approach the mandible size of the new giant Solenodon. With exception of the material from Caverna Pio Domingo in Pinar del Rio, Cueva de Calero in Matanzas, and Caimanes III in Santiago de Cuba, most of the specimens are from Cueva Paredones (a fossil site which is both the type locality of the giant species and an important cave deposit for Late Pleistocene S. cubanus).

Solenodon "new species A"

Holotype. Nearly complete skull, MNHNC 421/123, lacking the braincase, with R M^1 and M^3, and L C^1, P^1, P^2, M^1, and M^2 (Figs. II-4, II-8, II-9, II-13).

Type Locality and Age. Cueva Paredones, Ceiba de Agua, Provincia La Habana, Cuba; a Late Pleistocene fossil cave deposit, as suggested by the known associate vertebrate fauna.

Referred Material. USNM 299480, partial L femur from Abra de Andres, Altura de Esperón, Sierra del Anafe, northeast of Guanajay, Provincia La Habana, Cuba. Collected by Oscar Arredondo and Cesar García del Pino on 15 March 1958 (Arredondo 1970, Morgan et al. 1980). OA 301.E , partial associate skeleton, including L humerus, R radius, R innominate, L femur, R proximal and distal tibia, and L calcaneus. Caverna de Pío Domingo, Ensenada Pica-Pica, Sierra de Sumidero, Provincia Pinar del Rio, Cuba. Collected by Oscar Arredondo and J. N. Otero, January 1954 Morgan et al. 1980). IES/ACC 278, complete R humerus; MNHNC, R proximal humerus, collected by Manuel Iturralde in April 1991; IES/ACC 2431-3675, incomplete edentated palate; IES/ACC, occipital including condyles and posteriormost portion of supraoccipital with lambdoidal crest; all from the type locality, Cueva Paredones, Ceiba de Agua, Provincia La Habana.

Distribution. In addition to the type locality this new Solenodon is also known from Abra de Andres, Altura de Esperón, Sierra del Anafe, northeast of Guanajay, Provincia La Habana, and from Caverna de Pío Domingo, Ensenada Pica-Pica, Sierra de Sumidero, Provincia Pinar del Rio.

Diagnosis. Solenodon "new species A" can be separated by all other species in the genus by its larger size. It differs from the two Hispaniolan species in morphology (see Diagnosis for S. cubanus and S. paradoxus) and size, being closer in morphology to the Cuban Solenodon. It can be distinguished from S. cubanus by its more prominent pterygoid process, narrower internal narial opening, comparatively more inflated C^1, and broader upper premolars, wider anteorbital region at lacrimal foramen, proportionally larger diameter and massiveness of rostrum.

Description. The large fossil Solenodon is significantly larger than all other samples in 16 (palatal length, length of maxillary toothrow, anteorbital constriction, zygomatic breadth, squamosal breadth, condylar breadth, maximum length of C^1, maximum width of C^1, maximum width of P^1, maximum length of P^2, maximum width of P^2, total length of femur, maximum width of femur, minimum shaft width of femur, total length of humerus, and maximum width of humerus) of the 29 measurements available for its sample. It overlaps with the remaining samples in alveolar length of upper molar toothrow, length of upper molar toothrow, breadth across maxillary molar toothrow, interorbital constriction, maximum length of P^1, maximum length of M^1, maximum width of M^1, maximum length of M^2, maximum width of M^2, maximum length of M^3, maximum width of M^3, minimum shaft width of humerus, and minimum shaft width of ulna. The femur from Abra de Andres already has been discussed and illustrated in detail by Morgan et al. (1980). A more comprehensive description and comparison of this new taxon will be presented elsewhere.

Comparisons. See Comparisons for *S. cubanus*.

Solenodon marcanoi Patterson 1962

Distribution. Quaternary of Hispaniola; late Pleistocene-early Holocene of Dominican Republic and late Pleistocene throughout post-Columbian of Haiti.

Revised diagnosis. Significantly smaller than *Solenodon* "new species A", *S. paradoxus* and *S. cubanus* in cranial, mandibular, dental and limb bone dimensions. In morphology, *S. marcanoi* shows an intermediate condition between Cuban and Hispaniolan taxa. As in *S. paradoxus*, it differs from the two Cuban species, from which is geographically separated, in mesopterygoid fossa being wider anteriorly than posteriorly; pterygoid processes reduced, oriented inwards or at a converging angle; presence of the os proboscis socket in from of the premaxilla; upper and lower unicuspid and bicuspid dentition laterally compressed. As in *S. cubanus*, it differs from *S. paradoxus*, in the presence of a distinct diastema between I^3 and C^1 and between C^1 and P^1; rostrum short, of reduced diameter; accessory cusps on C^1, P^1 and P^2 are absent or vestigial; P^2 triangular, though not lingually expanded.

Comparisons. S. marcanoi (Figs. II-4, II-10, II-11, II-12, II-13) is significantly smaller than all other species of Solenodon in 41 cranial, mandibular, dental and limb bone measurements (Table II-3). It also averages smaller than other extinct and living Solenodon in 12 additional measurements, with only minor overlap with the South Hispaniolan form (condylar breadth, maximum length of P^2, maximum length of P_1, maximum length of P_2, maximum length of P_4, maximum width of femur) and with S. cubanus (postpalatal length, maximum length of M^2, maximum length of M_1, maximum length of M_2, maximum width of humerus) or both (mastoid breadth, maximum length of M^1, minimum shaft width of ulna). In skull appearance (Figs. II-10, II-11, II-12), a few exceptionally cryptic South Hispaniolan S. paradoxus approach marcanoi, but both are easily separated, among a number of characters, primarily by the larger teeth and broader skull of the former. There is much overlap in the size of the limb bones. Although the femur, humerus, and ulna in some South Hispaniolan and Cuban animals resemble S. marcanoi in overall size, the limb bones of S. marcanoi are shorter in length, and their width is certainly not noticeably larger as previously considered (Patterson 1962).

Geographic variation. The results of univariate analysis between the samples of S. marcanoi from Haiti (F) and the type locality in Sierra de Neiba, Dominican Republic (G) are shown in Table II-3. Only 21 measurements of the latter fossil sample (including the type series plus further collections referred to S. marcanoi from the same cave site) are available for comparison. On the basis of this material, the sample from Rancho la Guardia is significantly larger than the S. marcanoi sample from southwestern Haiti in six mandibular and dental measurements (length of mandibular toothrow, alveolar length of P_4-M_3, maximum width of P_1, maximum width of P_4, maximum width of M_1, maximum width of M_2). Both samples overlap in length of mandibular toothrow, depth through coronoid process, angular condylar height, maximum length of P_1, maximum length of P_4, maximum length of M_1, maximum length of M_2).

A closer examination of Haitian samples revealed that the two mandibles from the Massif de la Selle (UF 128964 from Trouing Marassa, and UF 125173 from Trouing de la Scierie, La Visite, Dept. de l'Ouest, Haiti) are actually much larger than the mandibles from Camp Perrin (Sa Wo, Dept. du Sud) and from the Massif de La Hotte (Trouing Jeremy #1, #5 and #8, Formon, Dept. du Sud, Haiti) and resemble in size those of the type locality in Sierra de Neiba. The results of the analysis also show that the type locality sample is significantly larger than the Haitian sample in all (9) limb bone measurements but one, and that it overlaps primarily with the South Hispaniolan and Cuban samples.

Taxonomic conclusions. Despite the size differences in mandibular and lower teeth measurements between La Selle-Neiba samples and La Hotte, there is no doubt about the identity of these mandibles, specimens from all three areas represent S. marcanoi. Unfortunately, the scarcity of Massif de la Selle material precludes any reasonable judgement about the possible differences between this and the samples from the type locality in Dominican Republic and from La Hotte region in Haiti. Additional material would be desirable for an adequate evaluation of their geographic relationships. Close examination of the limb bones, however, indicates that some of the specimens from the type locality that have been assigned to S. marcanoi, including specimens of the type series (MCZ 20325, MCZ 20329, MCZ 20321, MCZ 7263, MCZ 7265) and further collections attributed to this taxxon (CM 35036, UF unnumbered), are close in size to the S. paradoxus population from South Hispaniola, and probably represents S. paradoxus (Fig. II-13, Tables II-9, II-10, II-11). Fossil or sub-fossil material of S. paradoxus is known from Rancho la Guardia. Because the existence of the smaller S. paradoxus population from South Hispaniola was previously unknown, comparison of the S. marcanoi type series with S. paradoxus (Patterson 1962) was based exclusively on North Hispaniolan specimens; MCZ 12384, MCZ 12416, and MCZ 34828 are all from the Cordillera Central region in the Dominican Republic. The proportional dimensions of the femora and humerus of the different Solendon taxa, as presented in this study, are shown for comparison in Fig. II-14.

Solenodon marcanoi

Antillogale marcanoi Patterson, 1962. Breviora, 165:2.
Solenodon (marcanoi) Van Valen, 1967. Bull. Amer. Mus. Nat. Hist., 135 (5): p. 255.
Solenodon marcanoi Varona, 1974. Acad. Cien. Cuba. p. 7.

Holotype. MCZ 7261, partial R mandible with P_2-M_2. Obtained by Bryan Patterson in 1958.

Type locality and Age. cave 2 km SE Rancho la Guardia, Hondo Valle, Elias Piña Province, Dominican Republic. Late Pleistocene.

Measurements of holotype. Mandibular toothrow, 21.4; alveolar length of P_4-M_3, 12.8; length of P_4, 3.5; width of P_4, 2.4; length of M_1, 3.6; width of M_1, 3.1; length of M_2, 3.4; width of M_2.

Distribution. Known from the massifs of La Hotte and La Selle in Haiti, and from Sierra de Neiba in the Dominican Republic.

Remarks. The new material of S. marcanoi from southwestern Haiti provides the opportunity for clarification of the interspecific relationships of Solenodon, and might also prove useful in the illumination of their evolutionary relationships. Although a detailed re-description of the skull, mandible, dentition and post-cranial skeleton of S. marcanoi will be presented elsewhere, I must comment that upon examination of the skulls, I believe Antillogale is certainly not much different from Solenodon.

Referred material. MCZ 7261, partial R mandible with P_2-M_2 (type specimen); MCZ 7262, L mandible with P_4-M_2; MCZ 7264, L humerus lacking proximal epiphysis; MCZ 7266, partial L mandible; MCZ 20320, L mandible with I_3,P_1; MCZ 20324, proximal R femur; MCZ 20322, R humerus; MCZ 20327, R distal humerus; MCZ 20328, distal humerus (2); MCZ 20323, L femur; MCZ 20326, calcaneum; MCZ 20325, ulna; MCZ 20329, distal humerus; MCZ 20321, R femur; MCZ 7263, R humerus; MCZ 7265, R ulna; from Cave 2 km SE Rancho la Guardia, Hondo Valle, Elias Piña Province, Dominican Republic. Late Pleistocene. 1958. Collected by Bryan Patterson. CM 35036, R femur, from Cave 2 km SE Rancho la Guardia, Hondo Valle, Elias Piña Province, Dominican Republic. Late Pleistocene.

UF 128162, complete skull missing R I^3,P^2,M^3, and L I^2,I^3,P^1; UF 128964, complete mandible with I_3-M_3; from Trouing Marassa (=Trujin Bridge, 18° 17'N, 72° 17'N; UTM-YR878297), La Visite, Dept. de l'Ouest, Haiti. July 1983. Late Pleistocene-Holocene. Collected by Dan Cordier.

UF 125174, partial skull and associate partial skeleton, including R humerus, R radius, L and R ulna, L and R innominate, L and R femur, and R tibia; from Trouing Carfinéyis, 2 km E of Cavalier, La Visite, Dept. de l'Ouest, Haiti; 950 m. September 1984. Late Quaternary. Collected by Dan Cordier.

UF 125173, L mandible with M_2-M_3; from Trouing de la Scierie, La Visite, Dept. de l'Ouest, Haiti. September 1983. Late Quaternary. Collected by Dan Cordier.

UF 128163, partial skull with R I^1, P^4-M^2, and L I^1,P^4-M^3; UF 128164, R mandible with I_2-M_3; UF 128165, L mandible with I_2-M_3; UF 128166, R mandible with P_4-M_2; UF 128167, R mandible with P_1-M_1; UF 128168, L mandible with P_2,P_4,M_2,M_3; UF 128169, L mandible with P_1; UF 128170, R humerus; UF 128171, R humerus; UF 128172, L humerus; from Trouing Jeremy #1 (18° 20'N, 74° 02'W; UTM-XR030274), Formon, Massif de la Hotte, Dept. du Sud, Haiti. January 1984. Late Pleistocene-Holocene. Collected by Dan Cordier.

UF 128180, partial skull with L I^1,P^4-M^2 and R I^1,P^1-P^4,M^2,M^3; UF 128181, rostrum; UF 128182, anterior fragment of rostrum; UF 128183, L maxilla fragment, edentate; UF 128184, R mandible with P_1-M_3; UF 128185, L mandible with P_1,P_4-M_2; UF 128186-128188, L mandibles, edentated; UF 128189, R mandible with M_3; UF 128190-128191, R and L humerus; UF 128192-128193, R distal humerus (2); UF 128194, L femur; UF 128195, L mandible with P_1-M_3; UF 128196, R mandible with I_1,I_2,C_1; from Trouing Jeremy #5 (18° 21'N, 74° 01'W; UTM-XR030277), Formon, Massif de la Hotte, Dept. du Sud, Haiti. January 1984. Late Pleistocene-Holocene. Collected by Dan Cordier.

UF 128197, R humerus; UF 128198, L humerus; UF 128199, L femur; from Trouing Jeremy #8 (18° 21'N, 74° 01'W; UTM-XR030277), Formon, Massif de la Hotte, Dept. du Sud, Haiti. February 1984. Late Pleistocene-Holocene. Collected by Dan Cordier.

UF 125175, partial skull; UF 125177, R mandible; UF 125178, R mandible fragment, edentated; UF 125179, R mandible with M_3; UF 125180, L mandible, edentated; UF 125181, L mandible with P_2,P_4; UF 125182, R mandible with P_4-M_2; UF 125183, L mandible with P_4; UF 125184, R mandible, edentated; from Trou Woche Sa Wo, Camp Perrin, Dept. de Sud, Haiti. April 1983. Late Quaternary. Collected by M.K.Langworthy.

UF (unnumbered), R femur (2), L femur (3), L humerus (6), R humerus (1), complete ulna (1), partial ulna (3); from Trou Woche Sa Wo, Camp Perrin, Dept. de Sud, Haiti. 11-14 February 1978 (6-12"). Collected by Charles A. Woods. Sa Wo, 11-14 Feb. 1978. (6-12"). Collected by Charles A Woods. UF (unnumbered), R femur (2), L femur (3), L humerus (6), R humerus (1), 1 complete ulna [S. paradoxus?], partial ulna (3).

FIG. II-1

Map showing geographic samples of extant *Solenodon* in Cuba and Hispaniola. 1) Promontorio de Cabrera-Peninsula de Samana, northeastern Dominican Republic (North Hispaniola); 2) Los Haitises-Sierra de Seibo-Caribbean Coastal Plain, eastern Dominican Republic (North Hispaniola); 3) Cordillera Central-Cibao Occidental Valley, central north-central Dominican Republic (North Hispaniola); 4) Peninsula de Barahona, southwestern Dominican Republic (South Hispaniola); 5) Sierra de Baoruco, southwestern Dominican Republic (South Hispaniola); 6) Massif de la Hotte, southwestern Haiti (South Hispaniola); 7) eastern Cuba.

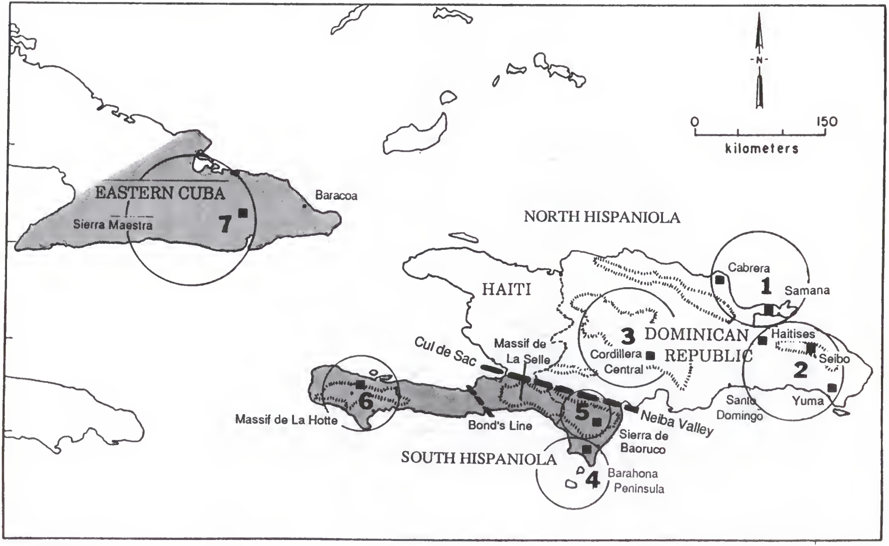

N
0
150
kilometers
EASTERN CUBA
Sierra Maestra
7
Baracoa
NORTH HISPANIOLA
HAITI
DOMINICAN REPUBLIC
1
Cabrera
Samana
2
Haitises
Seibo
Yuma
Santo Domingo
3
Cordillera Central
Cul de Sac
Massif de La Selle
Neiba Valley
5
Sierra de Baoruco
4
Barahona Peninsula
6
Massif de La Hotte
Bond's Line
SOUTH HISPANIOLA

FIG. II-2

Bivariate plot of values of length of upper molar toothrow (MMTR) and width of upper canine to show the relationship of extant Solenodon samples from Hispaniola (1-6) and Cuba (7).

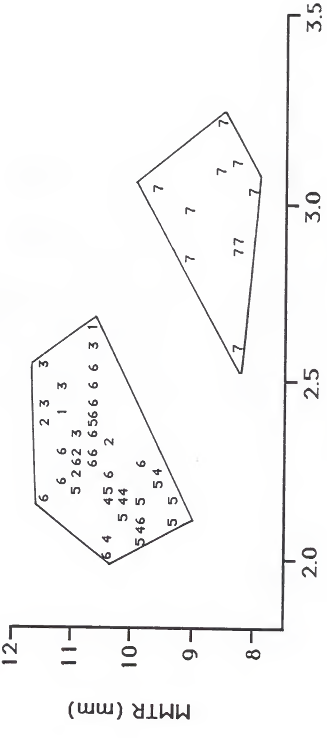

MMTR (mm)
12
11
10
9
8
2.0
2.5
3.0
3.5
WIDTH UPPER CANINE (mm)

FIG. II-3

Bivariate plot of values of width of the upper canine and length of upper molar toothrow to show the relationship of the four living and extinct *Solenodon* taxa. 1, *Solenodon* "new species A"; 4, *S*. *cubanus*; 5-6, *S*. *paradoxus*; 7, *S*. *marcanoi*.

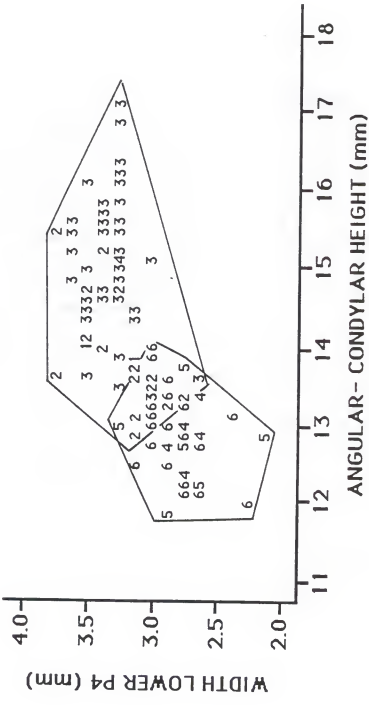

WIDTH LOWER P4 (mm)
2.0
2.5
3.0
3.5
4.0
ANGULAR- CONDYLAR HEIGHT (mm)
11
12
13
14
15
16
17
18

FIG. II-4

Lateral view of skull of living and extinct Solenodon showing relative size and dentition profile. a) Solenodon "new species A" (MNHNC 421/123); b) S. paradoxus, north Hispaniola (JAO 721); c) S. cubanus (USNM 37983); d) S. paradoxus, South Hispaniola (JAO 314); e) S. marcanoi (UF 128162).

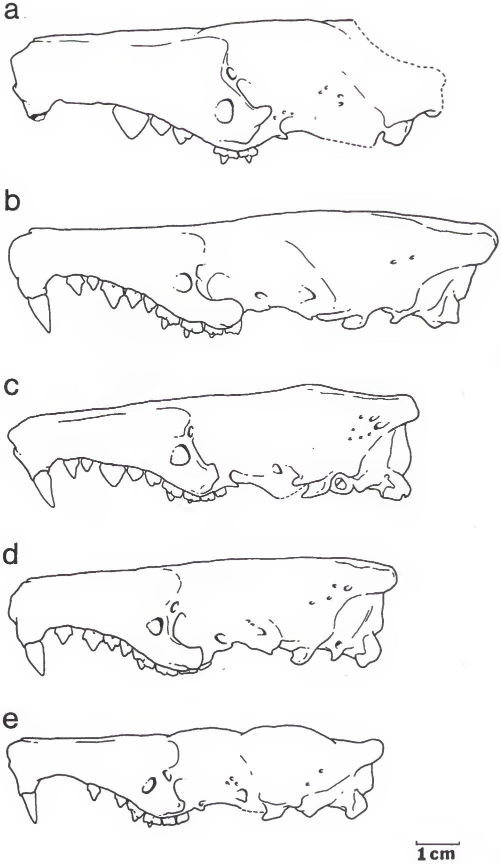

a
b
c
d
e
1 cm

FIG. II-5

Bivariate plot of values of width of the last lower premolar and angular-condylar height of the mandible to show the relationship of samples from north (1, 2, 3) and South (4, 5, 6) Hispaniola.

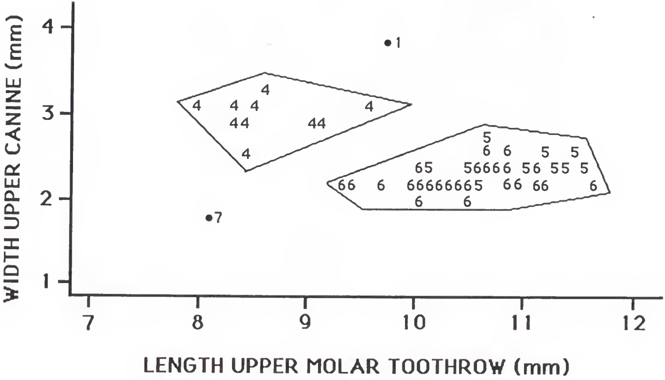

WIDTH UPPER CANINE (mm)
4
3
2
1
7
8
9
10
11
12
LENGTH UPPER MOLAR TOOTHROW (mm)
1
7

FIG. II-6

Dorsal and ventral views of skull showing differences in size between representative specimens of two geographic populations of *Solenodon paradoxus* from Hispaniola. a) *S. paradoxus paradoxus*, north Hispaniola, (JAO 721); b) *S. paradoxus* "new subspecies B", South Hispaniola, (JAO 476).

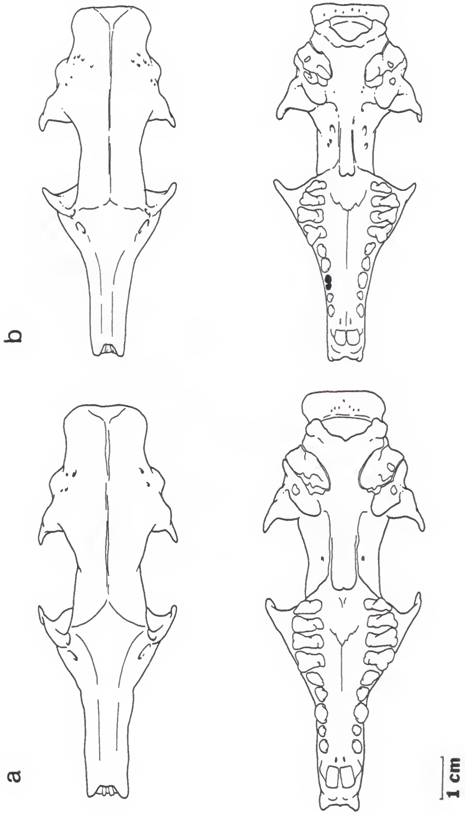

b
a
1 cm

FIG. II-7

Lateral views of the skull and mandible in representative specimens of geographic populations of *Solenodon* from Hispaniola. a) *S*. *paradoxus paradoxus*, north Hispaniola, (JAO 721); b) *S*. *paradoxus* "new subspecies B", South Hispaniola, (JAO 476).

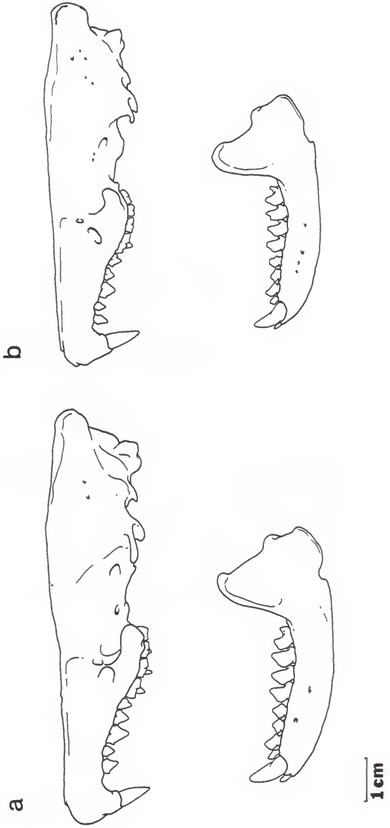

a
b
1cm

FIG. II-8

Dorsal and ventral views of skull in living and extinct species of *Solenodon* from Cuba. a) *Solenodon* "new species A" (MNHNC 421/123); b) *S*. *cubanus* (USNM 37983).

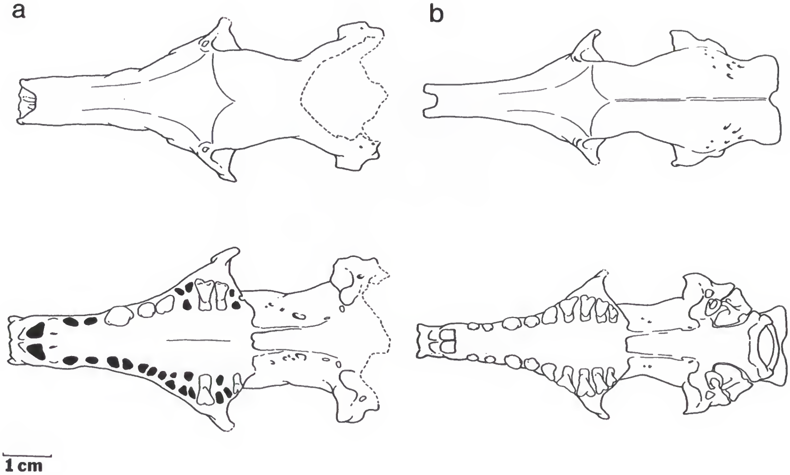

a
b
1 cm

FIG. II-9

Lateral views of the skull and mandible in representative specimens of geographic populations of *Solenodon* from Cuba. a) *Solenodon* "new species A", skull only (MNHNC 421/123); b) *S. cubanus* (USNM 37983).

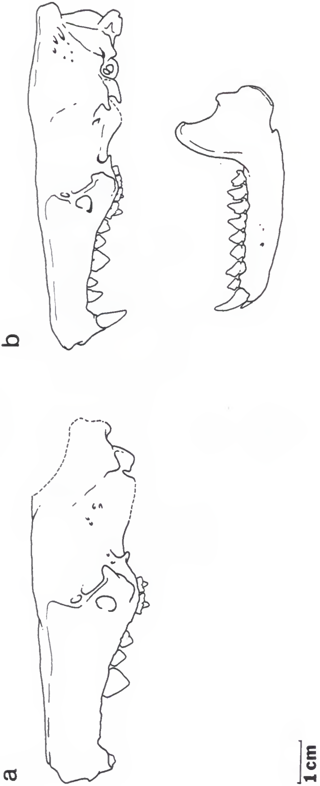

b
a
1 cm

FIG. II-10

Dorsal view of skull of living and extinct Solenodon from Hispaniola. a) S. marcanoi (UF 128162); b) S. paradoxus "new subspecies B", South Hispaniola (JAO 314); c) S. paradoxus paradoxus, north Hispaniola (JAO 721).

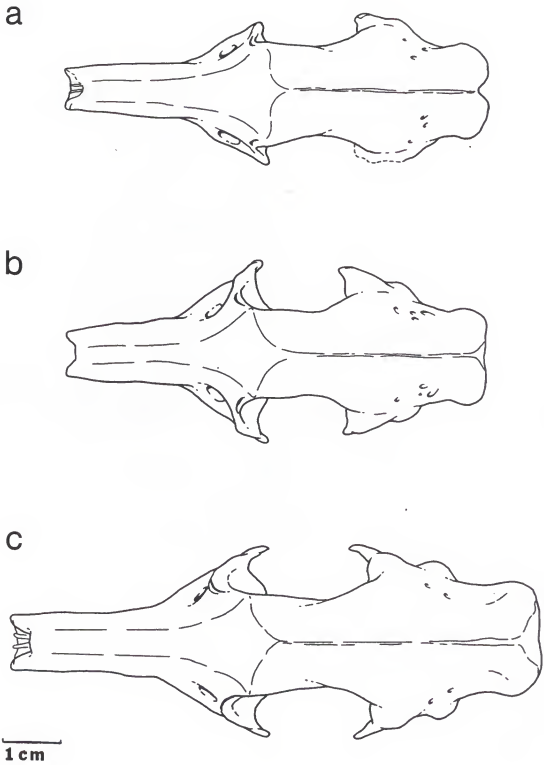

a
b
c
1 cm

FIG. II-11

Ventral view of skull of living and extinct *Solenodon* from Hispaniola. a) *S*. *marcanoi* (UF 128162); b) *S*. *paradoxus* "new subspecies B", South Hispaniola (JAO 314); c) *S*. *paradoxus paradoxus*, north Hispaniola (JAO 721).

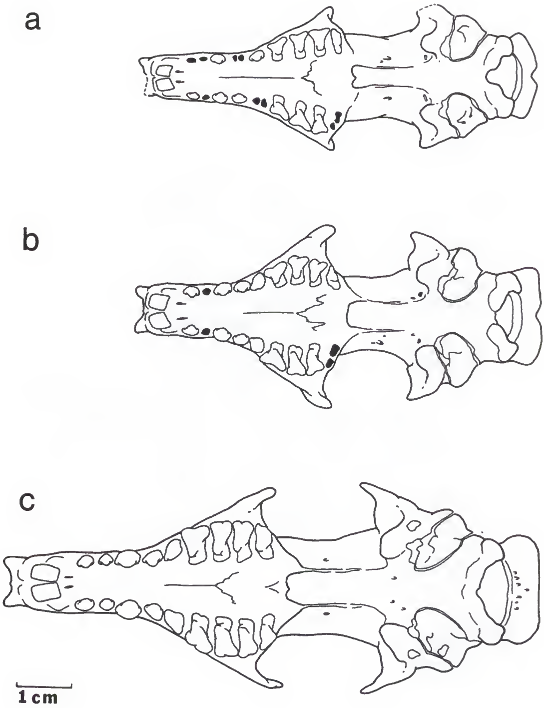

a
b
c
1 cm

FIG. II-12

Lateral view of skull and mandibles of living and extinct *Solenodon* from Hispaniola. a) *S. marcanoi*, (skull UF 128162, mandible UF 128165); b) *S. paradoxus* "new subspecies B", South Hispaniola (JAO 314); c) *S. paradoxus paradoxus*, north Hispaniola (JAO 721).

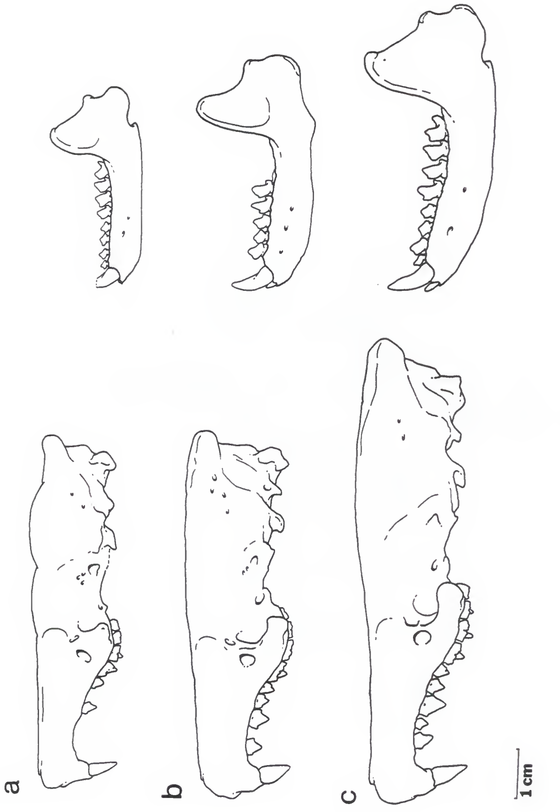

a
b
c
1 cm

FIG. II-13

Femur (F, a-d), humerus (H, e-g), and ulna (U, h-i) of small Hispaniolan *Solenodon*. Late Pleistocene material from Rancho La Guardia, Dominican Republic (type locality), attributed to *S*. *marcanoi*: a) MCZ 20321; b) CM 35036; e) MCZ 7263; h) MCZ 7265. Recent material of extant South Hispaniolan population of *S*. *paradoxus* "new subspecies B" from Sierra de Baoruco, Dominican Republic: c), f), and i) JAO 314. Later Quaternary material of *S*. *marcanoi* from Massif de la Hotte, Haiti: d), g), and j) UF 128174.

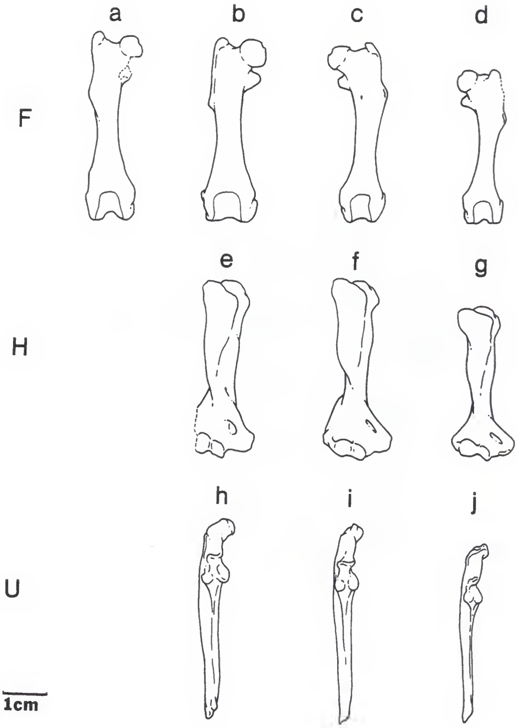

a
b
c
d
F
e
f
g
H
h
i
j
U
1cm

Fig. II-14

Femus (F, a-e) and humeri (H, a-e) of known living and extinct *Solenodon*. a) *Solenodon* "new species A," Cuba, femur JAO 301E, humerus IES/ACC 278; b) *S. cubanus*, Cuba, USNM 49508; c) *S. paradoxus paradoxus*, Dominican Republic, North Hispaniola, JAO 219; d) *S. paradoxus* "new subspecies B," Dominican Republic, South Hispaniola, JAO 314; e) *S. marcanoi*, Haiti, South Hispaniola, UF 128174.

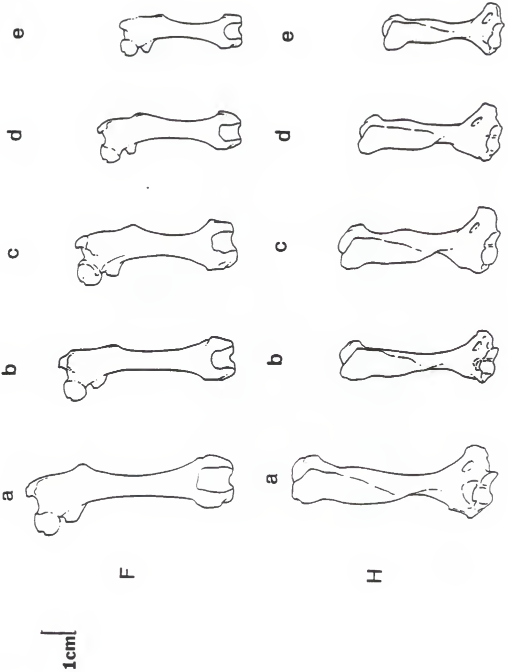

F
H
a
b
c
d
e
a
b
c
d
e
1cm

Table II-1. Secondary sexual variation in cranial, dental and post-cranial measurements of Recent samples of Solenodon from central Dominican Republic, Hispaniola (sample 3), and eastern Cuba (sample 7). Statistics given are number, mean, standard deviation, range, coefficient of variation and F value. Means for males and females that are significantly different at P< 0.05 are marked with an asterisk.

Sample	Sex	N	Mean ± SD	Range	CV	F	P
			Greatest length of skull				
Hisp	M	21	86.1 ± 2.92	81.0-91.5	2.2		
	F	27	86.8 ± 1.91	82.6-90.9	3.4	0.83	0.36
Cuba	M	5	77.7 ± 4.12	71.4-82.4	5.3		
	F	4	78.8 ± 3.03	75.5-82.6	3.9	0.21	0.67
			Condylobasal length				
Hisp	M	20	81.2 ± 2.88	76.0-86.6	2.1		
	F	26	81.0 ± 1.68	77.2-84.6	3.6	0.08	0.78
Cuba	M	5	73.0 ± 3.33	68.5-77.1	4.6		
	F	4	75.0 ± 2.59	71.8-77.8	3.5	0.96	0.36
			Palatal length				
Hisp	M	21	37.6 ± 1.42	34.8-40.4	2.4		
	F	27	37.4 ± 0.91	35.9-39.2	3.8	0.41	0.52
Cuba	M	5	33.9 ± 1.43	31.8-35.7	4.2		
	F	5	34.5 ± 0.94	33.2-35.6	2.7	0.55	0.48
			Postpalatal length				
Hisp	M	20	30.3 ± 1.18	27.6-32.3	2.8		
	F	25	30.7 ± 0.86	29.0-32.6	3.9	2.00	0.16
Cuba	M	5	26.9 ± 1.51	25.0-28.8	5.6		
	F	4	27.6 ± 1.36	26.0-29.3	5.0	0.51	0.50
			Alveolar length of upper molar toothrow				
Hisp	M	20	10.3 ± 0.72	9.1-12.4	6.3		
	F	25	10.4 ± 0.66	9.5-12.9	7.1	0.88	0.35
Cuba	M	5	8.0 ± 0.64	7.3-8.8	8.1		
	F	5	8.1 ± 0.28	7.6-8.4	3.5	0.03	0.88

Table II-1.--(Cont.)

Sample	Sex	N	Mean ± SD	Range	CV	F	P
			Length of upper molar toothrow				
Hisp	M	20	10.9 ± 0.49	9.9-11.8	3.7		
	F	24	11.2 ± 0.42	10.3-12.0	4.5	3.35	0.07
Cuba	M	5	8.7 ± 0.62	8.0-9.6	7.1		
	F	5	8.6 ± 0.34	8.3-9.2	3.9	0.26	0.62
			Length of maxillary toothrow				
Hisp	M	21	26.4 ± 0.79	24.9-27.6	2.3		
	F	24	26.3 ± 0.60	25.2-27.3	3.0	0.07	0.79
Cuba	M	5	23.5 ± 1.21	21.7-24.7	5.2		
	F	5	23.7 ± 0.76	22.6-24.5	3.2	0.15	0.71
			Breadth across maxillary toothrow				
Hisp	M	20	23.6 ± 0.79	22.1-25.6	3.3		
	F	25	24.2 ± 0.81	22.5-25.9	3.4	5.10	0.02*
Cuba	M	5	21.5 ± 1.44	20.3-23.9	6.7		
	F	5	21.2 ± 1.15	20.4-23.3	5.4	0.08	0.79
			Maximum length of C^1				
Hisp	M	5	4.6 ± 0.38	4.3-5.1	2.3		
	F	4	4.4 ± 0.10	4.3-4.6	8.2	1.02	0.34
Cuba	M	5	4.5 ± 0.26	4.1-4.7	5.8		
	F	4	4.5.±.0.33	4.1-4.8	7.4	0.00	0.95
			Maximum width of C^1				
Hisp	M	5	2.4 ± 0.10	2.3-2.6	2.4		
	F	4	2.4 ± 0.58	2.4-2.5	4.4	0.26	0.62
Cuba	M	5	2.9 ± 0.24	2.6-3.2	8.1		
	F	4	2.9 ± 0.11	2.8-3.1	3.7	0.13	0.72
			Maximum width of WM^3				
Hisp	M	20	6.6 ± 0.28	6.0-7.1	5.0		
	F	26	6.7 ± 0.33	6.1-7.5	4.3	0.11	0.75
Cuba	M	5	4.8 ± 0.21	4.6-5.1	4.4		
	F	5	4.7 ± 0.37	4.3-5.3	7.9	0.35	0.57

Table II-1.--(Cont.)

Sample	Sex	N	Mean ± SD	Range	CV	F	P
Anteorbital constriction							
Hisp	M	21	14.0 ± 0.68	13.2-15.9	3.5		
	F	27	14.5 ± 0.50	13.5-15.5	4.9	6.95	0.01*
Cuba	M	5	14.9 ± 0.67	14.3-15.9	4.5		
	F	5	15.1 ± 0.79	14.5-16.4	5.3	0.07	0.80
Zygomatic breadth							
Hisp	M	16	34.3 ± 1.62	31.8-37.4	4.9		
	F	21	35.0 ± 1.70	32.0-39.0	4.7	1.36	0.25
Cuba	M	3	31.4 ± 0.74	30.5-31.9	2.4		
	F	4	32.5 ± 0.71	31.7-33.4	2.2	4.52	0.08
Interorbital constriction							
Hisp	M	21	14.9 ± 0.60	13.9-16.5	3.9		
	F	27	14.8 ± 0.57	13.6-16.3	4.1	0.51	0.48
Cuba	M	5	15.0 ± 0.80	14.4-16.4	5.3		
	F	5	15.4 ± 0.51	15.0-16.3	3.3	0.89	0.37
Squamosal breadth							
Hisp	M	21	32.2 ± 1.34	30.1-34.5	3.7		
	F	27	32.2 ± 1.20	29.2-34.0	4.2	0.01	0.93
Cuba	M	5	30.8 ± 0.76	29.8-31.9	2.5		
	F	4	30.9 ± 0.99	29.5-31.8	3.2	0.03	0.87
Mastoid breadth							
Hisp	M	20	25.9 ± 1.01	24.0-27.6	3.9		
	F	27	26.0 ± 1.01	23.7-28.4	3.9	0.11	0.75
Cuba	M	5	24.5 ± 0.54	23.8-25.0	2.2		
	F	4	24.8 ± 0.30	24.4-25.1	1.2	0.67	0.44
Breadth of the braincase							
Hisp	M	21	25.0 ± 0.96	23.4-26.5	2.5		
	F	26	24.9 ± 0.63	23.7-26.2	3.8	0.16	0.68
Cuba	M	5	25.3 ± 0.86	24.3-26.4	3.4		
	F	4	24.5 ± 0.52	23.9-25.2	2.1	2.47	0.16

Table II-1.--(Cont.)

Sample	Sex	N	Mean ± SD	Range	CV	F	P
Condylar breadth							
Hisp	M	20	17.0 ± 0.72	15.7-18.0	4.3		
	F	26	16.9 ± 0.73	15.3-18.4	4.2	0.58	0.45
Cuba	M	5	15.9 ± 0.68	15.0-16.6	4.3		
	F	4	16.4 ± 0.79	15.7-17.2	4.8	1.01	0.35
Skull height							
Hisp	M	21	19.7 ± 1.05	17.3-21.3	4.5		
	F	26	20.3 ± 0.92	18.3-22.2	5.3	3.69	0.06
Cuba	M	5	19.0 ± 1.11	17.8-20.6	5.9		
	F	4	19.1 ± 0.63	18.1-19.6	3.3	0.01	0.92
Greatest mandible length							
Hisp	M	21	54.1 ± 1.94	50.9-58.1	2.2		
	F	27	54.5 ± 1.19	52.4-56.7	3.6	0.74	0.39
Cuba	M	5	48.8 ± 2.77	44.6-51.9	5.7		
	F	4	49.0 ± 1.55	47.1-50.4	3.2	0.01	0.91
Mandibular toothrow							
Hisp	M	21	27.3 ± 0.91	25.4-28.9	2.3		
	F	26	27.4 ± 0.64	26.1-28.8	3.3	0.22	0.64
Cuba	M	5	24.8 ± 1.25	22.9-26.1	5.1		
	F	5	25.4 ± 0.84	24.5-26.3	3.3	0.65	0.44
Alveolar length of P_4-M_3							
Hisp	M	21	17.1 ± 0.67	15.8-18.5	3.3		
	F	24	17.4 ± 0.57	16.2-18.4	3.9	2.00	0.16
Cuba	M	5	14.1 ± 0.53	13.5-14.7	3.8		
	F	5	14.1 ± 0.50	13.6-14.8	3.5	0.05	0.83
Depth through coronoid process of mandible							
Hisp	M	19	23.9 ± 1.17	22.3-26.0	4.2		
	F	27	24.2 ± 1.01	22.2-25.7	4.9	0.82	0.37
Cuba	M	5	22.4 ± 0.94	21.4-23.9	4.2		
	F	5	23.2 ± 0.85	22.2-24.2	3.7	2.0	0.20

Table II-1.--(Cont.)

Sample	Sex	N	Mean ± SD	Range	CV	F	P
			Angular-condylar height				
Hisp	M	21	15.1 ± 0.75	13.9-16.4	5.1		
	F	27	15.1 ± 0.77	13.4-16.9	4.9	0.05	0.83
Cuba	M	5	13.2 ± 1.15	12.0-14.7	8.7		
	F	4	13.6 ± 0.65	13.2-14.6	4.8	0.46	0.52
			Maximum length of P_4				
Hisp	M	20	4.3 ± 0.21	4.0-4.9	5.4		
	F	26	4.3 ± 0.23	3.7-4.7	5.0	0.18	0.68
Cuba	M	5	3.9 ± 0.53	3.3-4.7	13.6		
	F	5	3.9 ± 0.14	3.7-4.1	3.7	0.01	0.94
			Maximum width of P_4				
Hisp	M	20	3.3 ± 0.15	3.1-3.7	4.4		
	F	26	3.3 ± 0.15	3.1-3.6	4.4	0.56	0.46
Cuba	M	5	3.2 ± 0.13	3.1-3.4	3.9		
	F	5	3.2 ± 0.28	3.0-3.7	8.5	0.02	0.90
			Maximum length of M_1				
Hisp	M	19	4.6 ± 0.28	4.0-5.0	6.9		
	F	26	4.6 ± 0.31	4.0-5.1	6.2	0.09	0.77
Cuba	M	5	3.8 ± 0.15	3.6-4.0	3.9		
	F	5	3.7 ± 0.35	3.2-4.1	9.5	0.45	0.52
			Maximum width of M_1				
Hisp	M	19	4.3 ± 0.15	4.1-4.6	3.5		
	F	26	4.3 ± 0.15	4.1-4.7	3.6	1.25	0.27
Cuba	M	5	3.9 ± 0.23	3.7-4.2	5.7		
	F	5	3.7 ± 0.14	3.5-4.0	3.8	2.89	0.13
			Maximum length of M_2				
Hisp	M	20	4.6 ± 0.29	4.2-5.4	4.7		
	F	25	4.6 ± 0.22	4.3-5.1	6.3	0.02	0.88
Cuba	M	5	3.6 ± 0.10	3.4-3.7	2.8		
	F	5	3.7 ± 0.27	3.4-4.0	7.4	0.14	0.72

Table II-1.--(Cont.)

Sample	Sex	N	Mean ± SD	Range	CV	F	P
Maximum width of M_2							
Hisp	M	20	4.3 ± 0.17	4.1-4.6	3.2		
	F	25	4.3 ± 0.14	4.1-4.7	3.9	3.10	0.08
Cuba	M	5	3.7 ± 0.15	3.5-3.9	4.2		
	F	5	3.6 ± 0.16	3.3-3.8	4.5	2.37	0.16
Maximum length of M_3							
Hisp	M	20	5.3 ± 0.28	4.7-5.8	4.9		
	F	25	5.3 ± 0.26	4.7-5.7	5.3	0.15	0.69
Cuba	M	5	4.3 ± 0.16	4.1-4.5	3.8		
	F	5	4.1 ± 0.20	3.9-4.4	4.8	5.26	0.051
Maximum width of M_3							
Hisp	M	20	3.5 ± 0.15	3.3-3.8	5.1		
	F	25	3.5 ± 0.18	3.1-3.9	4.2	0.20	0.66
Cuba	M	5	2.8 ± 0.19	2.5-3.0	6.7		
	F	5	2.7 ± 0.31	2.2-3.0	11.5	0.55	0.48
Total length of femur							
Hisp	M	10	46.4 ± 1.76	43.3-48.6	3.2		
	F	17	47.0 ± 1.52	44.9-50.4	3.8	1.12	0.30
Cuba	M	2	46.6 ± 1.41	45.6-47.6	3.0		
	F	1	46.5				
Maximun width of femur							
Hisp	M	11	13.4 ± 0.53	12.3-13.9	3.1		
	F	17	13.5 ± 0.42	12.8-14.3	4.0	0.45	0.51
Cuba	M	3	12.8 ± 0.86	12.2-13.8	6.8		
	F	1	12.6				
Minimum shaft width of femur							
Hisp	M	11	5.2 ± 0.24	4.9-5.6	4.4		
	F	17	5.3 ± 0.23	5.0-5.8	4.5	1.05	0.32
Cuba	M	3	4.4 ± 0.46	4.1-4.9	10.5		
	F	1	4.5				

Table II-1.--(Cont.)

Sample	Sex	N	Mean ± SD	Range	CV	F	P
Total length of humerus							
Hisp	M	10	47.9 ± 1.61	45.5-49.7	3.1		
	F	17	48.1 ± 1.48	45.6-50.7	3.4	0.16	0.69
Cuba	M	3	42.5 ± 1.84	41.1-44.6	4.3		
	F	1	42.6				
Maximun width of humerus							
Hisp	M	11	17.9 ± 0.61	16.7-18.5	3.1		
	F	17	18.0 ± 0.56	17.0-18.8	3.4	0.17	0.68
Cuba	M	3	15.0 ± 0.66	14.4-15.7	4.4		
	F	1	15.9				
Minimum shaft width of humerus							
Hisp	M	11	5.1 ± 0.25	4.6-5.4	6.0		
	F	17	5.0 ± 0.30	4.6-5.8	5.0	0.72	0.40
Cuba	M	3	3.9 ± 8.90	3.8-4.0	2.3		
	F	1	4.0				
Total length of ulna							
Hisp	M	6	54.2 ± 2.72	50.3-58.0	3.3		
	F	11	52.5 ± 1.73	50.3-56.2	5.0	2.50	0.13
Cuba	M	2	48.6 ± 1.15	47.8-49.5	2.4		
	F	2	51.0 ± 2.62	49.1-52.8	5.1	1.30	0.37
Maximum width of ulna							
Hisp	M	6	7.1 ± 0.21	6.8-7.4	5.8		
	F	11	7.0 ± 0.41	6.2-7.6	3.1	0.48	0.50
Cuba	M	2	6.6 ± 0.56	6.1-7.2	8.6		
	F	2	6.9 ± 0.63	6.4-7.3	9.2	0.28	0.34
Minimum shaft width of ulna							
Hisp	M	6	2.2 ± 0.16	2.0-2.4	8.5		
	F	11	2.0 ± 0.17	1.7-2.3	7.2	3.08	0.09
Cuba	M	3	1.6 ± 0.26	1.3-1.9	16.2		
	F	2	1.7 ± 9.89	1.6-1.7	5.9	0.12	0.75

Table II-1.--(Cont.)

Sample	Sex	N	Mean ± SD	Range	CV	F	P
			Total length				
Hisp	M	27	529 ± 27.9	485-580	5.3		
	F	22	549 ± 43.2	498-715	7.9	3.82	0.05
Cuba	M	4	462 ± 47.4	429-530	10.3		
	F	6	426 ± 80.1	325-530	18.8	0.65	0.55
			Head-body length				
Hisp	M	13	296 ± 13.8	273-320	4.7		
	F	8	325 ± 67.3	286-490	20.7	2.28	0.14
Cuba	M	4	301 ± 47.9	260-360	15.9		
	F	6	253 ± 55.8	195-340	22.0	1.39	0.30
			Tail length				
Hisp	M	26	224 ± 14.3	202-254	6.4		
	F	22	227 ± 11.7	196-242	5.1	0.69	0.41
Cuba	M	4	161 ± 14.4	140-170	8.9		
	F	6	162 ± 23.9	130-190	14.8	0.19	0.83
			Hindfoot length				
Hisp	M	20	63.5 ± 4.9	56-72	7.8		
	F	17	64.7 ± 4.1	57-70	6.3	0.68	0.42
Cuba	M	4	52.0 ± 5.0	45-56	9.6		
	F	6	54.2 ± 2.6	50-56	4.7	5.08	0.03
			Ear length				
Hisp	M	22	28.5 ± 2.2	22-31	7.8		
	F	15	28.9 ± 4.1	21-38	14.2	0.12	0.72
Cuba	M	4	24.0 ± 8.2	15-31	34.4		
	F	6	28.8 ± 2.7	25-32	9.4	1.08	0.39
			Body weight (g)				
Hisp	M	17	801.4 ± 88.1	620-1080	11.0		
	F	8	860.7 ± 165.	726-1166	19.2	1.40	0.25
Cuba	M	2	769.0 ± 55.1	730-808	7.1		

Table II-2. Geographic variation in cranial and post-cranial measurements of seven samples of extant _Solenodon_ populations from north Hispaniola (samples 1, 2 and 3, Dominican Republic), South Hispaniola (samples 4, 5, Dominican Republic; and 6, Haiti) and eastern Cuba (sample 7). Statistics given are number, mean, standard deviation, range, coefficient of variation, F and P values, and results of Duncan's multiple range test (<0.05) showing nonsignificant subsets. Sample means that are significantly different are marked with asterisks: *(<0.05), **(<0.01), ***(<0.001). See Figure 2 and text for key to sample numbers.

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's		
			Greatest length of skull					
3	55	86.5 ± 2.36	81.0-91.5	2.7		I		
1	4	85.8 ± 3.51	82.7-90.9	4.1		I		
2	16	85.3 ± 2.25	80.9-88.4	2.6		I		
4	11	80.7 ± 2.21	76.3-83.1	2.7	33.36^{***}		I	
6	16	80.5 ± 2.18	76.2-83.5	2.7	0.0001		I	I
5	10	79.8 ± 2.90	72.3-82.6	3.6			I	I
7	12	78.2 ± 3.51	71.4-82.8	4.5				I
			Condylobasal length					
3	53	81.1 2.30	76.0-86.6	2.8		I		
1	4	80.3 ± 3.22	77.0-84.2	4.0		I		
2	16	79.9 ± 2.16	75.5-82.7	2.7		I		
6	16	76.4 ± 1.93	73.4-79.4	2.5	25.94^{***}		I	
4	11	75.7 ± 2.53	71.2-78.4	3.3	0.0001		I	I
5	10	75.2 ± 3.15	67.1-78.9	4.2			I	I
7	12	73.9 ± 2.87	68.6-77.8	3.9				I
			Palatal length					
3	55	37.4 ± 1.15	34.8-40.4	3.1		I		
2	16	37.1 ± 1.05	35.0-38.6	2.8		I		
1	4	37.0 ± 0.89	36.4-38.3	2.4		I		
6	19	35.5 ± 0.94	34.0-37.0	2.7	31.49^{***}		I	
4	12	34.5 ± 1.10	32.8-35.8	3.2	0.0001		I	I
7	14	34.3 ± 1.07	31.8-35.7	3.1				I
5	10	34.1 ± 1.44	30.8-35.7	4.2				I

Table II-2.(Cont.)

Sample					F	Results			
No	N	Mean ± SD	Range	CV	P	Duncan's			
			Postpalatal length						
1	4	31.0 ± 2.05	28.2-32.6	6.7		I			
3	52	30.5 ± 1.02	27.6-32.3	3.4		I			
2	18	30.1 ± 1.22	27.9-32.0	4.1		I	I		
4	11	29.1 ± 1.4	26.8-31.2	4.7	17.69***		I	I	
6	17	29.0 ± 0.97	27.6-31.0	3.4	0.0001			I	
5	10	28.8 ± 1.36	25.6-30.2	4.7				I	
7	12	27.1 ± 1.27	25.0-29.3	4.7					I
			Alveolar length of upper molar toothrow						
1	4	10.5 ± 0.11	10.4-10.6	1.0		I			
3	52	10.3 ± 0.67	9.1-12.9	6.5		I			
2	18	10.9 ± 0.38	10.4-11.7	3.5		I	I		
6	21	9.7 ± 0.50	8.7-10.6	5.2	26.37***		I	I	
4	12	9.6 ± 0.68	7.9-10.7	7.1	0.0001		I	I	
5	10	9.5 ± 0.60	8.4-10.4	6.3				I	
7	14	8.2 ± 0.62	7.3-9.8	7.6					I
			Length of upper molar toothrow						
3	51	11.1 ± 0.45	9.9-12.0	4.1		I			
2	18	10.9 ± 0.38	10.4-11.7	3.5		I			
1	4	10.9 ± 0.30	10.6-11.3	2.8		I			
6	18	10.7 ± 0.39	10.0-11.6	3.6	57.05***	I			
4	12	10.3 ± 0.41	9.6-11.1	4.0	0.0001		I		
5	10	10.1 ± 0.55	9.3-11.0	5.5			I		
7	12	8.6 ± 0.44	8.0-9.6	5.1				I	
			Length of maxillary toothrow						
3	52	26.3 ± 0.76	24.5-27.6	2.9		I			
1	4	25.7 ± 0.75	25.1-26.8	2.9		I			
2	18	25.6 ± 0.93	23.6-27.5	3.6		I			
6	21	24.5 ± 0.75	23.5-25.7	3.1	38.08***		I		
4	12	24.2 ± 0.81	23.0-25.7	3.3	0.0001		I	I	
7	14	23.7 ± 0.87	21.8-24.7	3.7				I	
5	10	23.5 ± 0.95	21.6-25.1	4.1				I	

Table II-2.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's		
Breadth across maxillary toothrow								
3	52	23.9 ± 0.87	21.7-25.9	3.7		I		
1	4	23.2 ± 0.50	22.7-23.9	2.2		I		
2	17	23.2 ± 1.04	21.3-25.3	4.5		I		
6	21	23.1 ± 0.73	22.1-24.9	3.2	23.07^{***}	I		
4	12	21.7 ± 1.24	19.6-23.8	5.7	0.0001		I	
7	14	21.5 ± 1.16	20.3-23.9	5.4			I	
5	10	21.2 ± 1.01	19.2-22.5	4.8			I	
Anteorbital constriction								
7	14	15.0 ± 0.72	14.3-16.4	4.8		I		
3	55	14.2 ± 0.65	12.9-15.9	4.6			I	
1	4	13.8 ± 0.34	13.4-14.2	2.5			I	I
2	17	13.8 ± 0.81	12.6-15.1	5.9	9.90^{***}		I	I
6	21	13.6 ± 0.61	12.6-14.6	4.5	0.0001			I
4	12	13.5 ± 0.40	12.7-14.3	3.0				I
5	10	13.5 ± 1.08	11.6-14.9	8.1				I
Zygomatic breadth								
3	43	34.5 ± 1.68	31.5-39.0	4.9		I		
2	15	33.4 ± 1.79	30.3-35.8	5.4		I	I	
1	4	33.2 ± 1.15	31.9-34.4	3.5		I	I	
5	9	32.8 ± 1.06	31.2-34.5	3.2	8.07^{***}		I	
7	9	32.4 ± 1.31	30.5-35.2	4.0	0.0001		I	
4	11	32.4 ± 1.26	30.1-34.9	3.9			I	
6	18	32.2 ± 0.89	30.1-34.2	2.8			I	
Interorbital constriction								
7	13	15.2 ± 0.62	14.5-16.4	4.1		I		
1	5	15.1 ± 0.38	14.7-15.7	2.6		I	I	
3	55	14.9 ± 0.58	13.6-16.5	3.9		I	I	I
2	17	14.9 ± 0.50	13.6-15.9	3.4	2.02	I	I	I
6	20	14.7 ± 0.44	13.7-15.4	3.0	0.06	I	I	I
4	11	14.6 ± 0.43	14.0-15.4	3.0			I	I
5	10	14.5 ± 0.48	13.6-15.6	3.3				I

Table II-2.(Cont.)

Sample No	 N	Mean ± SD	Range	CV	F P	Results Duncan's		
			Squamosal breadth					
3	55	32.1 ± 1.29	29.2-34.5	4.0		I		
1	5	31.4 ± 0.92	30.3-32.7	2.9		I	I	
7	12	30.9 ± 0.79	29.6-31.9	2.6			I	I
6	18	30.3 ± 0.92	28.9-31.6	3.0	11.46^{***}			I
2	17	30.2 ± 1.55	28.2-33.3	5.1	0.0001			I
4	11	30.2 ± 0.65	29.0-31.3	2.2				I
5	9	30.2 ± 0.83	28.6-31.6	2.8				I
			Mastoid breadth					
3	54	25.9 ± 1.01	23.7-28.4	3.9		I		
1	4	25.6 ± 1.25	23.8-26.6	4.9		I	I	
2	18	25.5 ± 0.94	23.5-27.1	3.7		I	I	
6	16	25.0 ± 0.75	23.7-26.1	3.0	9.29^{***}		I	I
5	9	24.6 ± 1.13	22.6-26.6	4.6	0.0001			I
7	12	24.6 ± 0.67	23.0-25.6	2.7				I
4	11	24.2 ± 0.54	23.4-25.1	2.3				I
			Breadth of the braincase					
7	12	25.1 ± 0.82	24.0-26.4	3.3		I		
3	54	24.9 ± 0.79	23.4-26.6	3.2		I	I	
1	5	24.5 ± 0.59	23.6-25.3	2.4		I	I	I
6	19	24.4 ± 0.64	23.1-25.2	2.7	4.85^{***}		I	I
2	18	24.3 ± 0.75	23.0-25.7	3.1	0.0002		I	I
4	11	24.2 ± 0.51	23.7-25.2	2.1				I
5	9	24.0 ± 0.93	22.0-25.3	3.9				I
			Condylar breadth					
3	53	17.0 ± 0.70	15.3-18.4	4.1		I		
2	18	16.8 ± 0.65	15.6-18.4	3.9		I	I	
1	4	16.7 ± 0.51	16.2-17.4	3.0		I	I	I
6	17	16.3 ± 0.49	14.8-16.8	3.0	6.95^{***}		I	I
5	10	16.2 ± 0.77	15.2-17.4	4.8	0.0001		I	I
7	12	16.1 ± 0.70	15.0-17.2	4.4				I
4	11	16.0 ± 0.55	15.4-16.9	3.4				I

Table II-2.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's			
			Skull height						
3	54	20.0 ± 0.96	17.3-22.2	4.8		I			
7	11	19.2 ± 0.89	17.8-20.6	4.7		I	I		
2	18	19.0 ± 1.38	17.0-21.3	7.3			I		
1	5	18.9 ± 1.19	17.4-20.5	6.3	6.76***		I		
6	17	18.8 ± 1.35	15.2-20.7	7.2	0.0001		I		
4	11	18.6 ± 1.03	17.3-20.5	5.6			I		
5	10	18.2 ± 1.19	16.5-20.4	6.6			I		
			Maximum length of C^1						
3	12	4.5 ± 0.37	3.9-5.2	8.3		I			
7	12	4.5 ± 0.27	4.1-4.8	6.1		I	I		
6	22	4.2 ± 0.28	3.8-4.7	6.7			I	I	
2	9	4.2 ± 0.19	3.9-4.5	4.5	19.64***		I	I	
1	4	4.2 ± 0.27	3.8-4.3	6.6	0.0001			I	
5	9	3.7 ± 0.20	3.3-4.0	5.6					I
4	9	3.5 ± 0.24	3.0-3.9	6.9					I
			Maximum width of C^1						
7	12	3.0 ± 0.16	2.6-3.2	5.7		I			
3	12	2.4 ± 0.97	2.2-2.6	4.1			I		
1	4	2.3 ± 0.19	2.1-2.6	8.1			I		
2	9	2.3 ± 0.85	2.1-2.4	3.7	69.66***		I		
6	22	2.3 ± 0.12	2.0-2.5	5.6	0.0001		I		
5	9	2.1 ± 0.59	2.0-2.2	2.8				I	
4	9	2.1 ± 0.59	2.0-2.2	2.8				I	
			Maximum width of M^3						
3	53	6.6 ± 0.35	5.2-7.5	5.4		I			
1	4	6.2 ± 0.17	6.1-6.4	2.9			I		
2	18	6.2 ± 0.58	5.4-7.7	9.3			I		
6	19	5.7 ± 0.38	5.2-6.7	6.8	39.06***			I	
5	10	5.5 ± 0.47	4.8-6.4	8.6	0.0001			I	
4	12	5.4 ± 0.84	4.4-7.2	15.4				I	
7	12	4.7 ± 0.31	4.2-5.3	6.6					I

Table II-2.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's				
			Greatest mandible length							
3	55	54.2 ± 1.58	50.9-58.1	2.9		I				
1	6	53.6 ± 1.35	51.8-55.3	2.5		I	I			
2	17	52.8 ± 1.39	50.9-55.3	2.6			I			
6	23	50.6 ± 1.48	47.7-52.6	2.9	38.99***			I		
4	11	50.2 ± 1.31	47.4-51.6	2.6	0.0001			I	I	
5	9	49.2 ± 1.58	45.2-50.5	3.2					I	I
7	13	48.9 ± 1.97	44.7-51.9	4.0						I
			Length of mandibular toothrow							
3	54	27.3 ± 0.79	25.1-28.9	2.9		I				
1	6	26.9 ± 0.63	25.9-27.7	2.3		I				
2	18	26.7 ± 1.31	23.3-28.2	4.9		I				
6	24	25.7 ± 0.76	24.3-27.4	3.2	25.28***		I			
4	11	25.4 ± 0.76	24.1-26.3	3.0	0.0001		I			
7	14	25.2 ± 0.93	23.0-26.3	3.7			I	I		
5	9	24.6 ± 0.85	23.5-26.3	3.5				I		
			Alveolar length of P_4-M_3							
1	6	17.3 ± 0.46	16.7-17.9	2.7		I				
3	52	17.2 ± 0.68	14.9-18.5	4.0		I				
2	18	16.9 ± 0.74	15.8-18.2	4.4		I				
6	24	16.1 ± 0.51	15.4-17.3	3.2	55.22***		I			
4	11	16.0 ± 0.53	15.3-16.8	3.3	0.0001		I			
5	9	15.4 ± 0.59	14.6-16.7	3.8				I		
7	14	14.2 ± 0.44	13.5-14.8	3.1					I	
			Depth through coronoid process							
3	53	24.1 ± 1.09	22.2-26.2	4.5		I				
1	6	23.3 ± 1.08	22.0-24.5	4.7		I	I			
2	17	23.0 ± 1.31	20.6-25.0	5.7			I	I		
4	11	22.9 ± 0.79	21.5-23.9	3.5	10.96***		I	I		
7	14	22.5 ± 1.13	20.6-24.2	5.0	0.0001		I	I		
6	23	22.5 ± 0.82	20.6-23.6	3.7			I	I		
5	9	22.2 ± 0.89	21.1-24.1	4.0				I		

Table II-2.(Cont.)

Sample					F	Results		
No	N	Mean ± SD	Range	CV	P	Duncan's		
Angular-condylar height								
3	55	15.0 ± 0.81	13.4-17.1	5.4		I		
1	6	14.7 ± 0.68	13.9-15.6	4.6		I		
2	17	13.8 ± 0.86	12.2-15.6	6.2			I	
7	13	13.2 ± 0.90	12.1-14.7	6.8	33.76^{***}			I
4	11	13.1 ± 1.00	12.6-15.1	7.6	0.0001			I
6	24	12.9 ± 0.52	12.0-14.0	4.0				I
5	9	12.8 ± 0.62	11.9-13.8	4.8				I
Maximum length of P_4								
1	5	4.4 ± 0.27	3.9-4.7	6.3		I		
3	53	4.3 ± 0.23	3.7-4.9	5.6		I		
2	17	4.2 ± 0.23	3.8-4.7	5.5		I		
6	23	3.9 ± 0.29	3.5-4.9	7.4	12.33^{***}		I	
4	11	3.9 ± 0.38	3.5-4.6	9.8	0.0001		I	
7	13	3.9 ± 0.32	3.4-4.7	8.4			I	
5	9	3.7 ± 0.24	3.5-4.2	6.6			I	
Maximum width of P_4								
3	53	3.3 ± 0.17	2.7-3.7	5.6		I		
1	5	3.3 ± 0.15	3.1-3.4	4.6		I		
7	13	3.2 ± 0.18	3.1-3.7	5.7		I		
2	18	3.2 ± 0.31	2.8-3.8	9.6	28.65^{***}	I		
6	23	2.8 ± 0.20	2.3-3.1	7.1	0.0001		I	
4	10	2.7 ± 0.18	2.6-3.2	6.4			I	
5	9	2.7 ± 0.28	2.2-3.2	10.4			I	
Maximum length of M_1								
1	4	4.8 ± 0.19	4.6-5.0	4.1		I		
3	52	4.6 ± 0.30	4.0-5.1	6.5		I		
2	18	4.6 ± 0.19	4.1-4.8	4.1		I		
6	23	4.5 ± 0.20	4.2-5.0	4.5	23.81^{***}	I		
4	11	4.3 ± 0.27	4.0-4.9	6.1	0.0001		I	
5	9	4.2 ± 0.24	4.0-4.7	5.6			I	
7	13	3.7 ± 0.29	3.2-4.1	7.9				I

Table II-2.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's			
Maximum width of M_1									
3	52	4.3 ± 0.17	3.8-4.7	4.1		I			
1	4	4.2 ± 0.85	4.1-4.3	2.1		I	I		
2	18	4.2 ± 0.22	3.9-4.7	5.3		I	I		
6	23	4.1 ± 0.18	3.8-4.4	4.3	22.17^{***}		I		
7	13	3.9 ± 0.19	3.6-4.2	5.0	0.0001			I	
4	10	3.8 ± 0.29	3.5-4.6	7.8				I	I
5	9	3.7 ± 0.26	3.3-4.2	7.1					I
Maximum length of M_2									
3	52	4.6 ± 0.26	4.0-5.4	5.6		I			
1	5	4.6 ± 0.19	4.4-4.9	4.1		I			
2	18	4.6 ± 0.25	4.1-5.0	5.4		I			
6	22	4.5 ± 0.20	4.1-5.0	4.6	35.19^{***}	I			
4	11	4.5 ± 0.20	4.2-4.8	4.5	0.0001	I			
5	8	4.2 ± 0.16	3.9-4.4	3.9			I		
7	13	3.6 ± 0.18	3.4-4.0	5.2				I	
Maximum width of M_2									
3	52	4.3 ± 0.17	3.8-4.7	4.0		I			
1	6	4.2 ± 0.11	4.1-4.4	2.7		I			
2	18	4.2 ± 0.20	3.9-4.7	4.8		I			
6	22	4.1 ± 0.17	3.8-4.5	4.0	33.59^{***}	I			
4	10	3.9 ± 0.25	3.7-4.5	6.5	0.0001		I		
5	8	3.7 ± 0.23	3.5-4.3	6.1			I	I	
7	13	3.6 ± 0.15	3.4-3.9	4.3				I	
Maximum length of M_3									
3	52	5.3 ± 0.27	4.7-5.8	5.2		I			
1	5	5.3 ± 0.10	5.2-5.4	1.8		I			
2	18	5.1 ± 0.25	4.7-5.9	4.9		I	I		
6	18	5.0 ± 0.23	4.4-5.4	4.7	36.03^{***}		I		
4	11	4.9 ± 0.26	4.5-5.3	5.3	0.0001		I	I	
5	9	4.7 ± 0.28	4.3-5.3	6.0				I	
7	13	4.2 ± 0.22	3.9-4.5	5.2					I

Table II-2.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's			
Maximum width of M_3									
3	52	3.5 ± 0.19	3.0-4.0	5.5		I			
1	5	3.5 ± 0.17	3.3-3.7	5.0		I			
2	18	3.5 ± 0.19	3.1-3.9	5.6		I			
6	18	3.3 ± 0.11	3.1-3.5	3.5	22.99***	I			
4	11	3.1 ± 0.30	2.9-3.9	9.6	0.0001		I		
5	9	3.0 ± 0.19	2.7-3.4	6.4			I	I	
7	13	2.9 ± 0.39	2.2-3.9	13.5				I	
Total length of femur									
1	3	47.1 ± 1.35	45.7-48.3	2.9		I			
3	29	46.8 ± 1.61	43.3-50.4	3.4		I			
7	5	46.7 ± 0.78	45.6-47.6	1.7		I			
2	10	46.3 ± 1.40	44.3-48.8	3.0	10.94***	I			
6	24	44.8 ± 1.44	42.4-47.6	3.2	0.0001		I		
4	10	43.8 ± 1.40	41.4-45.5	3.2			I		
5	8	43.6 ± 1.43	41.0-45.8	3.3			I		
Maximum width of femur									
3	30	13.4 ± 0.45	12.3-14.3	3.4		I			
1	4	13.3 ± 0.49	12.8-14.0	3.7		I			
2	10	13.3 ± 0.80	12.3-14.6	6.1		I			
7	6	12.7 ± 0.61	12.1-13.8	4.8	9.90***		I		
4	9	12.6 ± 0.42	11.9-13.3	3.3	0.0001		I		
5	8	12.5 ± 0.55	11.6-13.3	4.4			I		
6	25	12.4 ± 0.56	11.4-13.4	4.5			I		
Minimum shaft width of femur									
1	4	5.5 ± 0.59	5.2-6.4	10.7		I			
2	10	5.4 ± 0.35	4.8-5.9	6.6		I	I		
3	30	5.3 ± 0.24	4.9-5.8	4.7		I	I		
5	8	5.1 ± 0.43	4.6-6.0	8.4	11.96***		I	I	
4	10	5.1 ± 0.40	4.5-5.7	8.0	0.0001		I	I	
6	25	4.7 ± 0.24	4.3-5.4	5.1				I	
7	6	4.5 ± 0.31	4.1-4.9	6.9					I

Table II-2.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's		
			Total length of humerus					
3	29	48.0 ± 1.45	45.5-50.7	3.0		I		
1	3	47.1 ± 0.52	46.7-47.7	1.1		I		
2	11	46.8 ± 1.54	43.9-49.0	3.3		I		
4	8	44.2 ± 1.23	42.2-45.4	2.9	27.90***		I	
6	21	44.0 ± 1.36	40.6-46.8	3.1	0.0001		I	
5	8	43.9 ± 1.30	41.3-45.6	3.0			I	
7	5	42.6 ± 1.35	41.2-44.6	3.2			I	
			Maximum width of humerus					
3	30	17.9 ± 0.59	16.7-18.8	3.3		I		
1	3	17.9 ± 0.35	17.6-18.3	2.0		I		
2	11	17.8 ± 0.53	16.8-18.5	3.0		I		
6	22	17.3 ± 0.57	16.1-18.2	3.3	23.51***	I	I	
5	8	17.0 ± 0.78	16.0-18.3	4.6	0.0001		I	
4	10	16.8 ± 0.65	15.8-18.1	3.9			I	
7	6	14.9 ± 0.75	14.1-15.9	5.0				I
			Minimum shaft width of humerus					
1	3	5.2 ± 0.28	4.9-5.4	5.5		I		
6	21	5.0 ± 0.23	4.5-5.4	4.5		I		
3	30	5.0 ± 0.29	4.6-5.8	5.7		I		
2	11	5.0 ± 0.35	4.4-5.5	7.1	15.25***	I		
5	8	4.9 ± 0.34	4.5-5.5	7.0	0.0001	I		
4	10	4.9 ± 0.30	4.3-5.4	6.2		I		
7	6	3.9 ± 0.70	3.8-4.0	1.8			I	
			Total length of ulna					
1	3	53.6 ± 1.13	52.3-54.3	2.1		I		
3	19	53.2 ± 2.09	50.3-58.0	3.9		I		
2	8	52.2 ± 1.39	50.0-54.0	2.7		I		
6	17	51.1 ± 1.13	49.0-53.4	2.2	4.66***	I		
4	7	51.1 ± 1.59	49.3-53.8	3.1	0.0006	I	I	
7	6	49.6 ± 1.90	47.8-52.8	3.8			I	
5	6	49.4 ± 4.53	40.6-53.8	9.2			I	

Table II-2.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's				
Maximum width of ulna										
3	19	7.0 ± 0.33	6.2-7.6	4.7		I				
1	4	6.9 ± 0.39	6.4-7.2	5.7		I				
2	8	6.8 ± 0.47	6.0-7.4	6.9		I				
4	7	6.8 ± 0.33	6.3-7.1	4.9	4.49^{***}	I				
7	7	6.7 ± 0.47	6.1-7.3	7.0	0.0008	I	I			
5	6	6.7 ± 0.44	5.9-7.2	6.7		I	I			
6	16	6.4 ± 0.35	5.9-7.1	5.6			I			
Minimum shaft width of ulna										
1	3	2.2 ± 0.28	1.9-2.5	12.8		I				
3	19	2.1 ± 0.19	1.7-2.4	9.1		I	I			
6	17	2.0 ± 0.19	1.7-2.3	9.5		I	I			
2	8	2.0 ± 0.13	1.9-2.2	6.4	8.90^{***}		I	I		
4	7	1.8 ± 0.12	1.6-2.0	6.5	0.0001			I	I	
5	6	1.8 ± 0.20	1.5-2.1	11.6					I	I
7	7	1.6 ± 0.16	1.4-1.9	9.9						I

Table II-3. Geographic variation in cranial and post-cranial measurements of three samples of Recent *Solenodon* and four samples of Late Quaternary (including Late Pleistocene, Early Holocene, Amerindian, and post-Columbian material) from Cuba (samples A, B, C) and Hispaniola (D, E, F, G). Sample code: A-Cuban giant form, Late Pleistocene, Cuba; B-*S*. cf. *cubanus*, Late Quaternary, Cuba; C-*S*. *cubanus*, Recent; D-North Hispaniola, Recent; E-South Hispaniola, Recent; F-*S*. *marcanoi*, Late Quaternary, Tiburon Peninsula, Haiti; G-*S*. *marcanoi*, type locality, Late Pleistocene, Rancho La Guardia, Dominican Republic. Statistics given are number, mean, standard deviation, range, coefficient of variation, F value (*<0.05, **<0.01, ***<0.001) and Duncan's multiple range test (<0.05) showing nonsignificant subsets.

Sample Code/N		Mean ± SD	Range	CV	F P	Results Duncan's			
			Greatest length of skull						
D	75	86.2 ± 2.42	80.9-91.5	2.8		I			
E	37	80.3 ± 2.36	72.3-83.5	2.9			I		
B	1	79.9			55.67^{***}		I		
C	12	78.2 ± 3.51	71.4-82.8	4.5	0.0001		I		
F	1	71.6						I	
			Condylobasal length						
D	73	80.8 ± 2.34	75.5-86.6	2.9		I			
E	37	75.9 ± 2.47	67.1-79.4	3.2			I		
B	1	75.8			43.33^{***}		I		
C	12	73.9 ± 2.87	68.6-77.8	3.9	0.0001		I		
F	1	67.2						I	
			Palatal length						
A	1	40.7				I			
D	75	37.3 ± 1.12	34.8-40.4	3.0			I		
B	4	35.7 ± 1.56	33.9-37.2	4.4	79.07^{***}			I	
E	41	34.9 ± 1.25	30.8-37.1	3.6	0.0001			I	
C	14	34.3 ± 1.07	31.8-35.7	3.1				I	
F	5	28.4 ± 1.14	27.4-30.3	5.3					I
			Postpalatal length						
D	74	30.4 ± 1.14	27.6-32.6	3.8		I			
E	38	29.0 ± 1.18	25.6-31.2	4.1		I	I		
B	1	28.7			29.43^{***}	I	I		
C	12	27.1 ± 1.27	25.0-29.3	4.7	0.0001		I	I	
F	1	25.4						I	

Table II-3. (Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's				
Alveolar length of upper molar toothrow										
D	74	10.3 ± 0.60	9.1-12.9	5.9		I				
E	43	9.6 ± 0.57	7.9-10.7	5.9		I	I			
A	1	9.6			55.79^{***}	I	I			
B	4	8.8 ± 0.64	8.0-9.4	7.3	0.0001		I	I		
C	14	8.2 ± 0.62	7.3-9.8	7.6				I		
F	5	7.1 ± 0.37	6.6-7.6	5.3					I	
Length of upper molar toothrow										
D	73	11.0 ± 0.43	9.9-12.0	3.9		I				
E	40	10.4 ± 0.51	9.3-11.6	4.9		I				
A	1	9.7			100.98^{***}		I			
C	12	8.6 ± 0.44	8.0-9.6	5.1	0.0001			I		
F	3	7.9 ± 0.24	7.6-8.1	3.0					I	
Length of maxillary toothrow										
A	1	28.0				I				
D	74	26.1 ± 0.85	23.6-27.6	3.3			I			
B	4	25.2 ± 0.62	24.5-26.0	2.5	85.52^{***}		I	I		
E	43	24.2 ± 0.90	21.6-25.8	3.7	0.0001			I	I	
C	14	23.7 ± 0.87	21.8-24.7	3.7					I	
F	5	19.2 ± 0.92	17.6-20.0	4.8						I
Breadth across maxillary toothrow										
A	1	25.2				I				
B	3	23.7 ± 0.75	22.9-24.3	3.2		I				
D	73	23.7 ± 0.94	21.3-25.9	4.0	37.83^{***}	I	I			
E	43	22.3 ± 1.27	19.2-24.9	5.7	0.0001		I	I		
C	14	21.5 ± 1.16	20.3-23.9	5.4				I		
F	4	17.4 ± 0.25	17.2-17.8	1.4					I	
Anteorbital constriction										
A	1	19.0				I				
B	3	17.1 ± 0.52	16.8-17.8	3.3			I			
C	14	15.0 ± 0.72	14.3-16.4	4.8	47.59^{***}			I		
D	76	14.1 ± 0.69	12.6-15.9	5.0	0.0001			I	I	
E	43	13.5 ± 0.69	11.6-14.9	5.1					I	
F	5	11.5 ± 0.34	11.0-11.9	3.0						I

Table II-3.(Cont.)

Sample					F	Results			
No	N	Mean ± SD	Range	CV	P	Duncan's			
		Zygomatic breadth							
A	1	39.0				I			
B	3	34.3 ± 0.57	34.0-35.0	1.7			I		
D	62	34.2 ± 1.75	30.3-39.0	5.1	39.05***		I		
C	9	32.4 ± 1.31	30.5-35.2	4.0	0.0001		I		
E	38	32.4 ± 1.05	30.1-34.9	3.2			I		
F	4	24.5 ± 0.57	24.0-25.0	2.4				I	
		Interorbital constriction							
A	1	16.3				I			
B	2	15.7 ± 0.65	15.3-16.2	4.1		I	I		
C	13	15.2 ± 0.62	14.5-16.4	4.1	9.36***		I	I	
D	77	14.9 ± 0.56	13.6-16.5	3.7	0.0001			I	
E	41	14.6 ± 0.45	13.6-15.4	3.1				I	
F	5	13.7 ± 0.28	13.3-14.1	2.0					I
		Squamosal breadth							
A	1	35.4				I			
D	77	31.6 ± 1.53	28.2-34.5	4.8			I		
B	1	31.2			19.71***		I		
C	12	30.9 ± 0.79	29.6-31.9	2.6	0.0001		I		
E	38	30.3 ± 0.81	28.6-31.6	2.7			I		
F	2	24.1 ± 1.02	23.4-24.8	4.2				I	
		Mastoid breadth							
D	76	25.8 ± 1.01	23.5-28.4	4.0		I			
B	1	25.0			12.47***	I	I		
E	36	24.7 ± 0.85	22.6-26.6	3.5	0.0001	I	I		
C	12	24.6 ± 0.67	23.0-25.6	2.7		I	I		
F	1	23.4					I		
		Breadth of the braincase							
B	1	25.3				I			
C	12	25.1 ± 0.82	24.0-26.4	3.3	6.74***	I			
D	77	24.8 ± 0.81	23.0-26.6	3.3	0.0001	I			
E	39	24.2 ± 0.69	22.0-25.3	2.8		I			
F	1	22.1					I		

Table II-3.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's			
			Condylar breadth						
A	1	18.9				I			
D	75	16.9 ± 0.68	15.3-18.4	4.0			I		
F	1	16.3			11.16^{***}		I	I	
E	38	16.2 ± 0.58	14.8-17.4	3.6	0.0001		I	I	
C	12	16.1 ± 0.70	15.0-17.2	4.4			I	I	
B	1	15.3						I	
			Skull height						
D	77	19.7 ± 1.17	17.0-22.2	5.9		I			
C	11	19.2 ± 0.89	17.8-20.6	4.7	9.39^{***}	I			
E	38	18.6 ± 1.22	15.2-20.7	6.6	0.0001	I			
F	1	16.7					I		
			Maximum length of C^1						
A	1	5.7				I			
B	3	4.6 ± 0.22	4.4-4.8	4.7			I		
C	12	4.5 ± 0.27	4.1-4.8	6.1	16.53^{***}		I	I	
D	25	4.4 ± 0.34	3.8-5.2	7.9	0.0001		I	I	
E	40	3.9 ± 0.41	3.0-4.7	10.4				I	
F	2	2.8 ± 0.18	2.7-2.9	6.4					I
			Maximum width of C^1						
A	1	3.9				I			
B	3	3.1 ± 0.13	3.0-3.2	4.2			I		
C	12	3.0 ± 0.16	2.6-3.2	5.7	114.92^{***}		I		
D	25	2.3 ± 0.12	2.1-2.6	5.1	0.0001			I	
E	40	2.2 ± 0.13	2.0-2.5	5.8				I	
F	2	1.6 ± 0.35	1.3-1.8	22.8					I
			Maximum length of P^1						
A	1	3.6				I			
B	4	3.4 ± 0.21	3.2-3.7	6.1		I	I		
D	11	3.3 ± 0.30	2.8-3.7	9.1	19.79^{***}	I	I		
C	5	3.1 ± 0.11	2.9-3.2	3.5	0.0001		I	I	
E	9	2.8 ± 0.11	2.7-3.1	4.2				I	
F	3	2.1 ± 0.05	2.1-2.2	1.2					I

Table II-3.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's			
Maximum width of P^1									
A	1	2.7				I			
C	5	2.4 ± 0.05	2.4-2.5	2.1			I		
B	4	2.3 ± 0.12	2.2-2.4	5.1	62.20^{***}		I		
D	11	2.1 ± 0.09	1.9-2.2	4.5	0.0001			I	
E	9	2.0 ± 0.08	1.8-2.2	4.4				I	
F	3	1.4 ± 0.15	1.3-1.5	11.3					I
Maximum length of P^2									
A	1	4.9				I			
D	11	3.9 ± 0.28	3.5-4.3	7.2			I		
B	3	3.8 ± 0.62	3.4-4.6	16.2	14.07^{***}		I		
C	5	3.8 ± 0.44	3.1-4.2	11.6	0.0001		I		
E	9	3.2 ± 0.18	3.0-3.5	5.6				I	
F	3	2.7 ± 0.07	2.6-2.8	2.8				I	
Maximum width of P^2									
A	1	4.2				I			
B	3	3.8 ± 0.76	3.8-3.9	2.0			I		
C	5	3.7 ± 0.26	3.3-3.9	7.1	88.05^{***}		I		
D	11	2.4 ± 0.18	2.2-2.9	7.6	0.0001			I	
E	9	2.2 ± 0.17	2.0-2.5	7.9				I	
F	3	1.7 ± 0.23	1.5-2.0	13.5					I
Maximum length of P^4									
D	11	5.5 ± 0.47	4.8-6.5	8.5		I			
B	3	5.0 ± 0.11	4.9-5.1	2.2	32.66^{***}		I		
E	9	4.8 ± 0.19	4.5-5.1	4.6	0.0001		I	I	
C	12	4.5 ± 0.23	4.2-4.9	5.0				I	
E	4	3.6 ± 0.27	3.2-3.8	7.7					I
Maximum width of P^4									
D	11	6.8 ± 0.47	6.2-7.4	6.9		I			
B	3	6.4 ± 0.69	5.6-6.9	10.9	28.77^{***}	I	I		
C	12	6.2 ± 0.44	5.0-6.7	7.1	0.0001		I		
E	9	5.6 ± 0.26	5.4-6.2	4.6				I	
F	4	4.2 ± 0.43	3.9-4.5	10.1					I

Table II-3.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's			
Maximum length of M^1									
A	1	4.2				I			
D	11	4.2 ± 0.30	3.5-4.6	7.3		I			
B	4	4.0 ± 0.45	3.5-4.6	11.2	7.28***	I			
E	9	3.7 ± 0.30	3.3-4.2	8.0	0.0001	I	I		
C	11	3.5 ± 0.26	3.2-4.0	7.3			I		
F	3	3.3 ± 0.20	3.2-3.6	6.1			I		
Maximum width of M^1									
D	11	7.0 ± 0.50	6.4-7.8	7.3		I			
A	1	7.0				I			
C	11	6.7 ± 0.42	6.1-7.4	6.3	14.87***	I	I		
B	4	6.5 ± 0.12	6.3-6.6	1.9	0.0001	I	I		
E	9	6.0 ± 0.35	5.5-6.4	5.9			I		
F	3	5.0 ± 0.05	5.0-5.1	1.1				I	
Maximum length of M^2									
D	11	3.7 ± 0.35	3.2-4.4	9.8		I			
E	9	3.3 ± 0.20	2.8-3.5	6.3		I			
B	1	3.2			17.41***	I			
A	1	3.1			0.0001	I	I		
C	11	2.6 ± 0.32	2.0-3.0	12.5			I		
F	4	2.5 ± 0.31	2.1-2.9	12.3			I		
Maximum width of M^2									
A	1	7.0				I			
D	11	7.0 ± 0.52	6.3-8.1	7.5		I			
C	11	6.1 ± 0.34	5.7-6.8	5.5	20.35***		I		
E	9	6.1 ± 0.38	5.7-6.8	6.2	0.0001		I		
B	1	5.8					I		
F	4	4.7 ± 0.06	4.7-4.8	1.4				I	
Maximum length of M^3									
D	11	2.6 ± 0.09	2.4-2.8	3.8		I			
A	1	2.4			50.95***		I		
E	9	2.3 ± 0.13	2.1-2.6	5.7	0.0001		I		
C	11	2.0 ± 0.13	1.8-2.3	6.6				I	
F	4	1.7 ± 0.10	1.6-1.9	6.2					I

Table II-3.(Cont.)

Sample					F	Results					
No	N	Mean ± SD	Range	CV	P	Duncan's					
Maximum width of M^3											
D	75	6.5 ± 0.45	5.2-7.7	7.7		I					
E	41	5.6 ± 0.57	4.4-7.2	10.3	69.07***		I				
A	1	5.4			0.0001		I				
C	12	4.7 ± 0.31	4.2-5.3	6.6				I			
F	4	4.0 ± 0.24	3.6-4.2	6.2					I		
Greatest mandible length											
D	78	53.9 ± 1.62	50.9-58.1	3.0		I					
B	6	51.9 ± 2.27	49.3-55.1	4.4	133.47***		I				
E	43	50.2 ± 1.53	45.2-52.6	3.1	0.0001			I			
C	13	48.9 ± 1.97	44.7-51.9	4.0				I			
F	9	41.2 ± 2.43	38.7-46.7	5.9					I		
Length of mandibular toothrow											
D	78	27.1 ± 0.95	23.3-28.9	3.5		I					
B	11	26.8 ± 1.16	24.4-28.7	4.3		I					
E	44	25.4 ± 0.87	23.5-27.4	3.4	177.75***		I				
C	14	25.2 ± 0.93	23.0-26.3	3.7	0.0001		I				
G	4	21.9 ± 0.74	21.2-22.6	3.4				I			
F	15	20.0 ± 0.42	19.2-20.6	2.1					I		
Alveolar length of P_4-M_3											
D	76	17.2 ± 0.68	14.9-18.5	4.0		I					
E	44	15.9 ± 0.59	14.6-17.3	3.7			I				
B	15	15.2 ± 0.84	13.0-16.1	5.7	203.90***			I			
C	14	14.2 ± 0.44	13.5-14.8	3.1	0.0001				I		
G	5	12.9 ± 1.43	10.5-14.1	11.1						I	
F	18	12.2 ± 0.38	11.6-13.0	3.1							I
Depth through coronoid process											
B	7	24.2 ± 1.48	22.4-26.7	6.1		I					
D	76	23.8 ± 1.22	20.6-26.2	5.1		I					
C	14	22.5 ± 1.13	20.6-24.2	5.0	91.56***		I				
E	43	22.5 ± 0.84	20.6-24.5	3.7	0.0001		I				
G	3	17.6 ± 1.85	15.8-19.5	10.5				I			
F	11	16.6 ± 1.19	15.5-19.7	7.2				I			

Table II-3.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's					
		Angular-condylar height									
B	10	15.3 ± 0.92	13.7-16.6	6.0		I					
D	78	14.8 ± 0.95	12.2-17.1	6.4		I					
C	13	13.2 ± 0.90	12.1-14.7	6.8	87.64^{***}		I				
E	44	12.9 ± 0.68	11.9-15.1	5.3	0.0001		I				
G	3	10.8 ± 0.71	10.0-11.4	6.5				I			
F	13	10.0 ± 1.13	8.4-12.7	11.3				I			
		Maximum length of C_1									
B	1	5.0				I					
C	7	4.4 ± 0.19	4.1-4.6	3.5			I				
D	11	3.8 ± 0.23	3.5-4.3	6.2	77.78^{***}			I			
E	8	3.5 ± 0.13	3.3-3.8	3.7	0.0001				I		
F	3	2.3 ± 0.18	2.2-2.5	7.8						I	
		Maximum width of C_1									
B	1	2.9				I					
C	7	2.5 ± 0.28	2.1-2.9	11.5			I				
D	11	2.3 ± 0.15	2.1-2.6	6.6	25.21^{***}		I				
E	8	2.2 ± 0.15	2.0-2.5	6.8	0.0001		I				
F	3	1.3 ± 0.13	1.2-1.4	9.9				I			
		Maximum length of P_1									
B	6	4.1 ± 0.18	3.8-4.3	4.6		I					
C	7	3.6 ± 0.24	3.3-3.8	5.7	50.60^{***}		I				
D	11	3.3 ± 0.22	3.0-3.7	6.7	50.601		I				
E	9	2.8 ± 0.20	2.4-3.0	7.1				I			
F	8	2.5 ± 0.25	2.3-2.9	10.1				I	I		
G	1	2.3							I		
		Maximum width of P_1									
B	6	3.2 ± 0.22	3.0-3.6	6.9		I					
C	7	2.9 ± 0.16	2.7-3.2	5.7	114.48^{***}		I				
D	11	2.5 ± 0.08	2.3-2.6	3.6	0.0001			I			
E	9	2.2 ± 0.10	2.1-2.4	4.6					I		
G	1	1.9								I	
F	8	1.5 ± 0.17	1.3-1.8	10.8							I

Table II-3.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's				
Maximum length of P_2										
B	7	3.9 ± 0.30	3.7-4.2	7.7		I				
C	7	3.7 ± 0.16	3.3-4.5	10.8	31.96^{***}	I	I			
D	11	3.3 ± 0.33	2.9-4.0	9.8	0.0001		I			
E	9	2.8 ± 0.27	2.4-3.3	9.7				I		
F	7	2.4 ± 0.19	2.1-2.6	8.0					I	
Maximum width of P_2										
B	7	3.1 ± 0.12	2.9-3.3	4.1		I				
C	7	2.9 ± 0.14	2.6-3.0	4.9	255.05^{***}		I			
D	11	2.4 ± 0.08	2.3-2.5	3.5	0.0001			I		
E	9	2.1 ± 0.09	2.1-2.3	4.3					I	
F	7	1.5 ± 0.08	1.4-1.6	5.6						I
Maximum length of P_4										
D	75	4.3 ± 0.24	3.7-4.9	5.6		I				
B	6	4.3 ± 0.25	4.1-4.7	6.0	54.03^{***}	I				
E	43	3.9 ± 0.31	3.5-4.9	8.1	0.0001		I			
C	13	3.9 ± 0.32	3.4-4.7	8.4			I			
G	4	3.2 ± 0.15	3.1-3.5	4.6				I		
F	10	3.0 ± 0.15	2.7-3.2	5.2				I		
Maximum width of P_4										
B	7	3.3 ± 0.21	3.0-3.6	6.4		I				
D	76	3.3 ± 0.21	2.7-3.8	6.4	102.46^{***}	I				
C	13	3.2 ± 0.18	3.1-3.7	5.7	0.0001	I				
E	42	2.8 ± 0.21	2.2-3.2	7.7			I			
G	4	2.3 ± 0.14	2.1-2.5	6.1				I		
F	10	2.0 ± 0.14	1.8-2.3	7.1					I	
Maximum length of M_1										
D	74	4.6 ± 0.27	4.0-5.1	5.9		I				
E	43	4.4 ± 0.26	4.0-5.0	5.9		I	I			
B	4	4.2 ± 0.17	4.0-4.4	4.0	51.23^{***}		I			
C	13	3.7 ± 0.29	3.2-4.1	7.9	0.0001			I		
G	3	3.7 ± 0.45	3.3-4.2	12.4				I		
F	9	3.5 ± 0.21	3.2-3.8	6.2				I		

Table II-3.(Cont.)

Sample					F	Results				
No	N	Mean ± SD	Range	CV	P	Duncan's				
		Maximum width of M_1								
D	74	4.3 ± 0.19	3.8-4.7	4.6		I				
B	4	4.0 ± 0.09	3.9-4.1	2.3			I			
E	42	3.9 ± 0.29	3.3-4.6	7.3	96.37***		I			
C	13	3.9 ± 0.19	3.6-4.2	5.0	0.0001		I			
G	3	3.0 ± 0.12	2.8-3.1	4.2				I		
F	9	2.7 ± 0.17	2.5-3.0	6.4					I	
		Maximum length of M_2								
D	75	4.6 ± 0.25	4.0-5.4	5.4		I				
E	41	4.4 ± 0.21	3.9-5.0	4.8		I				
B	5	3.8 ± 0.46	3.0-4.3	12.2	80.12***		I			
C	13	3.6 ± 0.18	3.4-4.0	5.2	0.0001		I	I		
G	3	3.5 ± 0.34	3.3-3.9	9.7				I		
F	10	3.5 ± 0.19	3.2-3.7	5.5				I		
		Maximum width of M_2								
D	76	4.3 ± 0.18	3.8-4.7	4.3		I				
E	40	4.0 ± 0.28	3.5-4.5	6.9			I			
C	13	3.6 ± 0.15	3.4-3.9	4.3	101.54***			I		
B	4	3.6 ± 0.42	3.0-4.0	11.8	0.0001			I		
G	2	3.2 ± 0.16	3.0-3.3	4.9					I	
F	10	2.8 ± 0.23	2.3-3.1	8.4						I
		Maximum length of M_3								
D	75	5.3 ± 0.27	4.7-5.9	5.1		I				
E	38	4.9 ± 0.27	4.3-5.4	5.5	90.47***		I			
B	3	4.3 ± 0.23	4.0-4.4	5.4	0.0001			I		
C	13	4.2 ± 0.22	3.9-4.5	5.2				I		
F	8	3.9 ± 0.19	3.6-4.2	4.8					I	
		Maximum width of M_3								
D	75	3.5 ± 0.19	3.0-4.0	5.4		I				
E	38	3.2 ± 0.25	2.7-3.9	7.8	60.85***		I			
B	3	3.0 ± 0.07	3.0-3.1	2.3	0.0001		I	I		
C	13	2.9 ± 0.39	2.2-3.9	13.5				I		
F	9	2.5 ± 0.09	2.3-2.6	3.7					I	

Table II-3.(Cont.)

Sample					F	Results				
No	N	Mean ± SD	Range	CV	P	Duncan's				
Total length of femur										
A	2	61.9 ± 0.59	57.7-66.1	9.6		I				
B	2	48.0 ± 0.19	47.9-48.1	4.1			I			
C	5	46.7 ± 0.78	45.6-47.6	1.7	88.60***		I			
D	42	46.7 ± 1.53	43.3-50.4	3.3	0.0001		I			
E	42	44.3 ± 1.49	41.0-47.6	3.4				I		
G	6	41.3 ± 0.96	39.9-42.5	2.3					I	
F	5	35.5 ± 0.90	34.6-36.9	2.5						I
Maximum width of femur										
A	2	15.3 ± 0.38	14.9-15.4	2.5		I				
D	44	13.4 ± 0.54	12.3-14.6	4.1			I			
C	6	12.7 ± 0.61	12.1-13.8	4.8	51.57***		I	I		
B	2	12.7 ± 0.07	12.6-12.7	5.6	0.0001			I		
E	42	12.5 ± 0.52	11.4-13.4	7.9				I		
G	8	12.4 ± 0.45	12.0-13.2	3.6				I		
F	9	10.3 ± 0.47	9.3-11.0	4.5					I	
Minimum shaft width of femur										
A	3	6.5 ± 0.50	6.1-7.1	7.8		I				
D	44	5.3 ± 0.31	4.8-6.4	5.8			I			
G	10	5.3 ± 0.32	4.5-5.7	6.2	24.23***		I	I		
B	2	5.2 ± 0.13	5.1-5.3	2.5	0.0001		I	I		
E	43	4.9 ± 0.34	4.3-6.0	7.1				I	I	
F	12	4.6 ± 0.14	4.4-4.8	3.1					I	I
C	6	4.5 ± 0.31	4.1-4.9	6.9						I
Total length of humerus										
A	2	54.1 ± 0.30	51.9-56.2	5.7		I				
D	43	47.6 ± 1.51	43.9-50.7	3.2			I			
B	1	44.3			108.44***			I		
E	37	44.0 ± 1.29	40.6-46.8	2.9	0.0001			I		
C	5	42.6 ± 1.35	41.2-44.6	3.2				I	I	
G	2	40.8 ± 0.95	40.1-41.5	2.3					I	
F	8	35.0 ± 1.60	32.9-37.3	4.6						I

Table II-3.(Cont.)

Sample No	N	Mean ± SD	Range	CV	F P	Results Duncan's				
		Maximum width of humerus								
A	2	19.4 ± 0.80	18.9-20.0	4.1		I				
D	44	17.9 ± 0.56	16.7-18.8	3.1			I			
E	40	17.1 ± 0.66	15.8-18.3	3.8	54.15^{***}		I	I		
G	10	16.8 ± 1.15	15.0-18.9	6.8	0.0001			I		
B	2	15.8 ± 0.71	15.3-16.3	4.5					I	
C	6	14.9 ± 0.75	14.1-15.9	5.0					I	I
F	16	14.6 ± 0.93	13.1-16.5	6.4						I
		Minimum shaft width of humerus								
G	15	5.2 ± 0.28	4.6-5.7	5.6		I				
A	3	5.1 ± 0.18	4.9-5.3	3.6		I				
D	44	5.0 ± 0.30	4.4-5.8	6.0		I				
E	39	5.0 ± 0.29	4.3-5.5	5.7	20.02^{***}	I				
F	16	4.5 ± 0.42	4.0-5.3	9.3	0.0001		I			
B	3	4.5 ± 0.13	4.4-4.6	28.0			I			
C	6	3.9 ± 0.70	3.8-4.0	1.8				I		
		Total length of ulna								
D	30	52.9 ± 1.87	50.0-58.0	3.5		I				
E	30	50.8 ± 2.30	40.6-53.8	4.5	20.84^{***}	I				
C	6	49.6 ± 1.90	47.8-52.8	3.8	0.0001	I				
G	1	45.6					I			
F	2	40.9 ± 0.84	40.3-41.5	2.1				I		
		Maximum width of ulna								
G	1	7.2				I				
D	31	6.9 ± 0.37	6.0-7.6	5.4	14.46^{***}	I				
C	7	6.7 ± 0.47	6.1-7.3	7.0	0.0001	I				
E	29	6.5 ± 0.41	5.9-7.2	6.2		I				
F	3	5.1 ± 0.94	4.5-6.2	18.4			I			
		Minimum shaft width of ulna								
A	1	2.5				I				
D	30	2.1 ± 0.19	1.7-2.5	9.2			I			
G	1	2.0			7.21^{***}		I			
F	4	1.9 ± 0.10	1.8-2.0	5.1	0.0001		I	I		
E	30	1.9 ± 0.21	1.5-2.3	11.1			I	I		
C	7	1.6 ± 0.16	1.4-1.9	9.9				I		

Table II-4. Cranial, mandibular and limb bones variables used in discriminant function analysis of Recent Solenodon samples from Cuba and Hispaniola. Characters are listed in order of their usefulness in distinguishing groups, with the character with the greatest between-group variance and the least within-groups variance being selected first. The statistics are recalculated at each step. Analysis were run separately for each set of characters to maximize sample size.

Step	Character	F-value	U-statistic
	Cranial variables		
1	Length upper molar toothrow	34.5	0.812
2	Maximum width C^1	18.9	0.707
3	Interorbital constriction	5.3	0.415
4	Greatest length of skull	5.0	0.418
5	Squamosal breadth	4.4	0.367
6	Skull height	4.3	0.378
7	Maximum length C^1	3.9	0.349
8	Zygomatic breadth	3.8	0.372
9	Palatal length	3.6	0.371
10	Breadth of the braincase	2.8	0.287
11	Length of maxillary toothrow	2.3	0.253
12	Condylobasal length	2.0	0.282
13	Maximum width of M^3	2.0	0.236
14	Breadth across M^2-M^2	1.8	0.216
15	Anteorbital constriction	1.2	0.168
16	Condylar breadth	1.2	0.168
17	Alveolar length M^1-M^3	1.0	0.151
18	Mastoid breadth	0.7	0.108
19	Postpalatal length	0.6	0.095
	Mandibular variables		
1	Alveolar length of P_4-M_3	48.6	0.730
2	Maximum width of P_4	26.3	0.596
3	Maximum width of M_2	11.7	0.399
4	Angular-condylar height	6.6	0.274
5	Depth coronoid process	3.2	0.161
6	Maximum width of M_1	2.9	0.396
7	Length mandibular toothrow	2.7	0.140
8	Maximum length of M_2	2.2	0.114
9	Greatest mandible length	2.2	0.113
10	Maximum length of M_3	1.5	0.083
11	Maximum width of M_3	1.0	0.057
12	Maximum length of M_1	0.8	0.047
13	Maximum length of P_4	0.6	0.034

Table II-4.-(Cont.)

Step	Character	F-value	U-statistic
	Limb bone variables		
1	Humerus total length of	14.0	0.631
2	Femur total length	10.9	0.578
3	Humerus maximum width	7.2	0.479
4	Ulna minimum shaft width	3.7	0.329
5	Femur minimum shaft width	3.4	0.308
6	Ulna maximum width	3.3	0.318
7	Humerus minimum shaft width	3.1	0.299
8	Ulna total length	1.3	0.152
9	Femur maximum width	0.9	0.113

Table II-5. Classification matrix for seven samples of *Solenodon* from Hispaniola (samples 1-6) and Cuba (sample 7), based upon the discriminant functions of 41 morphometric characters. Values indicate the number of individuals classified into each group.

		Classification groups						
Sample	N	1	2	3	4	5	6	7
Cranial variables								
1) Samana-NH	4	4	0	0	0	0	0	0
2) Eastern-NH	7	0	7	0	0	0	0	0
3) Central-NH	7	0	0	7	0	0	0	0
4) Barahona-SH	9	0	0	0	8	1	0	0
5) Baoruco-SH	8	1	0	0	0	7	0	0
6) La Hotte-SH	14	0	0	0	1	0	13	0
7) Eastern Cuba	6	0	0	0	0	0	0	6
Mandible variables								
1) Samana-NH	4	3	0	1	0	0	0	0
2) Eastern-NH	16	1	10	2	0	0	3	0
3) Central-NH	48	7	4	36	0	1	0	0
4) Barahona-SH	10	0	0	1	6	3	0	0
5) Baoruco-SH	8	0	1	0	2	5	0	0
6) La Hotte-SH	17	0	0	0	0	1	16	0
7) Eastern Cuba	12	0	0	0	0	0	0	12
Limb bone variables								
1) Samana-NH	2	1	1	0	0	0	0	0
2) Eastern-NH	8	1	4	1	1	1	0	0
3) Central-NH	18	1	3	13	1	0	0	0
4) Barahona-SH	5	0	1	0	4	0	0	0
5) Baoruco-SH	5	0	0	0	1	4	0	0
6) La Hotte-SH	14	0	0	0	0	0	14	0
7) Eastern Cuba	4	0	0	0	0	0	0	4

Table II-6. Cranial, mandibular, and limb bone variables indicated by discriminant function analysis of six geographic samples of extant (Recent) *Solenodon paradoxus* from Hispaniola. Characters were ranked in order of their usefulness in distinguishing groups, with the character with the greatest between-group variance and the least within-groups variance being selected first. The statistics were recalculated at each step. Number of variables analyzed in each matrix is indicated in parenthesis.

Matrix Top ranked characters	F-value	U-statistic	Percent reduction in class
Skull and mandible variables (32)			100 %
Angular-condylar height	14.3	0.653	
Maximum length C^1	8.8	0.543	
Skull variables only (18)			95
Maximum length of C^1	17.1	0.666	
Skull height	6.4	0.445	
Mandible variables only (13)			70
Angular-condylar height	32.9	0.629	
Maximum width of M_2	9.0	0.320	
Maximum width of P_4	8.6	0.312	
Limb bone variables only (9)			72
Humerus total length	13.3	0.590	
Femur minimum shaft width	3.9	0.346	

Table II-7. Classification matrix for six samples of extant *Solenodon paradoxus* from Hispaniola (samples 1-5, Dominican Republic; sample 6, Haiti) based upon the discriminant functions of 41 morphometric characters. Values indicate the number of individuals classified into each group. NH, North Hispaniola; SH, South Hispaniola. Number of variables analyzed in each matrix is indicated in parenthesis.

		Classification groups					
Sample	N	1	2	3	4	5	6
Skull and mandible variables (32)							
1) Samana, NH	4	4	0	0	0	0	0
2) Eastern, NH	7	0	7	0	0	0	0
3) Central, NH	6	0	0	6	0	0	0
4) Barahona, SH	8	0	0	0	8	0	0
5) Baoruco, SH	6	0	0	0	0	6	0
6) La Hotte, SH	13	0	0	0	0	0	13
ALL	44	4	7	6	8	6	13
Skull variables only (18)							
1) Samana, NH	4	4	0	0	0	0	0
2) Eastern, NH	7	0	7	0	0	0	0
3) Central, NH	7	0	0	7	0	0	0
4) Barahona, SH	9	0	0	0	8	1	0
5) Baoruco, SH	8	0	0	0	0	8	0
6) La Hotte, SH	14	0	0	0	1	0	13
ALL	49	4	7	7	9	9	13
Mandible variables only (13)							
1) Samana, NH	4	3	0	1	0	0	0
2) Eastern, NH	16	1	10	3	0	0	2
3) Central, NH	48	5	5	37	0	1	0
4) Barahona, SH	10	0	0	1	6	3	0
5) Baoruco, SH	8	0	1	0	2	5	0
6) La Hotte, SH	17	0	0	0	0	1	16
ALL	103	9	16	42	8	10	18
Limb bone variables only (9)							
1) Samana, NH	2	1	1	0	0	0	0
2) Eastern, NH	8	1	4	1	1	1	0
3) Central, NH	18	1	3	13	1	0	0
4) Barahona, SH	5	0	0	0	4	1	0
5) Baoruco, SH	5	0	0	0	1	4	0
6) La Hotte, SH	14	0	0	0	0	0	14
ALL	52	3	8	14	7	6	14

Table II-8. Mandibular measurements of Recent *S. cubanus* (mean, sample, range) and selected Late Quaternary material from Cuba. See text for character code.

Character	Recent *Solenodon cubanus*	Late Quaternary OA 306E	 IES 228	 OA 22	 IES 3646	 OA 124/152
GML	48.9 (13) 44.7-51.9	55.1	-	53.2	53.2	-
MTR	25.2 (14) 23.0-26.3	27.7	28.7	27.4	27.1	27.2
P4M3	14.2 (14) 13.5-14.8	15.7	16.1	15.3	15.5	15.4
DCP	22.5 (14) 20.6-24.2	24.5	25.3	-	24.1	26.7
ACH	13.2 (13) 12.1-14.7	15.1	16.6	16.2	15.2	16.3

Table II-9. Femoral measurements of a sample of *S. marcanoi* from La Hotte in Haiti (mean, range, sample), attributed "*marcanoi*" specimens of the type series from Rancho la Guardia in Sierra de Neiba, and Recent *S. paradoxus* "new subspecies B" from South Hispaniola (whole sample from Sierra de Baoruco and Peninsula de Barahona-JAO, mean, range, sample). All Recent specimens are adults.

Population sample	Total length	Maximum width	Minimum width
S. marcanoi			
Hotte	35.5 34.6-36.9 (5)	10.3 9.3-11.0 (9)	4.6 4.4-4.8 (12)
"*S. marcanoi*"			
Neiba			
MCZ 20321	42.5	12.6	5.2
CM 35036	41.21	12.1	5.4
S. paradoxus "new subspecies B"			
South Hisp	44.3 41.0-47.6 (42)	12.5 11.4-13.4 (42)	4.9 4.3-6.0 (43)
JAO 314	41.0	11.6	4.6
JAO 462	41.4	12.6	4.9
UF 18818	42.4	11.4	5.0

Table II-10. Humeral measurements of a sample of *S. marcanoi* from La Hotte in Haiti (mean, range, sample), attributed "*marcanoi*" specimens of the type series from Rancho la Guardia in Sierra de Neiba, and Recent *S. paradoxus* from South Hispaniola (whole sample from Sierra de Baoruco and Peninsula de Barahona-JAO, mean, range, sample). All Recent specimens are adults.

Population sample	Total length	Maximum width	Minimum width
S.marcanoi			
Hotte	35.0 32.9-37.3 (8)	14.6 13.1-16.5 (16)	4.5 4.0-5.3 (16)
"*S. marcanoi*"			
Neiba			
MCZ 7263	40.1		5.5
MCZ 7264		17.6	5.1
S. paradoxus "new subspecies B"			
South Hisp	44.0 40.6-46.8 (37)	17.1 15.8-18.3 (40)	5.0 4.3-5.5 (39)
JAO 314	41.3	16.0	4.6
JAO 462	42.9	16.6	5.4
UF 18818	40.6	16.6	5.4

Table II-11. Ulna measurements of a sample of *S*. *marcanoi* from La Hotte in Haiti (mean, range, sample), attributed "*marcanoi*" specimens of the type series from Rancho la Guardia in Sierra de Neiba, and Recent *S*. *paradoxus* from South Hispaniola (whole sample and three specimens from Sierra de Baoruco and Peninsula de Barahona-JAO, mean, range, sample). All Recent specimens are adults.

Population sample	Total length	Maximum width	Minimum width
S.*marcanoi*			
Hotte	40.9 40.3-41.5 (2)	5.1 4.5-6.2 (3)	1.9 1.8-2.0 (4)
"*S*. *marcanoi*"			
Neiba			
MCZ 7265	45.6	7.2	2.0
UF	41.3	-	2.2
S. *paradoxus* "new subspecies B"			
South Hisp	50.8 40.6-53.8 (30)	6.5 5.9-6.2 (29)	1.9 1.5-2.3 (30)
JAO 314	40.6	5.9	1.7
JAO 445	49.3	6.8	1.8
UF 18820	49.0	6.4	2.2

Chapter III

LATE QUATERNARY AND RECENT DISTRIBUTION OF SOLENODON

Material and Methods

Field surveys, museum collections, zoological park records, and an extensive review of the literature were used to establish the historical and present distribution of the different species of Solenodon in Cuba, Haiti and the Dominican Republic. Field surveys were conducted in the Dominican Republic using the methodology described in Ottenwalder (1985). A total of 300 Recent and 110 Late Quaternary (Late Pleistocene, Early Holocene, Amerindian) specimens, nearly the all of the Solenodon material known to exist in paleontological and Recent mammal collections in North America, Cuba, the Dominican Republic and Europe, was examined for collection data. During four trips to Cuba, I also conducted interviews with scientists, examined private collections, and obtained published and unpublished literature not available elsewhere. For Late Quaternary material, chronology was established by faunal association or human evidence as defined in Morgan and Woods (1986). New distributional records are included in the figures.

Results

Solenodon paradoxus

The past and present distribution of S. paradoxus in the Dominican Republic and Haiti is shown in Fig. III-1.

Dominican Republic. Results of previous surveys in the Dominican Republic, establishing the known range of the species up to 1983, were described by Ottenwalder (1985). The existence of additional surviving populations was established in the following regions of the country:

a) Cordillera Central. Foraging tracks and reports of Solenodon were obtained from several localities during 2-week trips by horse across the interior mountains of the range between the San Juan Valley, on the south, and the Cibao Occidental Valley, on the north.

b) Cabrera Promontory. Four specimens were salvaged, and tracks and reports were obtained from this region, located in the northeastern portion of the country. These findings are discussed in some detail in Chapter V (Conservation problems: People-Solenodon conflict).

c) Distrito Nacional. One specimen was salvaged and reports obtained from a site located 17 km east of Santo Domingo, near the freeway connecting the city and the international airport. The site is a fairly disturbed secondary growth of low, open, scrub forest on Quaternary reef limestone. Archeological evidence suggests that

Solenodon was utilized as food by Amerindians in the same area where Santo Domingo, the capital city, is today.

d) Samana Peninsula. Observations of animals, signs and reports were recorded. A live adult male was captured for captive studies.

e) Sierra de Martín García. Foraging tracks were seen and reliable reports of sightings were received.

f) Sierra de Yamasa. Several animals reportedly were killed by dogs and people in Los Cacaos and Las Guacáras, in the vicinity of the extensive gold mining operation of Pueblo Viejo.

g) Other areas. Reports of were also obtained from the northern slopes of the Cordillera Septentrional (south of Sosua), and from the southernmost slopes of the Cordillera Central northwest of San Cristobal. None of these reports, however, is reasonably recent, and further efforts to search for the species should be undertaken to investigate the possibility that Solenodon might still survive in these regions.

Haiti. The range and status of S. paradoxus in Haiti was unknown until 1973 (Woods 1976, 1981, 1983, 1989). Since then, the species has been found to survive only in the Massif de la Hotte, on the southwestern end of the country. Here, S. paradoxus is restricted to an elevated (800-900 m) karstic plateau between Pic Macaya and Duchity, extending from Camp Perrin in the south, to Beaumont in the north. Until now, most specimens from that area have come from Plain Martin, within a 5-mile radius of the Catiche-Duchity region. An adult female, captured in April 1982 near Beaumont, is the last known animal caught alive. Late Pleistocene to post-Columbian material has been collected from the cave deposits of Trouing Jeremy and Sa Wo, near Camp Perrin (Massif de La Hotte), and from Morne La Visite (Massif de la Selle).

At least some of the specimens collected in the 1800's and early 1900's, labelled as of "Haiti," "Santo Domingo," or "Hispaniola," must have originated from Haitian territory. To my knowledge, the only confirmed Haitian animals are a series of 12 specimens in the collection of the Max Plank Institute (MPIH) that were obtained from that country in the early 1960's (H. Stephan pers. comm.). There is also a record by Sanderson (1939, p. 117) from Fonds Parisiens, on the south side of Lake Etang Saumatre: "It was there, between some cactus bushes, that we found the decaying remains of the only Solenodon we saw in Haiti. It had been dead a long time, and even my collector's enthusiasm was unable to extract from the mass more than a few teeth and some claws-monstrous mole-like that could dig even in Haitian soil." Although a rather marginal habitat for S. paradoxus, the locality is at the foothills of the northern slopes of the Massif de La Selle, where Solenodon was known to occur at higher elevations in the recent past.

Solenodon cubanus

Previous information about the distribution of S. cubanus is given by Varona (1983) and Abreu et al. (1990). The known Late Quaternary and Recent localities of the species are presented in Fig. III-2. Historically, live animals have only been known from eastern Cuba. With the exception of the holotype (Sierra Almiqui, Sierra de Nipe) most of the live specimens, collected between the early 1830's and 1889, came from the area of Bayamo (Poey 1838, 1851; Gundlach 1866, 1872, 1877, 1895) and the southern slopes of Sierra Maestra (True 1886). Since then, apparently all further specimens have originated from the northeastern portion: Cuchillas de Baracoa (Allen 1942, Barbour 1944); Sierra de Toa (Barbour 1944); Sierra de Nipe (Barbour 1944); Cuchillas de Moa (Bofill 1948); Sierra del Cristal (Muñoz 1974). The existence of Solenodon in several localities (Buenos Aires, Naranjos, Cimarrones) of Sierra del Escambray (Sancti Spiritus Province, central Cuba) reported by Sagra (1845) was questioned by Poey (1851) but later supported by Gundlach (1866, 1872, 1877, 1895). More recently, Varona (1983) reported "relatively fresh osteological material" obtained in Escambray in 1975. Its occurrence in Sierra de los Organos (Pinar del Río Province, western Cuba) was speculated by Varona (1983).

The species has been found in the following archeological sites: Cueva de José Brea, Sierra Pan de Azucar, Pinar del Río Province (Aguayo 1950); Cueva de la

Santa, Bacuranao, Colinas de Villareal, La Habana Province (Arredondo 1970); Cueva Funche, Península de Guanacahibes (Gonzalez 1981). Late Pleistocene-Early Holocene material of S. cubanus is known from Cueva San Lucas, Gran Sierra de Maisí (Allen 1918); Cueva Paredones, San Antonio de los Baños, La Habana (Arredondo 1955); Cueva de Tarará, Guanabacoa, La Habana (Arredondo 1955); Cueva del Indio, Sierra de Cubitas, Camaguey Province (Koopman and Ruibal 1955); Cueva del Tunel, La Habana (Arredondo 1970; Arredondo and Varona 1974; Acevedo et al. 1975).

Unpublished material was examined from the following archeological sites not included in Abreu et al. (1990): a) Residuario San Martín, Boca de Jaruco, La Habana Province; collected by O. Arredondo in 1987. b) La Gloria, Santiago de Cuba Province; collected 17 February 1990 by Ramon Navarrete Pujols. c) Los Negros, 25 km S Baire, Santiago de Cuba Province; collected 19 March 1976 by Ulises Feria Bencosme. d) Cueva Los Panaderos, Gibara, Holguin Province; collected "in the 1960's" by Milton Pino. e) Cueva del Circulo, Sierra de Cubitas, Camaguey Province; collected by Grupo Yarabey. Additional material, tentatively referred as Solenodon cf. S. cubanus, has been obtained recently from Cuban kitchen middens: a) Cueva de Calero, Camarioca, Matanzas Province, collected 1988 by Aida Martinez; and b) Caimanes III, 1.5 km from bay litoral and 150 m from Río Caimanes, Santiago de Cuba Province, collected by F.M.A. and Ramon Navarrete Pujols. More recently, Late Quaternary material of Solenodon was collected from Cueva del Mono Fósil, Sierra de Galeras, Cordillera de Guaniguanico, Pinar del Río Province among the associated fauna of the newly described Cuban howler monkey, Paralouatta varonai (Jaimez 1989; Rivero and Arredondo 1991).

Solenodon marcanoi

Before its discovery in several cave deposits in Haiti (Morgan and Woods 1986; Woods 1989), the distribution of S. marcanoi was restricted to the type locality in the Dominican Republic (Patterson 1962) (Fig. III-3). In Haiti, all S. marcanoi deposits have a Late Quaternary range, and well preserved skulls have been found with Rattus at sinkholes on the Plain of Formon (Woods 1989). This indicates that this species was still extant there during post-Columbian times. In Rancho de la Guardia, S. marcanoi deposits are Late Pleistocene in age, suggesting the possibility of its earlier extinction in north Hispaniola.

Solenodon "new species A"

The distribution of the giant Cuban solenodon is illustrated in Fig. III-4. The skull type, and two other previously unknown specimens, came from Cueva Paredones, a Late Pleistocene cave deposit located about 3 km SW Ceiba de Agua, San Antonio de los Baños, in Habana Province. According to a sketch map of the cave provided by Manuel Iturralde, the right proximal humerus (MNHNC unnumbered) collected by him in April of 1991 was found approximately 350 meters from the cave entrance, and 180 meters past the Salón del Pozo; a gallery known for the large number of fossils produced in the past (Cueva Paredones extends for approximately 500 meters).

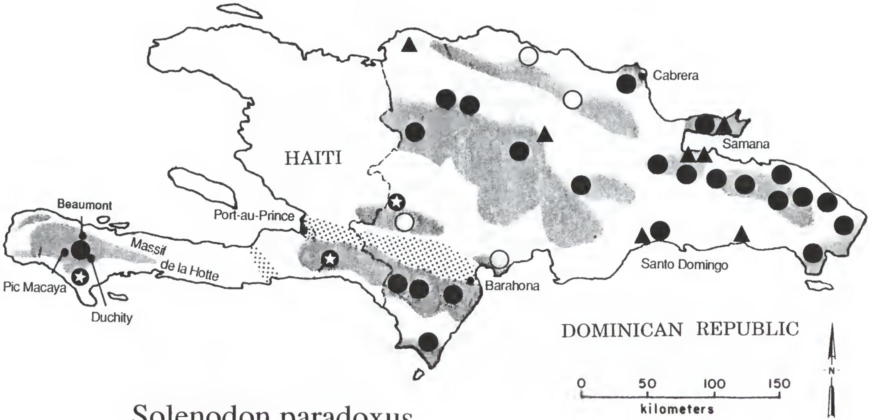
Extensive collections of Cuban fossil vertebrates, including a number of new species of extinct birds and mammmals, have been obtained from Paredones during the past 40 years (Arredondo 1961, 1970, 1971, 1982, 1984; Brodkorb 1969). Among the associated fauna collected from this cave, material referrable to *S. cubanus* has been found in much larger numbers than the giant form. Several mandibles intermediate in size between the two species, and tentatively assigned to *Solenodon* cf *S. cubanus*, have also been obtained from this cave and might represent the giant species. The fauna associated with the *Solenodon* material includes the following fossil or extinct genera: *Nesophontes*, *Megalocnus*, *Miocnus*, *Neocnus*, *Mesocnus*, *Heteropsomys*, *Geocapromys*, *Ornimegalomys*, *Tyto*, *Antillovultur*, and *Titanohierax*. Abra de Andrés, site of the largest known *Solenodon* femur has been previously described by Morgan *et al*. (1980). The third known locality, Caverna de Pío Domingo (OA 301.E), Pinar del Río Province, is also Late Pleistocene in age. This material, a partial skeleton, was found on a surface bone matrix bounded on travertine and calcareous concretions (O. Arredondo 1955, 1976; *in litt*. 1990). Excluding *Tyto*, *Antillovultur*, and

Titanohierax, its associated fauna is similar to that of Paredones.

All three localities are Late Pleistocene deposits, and located in the two westernmost Cuban provinces, Pinar del Río and La Habana, which suggest that the giant Cuban solenodon might have been restricted to western Cuba.

FIG. III-1.

Distribution of *S. paradoxus* in the Dominican Republic and Haiti. Closed circles, Recent; closed triangles, Amerindian; open squares, Late Quaternary; open circles, reports only. See Fig. II-1 for names of physiographic regions.



Solenodon paradoxus

FIG. III-2

Distribution of *S. cubanus*. Closed circles, Recent; closed triangles, Amerindian; stars, Late Quaternary; open circles, reports only.

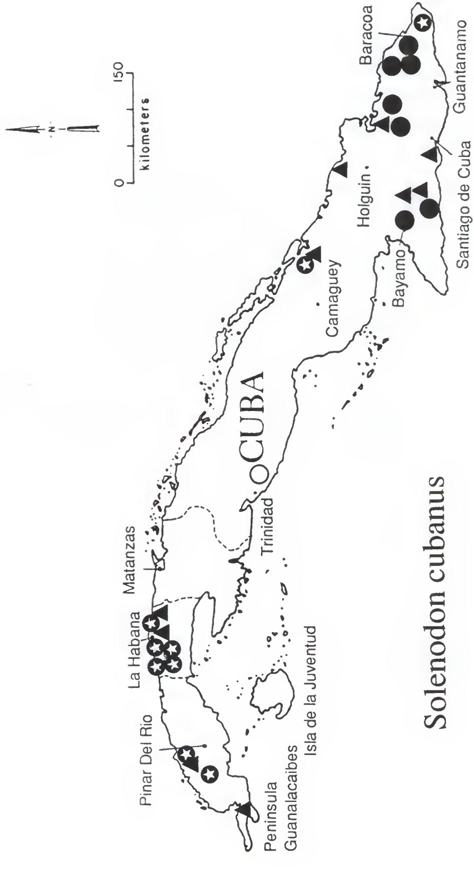
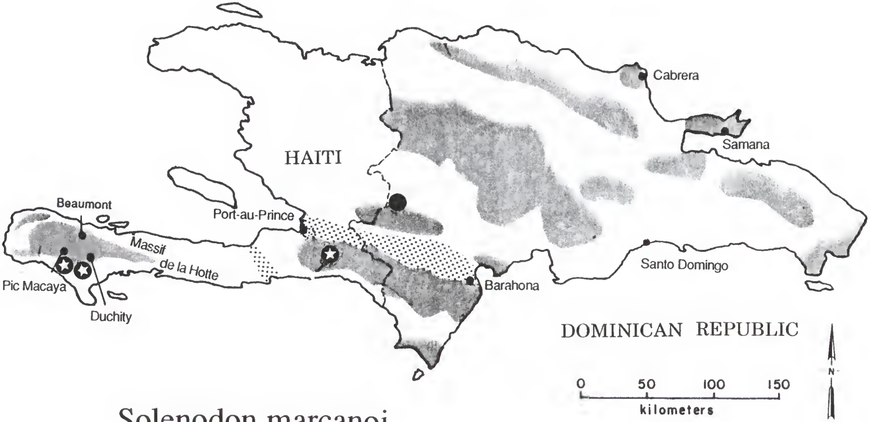

N
0
150
kilometers
Baracoa
Guantanamo
Santiago de Cuba
Holguin
Bayamo
Camaguey
CUBA
Trinidad
Matanzas
La Habana
Isla de la Juventud
Pinar Del Rio
Peninsula
Guanalacaibes
Solenodon cubanus

FIG. III-3

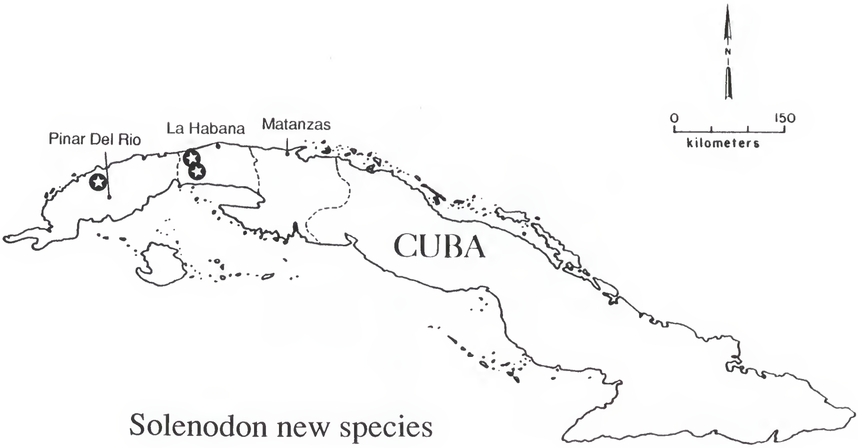
Distribution of *S. marcanoi* in the Dominican Republic and Haiti. Stars, Late Quaternary.; closed circles, Late Pleistocene.



Solenodon marcanoi

FIG. III-4

Map of Cuba showing the known distribution of Solenodon "new species A" (stars). All three localities are Late Pleistocene.


Pinar Del Rio
La Habana
Matanzas
CUBA
0
150
kilometers
N
Solenodon new species

CHAPTER IV

BIOLOGY

Materials and Methods

Observations on the biology of Solenodon paradoxus were recorded both in the wild and under captive conditions. Because of the rarity and secretive nocturnal habits of the species, data gathering is slow under field conditions. Therefore, the information presented here is based on small samples. In the wild, field work was primarily conducted in two areas of the Barahona Peninsula, the Sierra de Baoruco and the Oviedo region, both located in the southwestern corner of the Dominican Republic. Additional observations were recorded opportunistically throughout the country while conducting surveys for the species. The habitat in these two areas have been described previously (Ottenwalder 1985). Animals were captured by hand during nocturnal activity and with Havahart traps baited with live 3-4 day-old chicks. Studies in captivity were conducted in the Parque Zoologico Nacional of Santo Domingo (ZOODOM), Dominican Republic. A total of 31 animals was obtained or donated to the zoo between 1975 and 1989. Half of the animals survived only briefly and opportunity for more regular observations was limited to less than ten specimens.

Observations in captivity were made primarily between 1978-1980 and between January 1987-March 1989. Live individuals were available for study at intervals within these two time periods. The approximate age of young animals was established using a correlation between weight and age (Fig. IV-1) derived from Mohr (1936-38) and observations recorded during this study.

Diel activity and thermoregulation were studied using radiotelemetry. Solenodons are large, fossorial insectivores and impose constraints on transmitter configuration. Consequently, fully self-contained implantable subsystems were chosen to monitor deep-body temperature, activity and location. I used a 10-channel Telonics receiver and AVM implant transmitters. The transmitters were powered by lithium batteries and had an average weight of 20 g. Transmitters were calibrated at 0.5°C increments in a water bath with both digital and dial thermometers read in 0.1°C. At each temperature step, calibration experiments were replicated 10 times. The calibration curve was developed using the generated statistics and a linear regression.

Because of the endangered status of Solenodon, surgical implantation of the transmitter was first tested in a male fur-farm mink (Mustela vison) in captivity at the Santo Domingo Zoo. The implanted transmitter was calibrated in-situ for 36 days, with core body temperatures taken with a thermocouple inserted rectally at 6-8 cm. depth. In Solenodon, the transmitter was implanted peritoneally, and allowed to float freely in the body cavity. The procedures were conducted under anesthesia using Ketamine (15-20mg/Kg), and lasted for approximately 30 minutes. A captive adult male Solenodon was studied between April 1987 and March 1988. The animal was maintained in two quarantine rooms of the building housing the professional staff and veterinary facilities. Body temperature, ambient temperature, activity and behavior were recorded at intervals of 30 minutes throughout 24 hours in each monitoring session. Ambient temperature was recorded simultaneously. A total of 2,072 observations were recorded.

Results

Reproduction and Development

Information on the reproduction and development of *S. paradoxus* have been previously published by Mohr (1936-38), Eisenberg (1975, 1980), Ottenwalder (1979), Peña (1977), and Wislocki (1940). According to Eisenberg (1975), estrus lasts less than 24 hours and the interval between estrus periods of an individual ranges from nine to thirteen days.

Litter Size and Breeding season. As previously figured, there is no indication of reproductive seasonality in S. paradoxus and young may be born in any month of the year (Table IV-1). In the wild, I have recorded adult pairs with single juveniles, or with one juvenile and one subadult, in January, February, April, July, October, November, and December. The frequency of births per month recorded in wild caught females that arrived at the zoo of Santo Domingo was one in March (captive mating), one in May, two in August, and one in October. An aborted fetus from a mishandled captive female was also recorded in March.

A female obtained by the Bronx Zoo give birth to one young in late December, two weeks after her arrival to the zoo (Bridges 1936). A female that gave birth soon after arrival at the Museum of Comparative Zoology (Allen 1910, 1942), was reportedly collected in the Dominican Republic by G. Nelson "early in 1908" (MCZ 1908).

Solenodons were usually found in family groups of three, composed of an adult male, and adult female, and a single offspring. Less common are family groups of four, composed of an adult pair, a subadult, and a juvenile. Pairs with a pregnant female, and single females with young, are also occasionally encountered. Observations of solitary animals in the wild are uncommon.

All 22 juvenile and subadult animals I have recorded between 1975 and 1988, suggested litters of one young. Over 90 percent of the adult females of S. paradoxus caught with adult mates and young, had either single juveniles or near full grown subadults or both.

Three of seven adult females with young were also pregnant at the time of capture. Family group DZIC 4, captured June 30, consisted of an adult male, adult female, and a juvenile male with an estimated age of 3½ months that was still nursing but in the transition to solid food. The female gave birth 45 days after being captured on August 14. Family group DZIC 5, captured August 1, consisted of an adult male, adult female, and a juvenile female with an estimated age of 2 months. On August 14 the female was found upon death to be pregnant. Family group DZIC 7, captured 12 September, consisted of an adult male, adult female, and a juvenile male with an estimated age of 4½ months. The female gave birth on October 2.

These data suggest that interbirth interval is about 145 (±15) days, and that the average number of litters per year is two. As discussed above, litter size is usually one exceptionally two, hence the maximum number of young produced by a female in one year is probably two. If age at first reproduction is around 18 months, and assuming a maximum longevity of 12 years (N=1, captive data, Eisenberg 1981), the maximum number of young that could be produced by an average female in her lifetime is 20. Since in the wild mortality is likely to occur earlier than under optimum captive conditions, the total productivity of an average female would be lower.

Very little is published on reproduction in _S_. _cubanus_. A lactating female with "two very young ones" were reported by Gundlanch (1877). According to letters from Gundlach to A. Mestre (ACC 1982) these animals were probably captured in August. In the few further reports of captured animals of this species only single young were involved.

Sexual _Maturity_ _and_ _Gestation_. The only record available suggests in _S_. _paradoxus_ a long gestation of at least 84 days. The following observations were recorded on a captive pair at the Santo Domingo zoo, and represent the only recorded successful mating of _S. paradoxus_ in captivity. Of the breeding pair, the male arrived as a juvenile on 1 July 1976. The age of the male was estimated to be about three months old. Although the juvenile was observed to nurse several times after its arrival, weaning was in progress and he fed on prepared food daily. The female arrived on 23 March 1977 and was estimated to be 6-7 months old.

A 28 sq. m. rectangular, outdoor enclosure was used to house the solenodons. Inside the enclosure, three large (1.5 x 2.5 m) wooden cages, elevated about 0.5 m above the ground, were provided to isolate animals being introduced. In addition, three underground burrows of different dimensions and depths were also provided to allow the "ground floor" animals to choose their own sleeping chambers. The female was established in the enclosure in February of 1978, three weeks in advance of the introduction of males. Two males were separately introduced for brief periods to investigate compatibility. One of the two males was repeatedly accepted in the female sleeping burrow, thus the remaining male was no longer released in the enclosure. The female was recorded mating for the first time at an approximate age of 17 months.

In June 1978 the lower jaw of the chosen male was found to be fractured due to osteoporosis. Subsequently the food he was provided was prepared in a blender. Frequent encounters between the two animals were permitted after mid-July. The female was given the entire ground area of the enclosure and the male was provided with a large cage with access to the ground. The male was finally allowed to move at will. Intervals between encounters ranged from a few days to several weeks. Sexual activity was observed in September and matings in October and November. The male lost considerable weight after his jaw fracture and was separated from the female on December 4. He died two days later.

The female constructed and relocated the nest several times in February 1979, and finally gave birth on March 2, exactly 84 days after the death of the male. The female died three days later of metritis. Her postpartum body weight was 1,060 g, a 130 g decrease from her weight just before the birth. The three days old newborn was weak, dehydrated and hence removed for hand rearing. Its weigh, taken after the death of the mother, was 60 g. It died on the fifth day from pulmonary edema.

Birth and early development. Newborn weight ranged from 45 to 80 g (N=5, Table V-2), although Mohr (1936-38) estimated that at birth S. paradoxus might weigh up to 130 g. Examination of the only two preserved newborn specimens previously known (MCZ 7101, AMNH 201890; born, respectively, at the Museum of Comparative Zoology and at the Bronx Zoo), show that these two specimens have a larger body size and weigh than the newborns recorded in the zoo of Santo Domingo. It is possible that either stress-related premature births, female malnutrition or a combination of both, might have been involved in the low weight and smaller size of the newborns from the zoo.

The neonates are naked and altricial, and the body acquires a covering of hair in three or four weeks. Between seven and ten weeks of age the juvenile clings to the mother's inguinal teats and thereby accompanies her during her foraging. Teat-transport (Eisenberg 1975) has also been observed in S. cubanus (Gundlach 1895). Full pelage appears at six to nine weeks. Lactation seem to lasts between 60-90 days.

Body weights and measurements

External measurements and body mass of adult, subadult, juvenile and newborn S. paradoxus and S. cubanus are presented in Table IV-3. Hispaniolan solenodons are larger and heavier than the Cuban species. On the average, adult S. paradoxus weight 805 g., ranging from 620 to 1,166 grams. The minimum weigh is based on a wild caught female with young. The maximum weigh is that of a pregnant female with a presumed terminal fetus. Examination of the skulls of two females known to have bred showed the maxillary-premaxillary and interparietal-supraoccipital sutures still unfused. The lambdoidal and sagittal crests were also not yet well developed in these females.

Variation with age was analyzed in S. paradoxus using 41 cranial and post-cranial characters (Table IV-4). Adult and subadult samples only differed significantly in two measurements, zygomatic breadth and maximum width of P_4. Adults and subadults, which overlap in most measurements, form a subset that differs significantly from the juvenile subset in 30 measurements. All three age classes form a single subset in only two measurements (maximum width of M_2 and maximum width of M_3), and show no significant differences in five characters (alveolar length of upper molar toothrow, anteorbital constriction, interorbital constriction, maximum length of M_3, and minimum shaft width of femur). Juveniles differ significantly from adults and subadults in 33 characters.

Examination of the skull of several near full grown subadult individuals confirmed unfused sutures, undeveloped crests and, in some cases still emerging dentition, but overall skull proportions were comparable to that of adults. Subadults are also close to adults in external measurements. Analysis of these data indicate that subadults might attain adult size between six and eight months of age.

Mammal species with reduced sexual dimorphism, altricial young, and delayed sexual maturation, among other factors, exhibit high parental investment and tend to posses monogamous mating systems (Kleiman 1977, Ralls 1977, Zeveloff and Boyce 1980). Monogamy traits are clearly evident in Solenodon, and available data suggest that, in the presence of the parents, young exhibit delayed sexual maturation, only the adult pair breeds, and older juveniles aid in rearing young siblings. Such an scheme was described by Kleiman (1977) for mammals exhibiting obligate monogamy. The practice of fostering behaviors might also be possible in Solenodon. Alloparental care and adoption of young are, more than often, attributes of animals characterized by single offspring, prolonged parental investment and other traits typical of K-selected species (Riedman 1982).

Thermoregulation, Diel Activity and Behavior

The results of one 24-hour cycle relating changes in body temperature to the level of activity, ambient temperature and time of day are shown in Fig. IV-2. The relationship between ambient and body temperature for the same set of data is shown in Fig. IV-3. The animals were active mainly at night. During the day, the animals spent most of the time sleeping or resting, with an average body temperature of 33°C. Daytime resting was only interrupted by brief trips outside the burrow to urinate or defecate, and, less frequently, to drink. The minimum body temperatures recorded were 32.8°C during the post-absorptive, resting phase (core, radio-telemetry), and 31.1°C under anesthesia with Ketamine (rectal, digital thermometer).

Nocturnal activity is characterized by successive foraging trips at variable intervals. Body temperature increases gradually during nocturnal activity until a peak of 36°C is reached. Hispaniolan solenodons spend considerable time exploring. After foraging the animals rest for short periods in the nest-box. Little crepuscular activity was observed, though prolonged activity until early morning hours might be a function of foraging success.

At the range of temperatures tested, S. paradoxus proved its ability to maintain a constant body temperature differential with that of the environment (Fig. IV-3).

Observations were recorded at the mild ambient temperatures of Santo Domingo (26-29.5°C). These observations are consistent with those of Eisenberg and Gould (1966). Using rectal temperatures, Eisenberg and Gould (1966) showed that S. paradoxus was able to remain active and to maintain an average temperature differential of 6.4°C between ambient (at 24.0-26.8°C) and body temperatures, whereas Echinops entered torpor at 21.0-27.3°C during the same time period.

Average ambient temperatures in most Solenodon localities in the Dominican Republic is 24.8°C, with maximum-minimum ranges between 13.5° and 38.8°C (Ottenwalder 1985). However, the geographic range of the species include both, elevations above 2,000 meters were temperatures drop below 10°C during the winter months (with recorded absolutes of 0°C), and transitional dry forest at sea level. Since exposure of solenodons to extreme temperatures in the low and high ranges was not attempted due to the lack of a climatic chamber, the question remains as to the extent of thermoregulatory capacity in the Hispaniolan solenodon under extreme climatic conditions. Since activity above ground is probably influenced by environmental conditions, it is conceivable that limitations in thermoregulatory ability might be compensated for by the microclimate stability of the burrow and foraging tunnels.

Solenodons are among the largest members of the Insectivora. Like other mammals with low body temperatures, they have abdominal testes and exhibit periodic descensus, probably coinciding with spermatogenesis. Furthermore, their K-selected life history strategy (prolonged longevity, slow development, small litter size, low densities), exploitation of an insectivorous food source, semifossorial habits, low habitat productivity and low body temperature, all converge to suggest low metabolic rates. With the exception of species with relatively small body size, mammals feeding on soil and litter fauna usually have low body temperatures, and a reduced capacity to regulate body temperature at low environmental temperatures (McNab 1980, 1983), in part probably as an adaptation to the periodicity in the availability of soil invertebrates. McNab (1979) has also shown that basal rates of metabolism are lower than expected in fossorial and burrowing mammals weighing more than 80 g.

Parasites and Diseases

Post mortems of 58 captive S. paradoxus, including recent wild caught animals, revealed the presence of endoparasites in 28 individuals (Appendix 2). In 13 of these cases, parasites were suspected as the direct cause of death in captivity. Helminth parasite loads ranged from low to heavy. Acanthocephalans were usually found in skeletal muscle, mesentery, stomach cavity, and liver diaphragm, whereas the cestodes, nematodes and trematodes were found in the small intestine. Juveniles and subadults were usually free of parasites, while the diversity of the parasite community tended to increase with the age of the animal. Helminth parasites were sometimes associated with infections caused by pathogenic bacteria (e.g., *Micrococcus*, *Pseudomonas*, and *Salmonella*).

Faecal flotation analyses of 19 *S. paradoxus* gave the following results: eight negative, one heavily infested with tapeworms, one with taenias and eggs of two unidentified nematodes, five heavily infested with cestodes of the Hymenolepididae and four with tapeworms resembling *Hymenolepis*. Examination of the intestine and mesentery of four *S. paradoxus* revealed two acanthocephalans, *Oligacanthorynchus thumbi* and *Centrorhynchus* sp.

There are frequent reports in the literature of solenodons with parasites. W. Peters (1863) commented that some of the Cuban animals he received in 1860 died of a rare helminthiasis, and "unidentified whitish cysts resembling grease nodules" were found by Mohr (1935-38) in Hispaniolan solenodons maintained at Hamburg. Poey (1851, p. 433) described parasites from one of four *S. cubanus* he maintained in captivity: [the animal] "had the whole body infested with helminths, wrapped in a white sac; they were of all sizes, in the subcutaneous tissue, and within the muscles primarily in the neck, where such sacs were accumulated. Opening the sacs, they appear white and coiled, attaining several inches in length, flattened like taenias, but not articulated, thinner necks, head somewhat bulky."

Three S. paradoxus received in 1910 by the New York Zoological Park died during the first week following their arrival (Bridges 1958). The autopsy concluded that the cause of death was acute peritonitis due to a large stock of unidentified intestinal parasites that had invaded the peritoneum and stomach (Hornaday 1910; NYZS postmortem records).

Several species of helminths have been reported from Solenodon (Table IV-5). These include nematodes, cestodes, trematodes and acanthocephalans. My observations suggest that some of these might be synonymous. Sandground (1938) described three species of parasitic worms and mentioned the muscle-invading larvae of an unidentified acanthocephalan from three adult S. paradoxus. A Cuban solenodon that died in captivity in 1943 at the Zoo of La Habana was found upon autopsy to be infested with cestodes of the family Hymenolepididae (Perez 1960). Nematodes of the family Physalopteridae were detected during a postmortem examination of a male S. cubanus from La Habana Zoo in 1975 (Lorenzo et al. 1981). According to Varona (1983), the animals apparently died of digestive problems following an endoparasitic infection.

Three of the seven S. paradoxus examined at the Centro Nacional de Investigaciones Agropecuarias (CENIA) in 1972 and 1973 were reported to be infested with cysts of Acanthocephala. The worms were referred to the species Macracanthorhynchus hirundinaceus (Ricart de Melgen et al. 1973). Solenodons feed primarily on soil invertebrates, particularly arthropods. Our analyses of Hispaniolan solenodon scats revealed that Phyllophaga (Coleoptera: Scarabeidae) were common prey items in the wild. Phyllophaga, which is a diverse and common genus in the Dominican Republic, seems to be an important intermediate host of acanthocephalans. Other beetles, including coprophagous Scarabeidae and many tenebrionids, presumably preyed upon by S. paradoxus, are known to be both intermediate hosts of diverse assemblages of cestodes, nematodes, trematodes, and acanthocephalans.

It is possible that some of the parasites resembling Hymenolepis nana that were found in some S. paradoxus in the Santo Domingo Zoo might actually represent Vampirolepis (Hymenolepis) wislockii. Hymenolepis nana is usually a parasite of birds and it is unlikely that wild solenodons represent natural hosts. If Hymenolepis is indeed involved, it might be only found in solenodons held under captive conditions, the source of the parasites being week-old chicks, newborn mice or other contaminated food items offered as food.

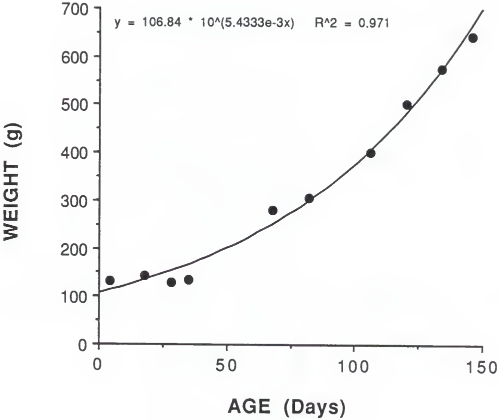
Macracanthorhynchus hirundinaceus was reported by de Melgen et al. (1973) in three wild caught specimens of the Hispaniolan Solenodon, S. paradoxus. However, M. hirundinaceus has not been reported among the helminth species identified by other authors from either the Hispaniolan or the Cuban Solenodon. The only previous reference of Solenodon as hosts of acanthocephala is from Sandground (1938) who recorded the muscle-invading larvae of an unidentified acanthocephalan from three adult S. paradoxus, later described by Haffner (1939) as Oligacanthorynchus thumbi.

Of two species of thorny-headed worms I obtained, one was identified (E. A. Harris, pers. comm.) as Centrorhynchus sp., and the other as to the species described by Haffner (Oligacanthorynchus thumbi). Centrorhynchus is usually a parasite of birds, occasionally mammals, but the larval stages have been found encysted in amphibians and reptiles as well. The intermediate host would be an insect yet unknown. The final host, as has been suggested (E. A. Harris, pers. comm.), might be a bird of prey that feeds on Solenodon. I found no reports of Centrorhynchus isolation from West Indian birds of prey or large snakes, but only from the Cuban lizard cuckoo (Saurothera merlini), a well known predator of small reptiles and insects (Coy and Lorenzo 1982). Oligacanthorynchus has a similar life-history to Centrorhynchus, the adults being found in birds and mammals, and the larvae in insects.

Whether the acanthocephalan reported by Ricart de Melgen et al. (1973) is indeed M. hirundinaceus or one of the other two species mentioned is uncertain. If in fact, the diagnosis made by de Ricart de Melgen et al. (1973) is correct, and Solenodon is parasitized by M. hirundinaceus, then this an erratic host-parasite cycle and the infestation could be obtained through the ingestion of Coleoptera, which are known to be intermediate hosts of this swine parasite. In this case, Macracanthorhynchus could have been introduced with the pigs that arrived in Hispaniola in 1493 with Columbus. This parasite is frequent in domestic stock, but no information is available concerning its status in feral animals of Cuba and Hispaniola, which are also relatively common in Solenodon habitats. Since an introduced parasite could have a profound impact on the endemic Solenodon, the possibility that Macracanthorhynchus might be parasitizing solenodons should be investigated.

Fig. IV-1

Exponential correlation between age and weight in *Solenodon paradoxus*.



y = 106.84 * 10^(5.4333e-3x)   R^2 = 0.971
WEIGHT (g)
700
600
500
400
300
200
100
0
0
50
100
150
AGE (Days)

FIG. IV-2

Diel activity, body temperature and behavior in a captive adult male <u>Solenodon paradoxus</u>.

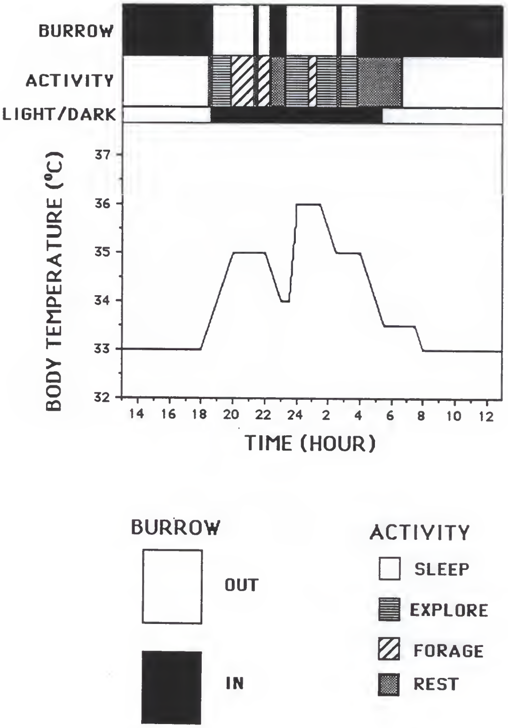

BURROW
ACTIVITY
LIGHT/DARK
BODY TEMPERATURE (°C)
37
36
35
34
33
32
14
16
18
20
22
24
2
4
6
8
10
12
TIME (HOUR)
BURROW
OUT
IN
ACTIVITY
SLEEP
EXPLORE
FORAGE
REST

FIG. IV-3

Relationship of ambient temperature and core body temperature in a captive adult male *Solenodon paradoxus*.

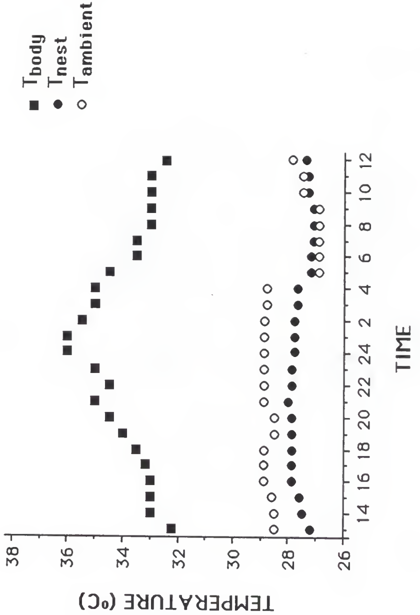

■ T_{body}
● T_{nest}
○ $T_{ambient}$
TEMPERATURE (°C)
38
36
34
32
30
28
26
14
16
18
20
22
24
2
4
6
8
10
12
TIME

Table IV-1. Recorded births and pregnancies of wild caught and captive <u>Solenodon paradoxus</u>.

	FEMALE NUMBER	BIRTH DATE	LITTER SIZE
MCZ-Harvard			
	7101	early 1908	1
NYZS-Bronx			
	9003	26 Dec 1935	1
ZOODOM			
	3-B-1	18 May 1976	1
	4-B-1	15 Aug 1976	1
	5-B-1	14 Aug 1976	1
	7-B-1	2 Oct 1976	1
	8-1	2 Mar 1979	1
	7-B-2	30 Mar 1982	1

Table IV-2. Measurements and weights of newborn *Solenodon paradoxus*. Estimated weights are marked with asterisks.

YEAR	SEX	AGE AT DEATH (days)	WEIGHT (g)	MEASUREMENTS				PLACE
				TL	TA	HF	EA	
1908	F	3	60-80*	180	70	29	7.0	MCZ
1935	F	2	70-80*	196	72	30	7.5	NYZS
1976	F	4	58.5	156	60	25	7.0	ZOODOM
1976	F	3	45	170	57	25	8.0	ZOODOM
1979	M	5	60	170	68	28	7.5	ZOODOM

Table IV-3.-External measurements (mm) and weights (g) of adult, subadult, juvenile and newborn *Solenodon paradoxus* and *S. cubanus*[1].

Species/ Age class	N	Mean ± SD	Range	CV
		Total length		
S. paradoxus				
Adult	74	529.9 ± 35.4	470-715	6.7
Subadult	14	493.4 ± 53.3	365-572	10.8
Juvenile	12	366.7 ± 59.1	264-477	16.1
Newborn	5	176.4 ± 16.3	156-196	9.3
S. cubanus				
Adult	10	447.8 ± 65.3	325-530	14.6
Subadult	1	475.0		
Juvenile	1	332.0		
		Head-body length		
S. paradoxus				
Adult	39	298.2 ± 38.7	225-490	13.0
Subadult	11	268.9 ± 39.8	200-335	14.8
Juvenile	10	217.7 ± 31.1	134-262	14.3
Newborn	5	111.5 ± 12.3	96-124	11.1
S. cubanus				
Adult	11	277.5 ± 55.1	195-360	20.0
Subadult	2	252.5		
		Length of tail		
S. paradoxus				
Adult	74	224.6 ± 13.9	196-254	6.2
Subadult	14	216.8 ± 26.8	154-267	12.4
Juvenile	10	137.8 ± 41.8	75-215	30.3
Newborn	5	65.9 ± 7.1	57-72.5	10.7
S. cubanus				
Adult	11	162.8 ± 19.1	130-190	11.7
Subadult	1	173.0		
Juvenile	1	127.0		

Table IV-3.-(Cont.)

Species/ Age class	N	Mean ± SD	Range	CV
		Length of hindfoot		
S. paradoxus				
Adult	60	62.4 ± 4.9	54-72	7.8
Subadult	12	63.5 ± 5.4	56-75	8.5
Juvenile	11	53.4 ± 5.5	44-61	10.4
Newborn	5	27.5 ± 2.3	25-30	8.5
S. cubanus				
Adult	11	54.4 ± 4.9	45-65	9.1
Subadult	2	55.0		
		Length of ear		
S. paradoxus				
Adult	57	28.1 ± 2.8	21-38	9.8
Subadult	12	26.9 ± 3.6	19-35	13.5
Juvenile	9	22.3 ± 4.9	11-26	21.9
Newborn	4	8.0 ± 1.0	7-9.3	12.4
S. cubanus				
Adult	11	27.2 ± 5.5	15-32	20.3
Subadult	2	29.0		
		Body mass		
S. paradoxus				
Adult	39	805.5 ± 120.9	620-1166	15.0
Subadult	10	606.0 ± 132.5	400-784	21.9
Juvenile	8	308.0 ± 163.6	122-510	53.1
Newborn	5	63.0 ± 13.0	45-80	20.7
S. cubanus				
Adult	2	769.0 ± 55.2	730-808	7.2
Subadult	1	455		

---

[1] Data for _Solenodon cubanus_ in part from Peters (1863), Barbour (1944), Eisenberg and González (1982), and Abreu _et al_. (1990).

Table IV-4.-Variation with age in cranial and post-cranial measurements of *Solenodon paradoxus*. Statistics given are number, mean, standard deviation, range, coefficient of variation, F value (*<0.05, **<0.01, ***<0.001). Means found to be significantly different were tested with Duncan's multiple range test (P <0.05) to determine nonsignificant subsets. Age class: I-adult, II-subadult, III-juvenile.

					F	Results	
Age	N	Mean ± SD	Range	CV	P	Duncan's	
			Greatest length of skull				
I	112	84.3 ± 3.66	72.3-91.5	4.4		I	
II	22	83.9 ± 2.54	78.8-87.4	3.0	59.48^{***}	I	
III	7	68.7 ± 6.28	62.8-78.8	9.1	0.0001		I
			Condylobasal length				
I	110	79.2 ± 3.32	67.1-86.6	4.2		I	
II	22	79.1 ± 2.05	74.8-83.4	2.6	57.87^{***}	I	
III	7	65.2 ± 6.25	57.8-75.0	9.6	0.0001		I
			Palatal length				
I	116	36.5 ± 1.65	30.8-40.4	4.5		I	
II	25	36.3 ± 1.38	32.5-38.7	3.8	48.52^{***}	I	
III	8	30.3 ± 3.26	26.6-35.5	10.8	0.0001		I
			Postpalatal length				
I	112	29.9 ± 1.34	25.6-32.6	4.5		I	
II	22	29.5 ± 1.68	23.2-31.4	5.7	46.60^{***}	I	
III	7	24.4 ± 2.54	21.5-28.5	10.4	0.0001		I
			Alveolar length of upper molar toothrow				
II	26	10.2 ± 0.58	9.1-11.9	5.7			
I	117	10.1 ± 0.67	7.9-12.9	6.7	0.69	ns	
III	9	10.1 ± 0.64	8.8-10.9	6.3	0.5032		
			Length of upper molar toothrow				
II	26	11.0 ± 0.57	9.5-12.6	5.2		I	
I	113	10.8 ± 0.54	9.4-12.0	5.1	5.05^{**}	I	
III	9	10.4 ± 0.57	9.2-11.2	5.6	0.007		I

Table IV-4.-(Cont.)

Age	N	Mean ± SD	Range	CV	F P	Results Duncan's		
			Length of maxillary toothrow					
II	26	25.5 ± 0.90	23.6-27.3	3.5		I		
I	117	25.4 ± 1.35	20.2-27.6	5.4	30.79***	I		
III	9	21.9 ± 1.56	19.2-24.4	7.2	0.0001		I	
			Breadth across maxillary toothrow					
I	116	23.2 ± 1.26	19.2-25.9	5.4		I		
II	26	23.0 ± 0.92	20.5-24.1	4.0	5.45**	I		
III	8	21.7 ± 1.01	19.9-22.9	4.7	0.0052		I	
			Anteorbital constriction					
I	119	13.9 ± 0.74	11.6-15.9	5.4				
II	26	13.8 ± 0.91	10.4-15.1	6.6	0.20	ns		
III	8	13.7 ± 0.67	12.9-14.7	4.9	0.8158			
			Zygomatic breadth					
I	100	33.5 ± 1.74	30.1-39.0	5.2		I		
II	22	31.5 ± 1.84	28.0-36.2	5.8	87.65***		I	
III	8	25.1 ± 2.12	22.0-28.4	8.5	0.0001			I
			Interorbital constriction					
II	25	14.9 ± 0.46	14.1-15.8	3.1				
I	118	14.8 ± 0.53	13.6-16.5	3.6	1.51	ns		
III	10	14.5 ± 1.59	10.2-16.0	11.0	0.2248			
			Squamosal breadth					
I	115	31.2 ± 1.47	28.2-34.5	4.7		I		
II	24	30.6 ± 1.05	28.9-32.8	3.4	43.61***	I		
III	9	26.6 ± 1.49	24.8-29.3	5.6	0.0001		I	
			Mastoid breadth					
I	112	25.4 ± 1.10	22.6-28.4	4.4		I		
II	22	25.1 ± 0.79	23.7-26.9	3.2	42.79***	I		
III	9	22.0 ± 1.44	19.9-24.2	6.6	0.0001		I	
			Breadth of the braincase					
I	116	24.6 ± 0.81	22.0-26.6	3.3		I		
II	23	24.5 ± 0.62	23.3-25.8	2.5	27.48***	I		
III	9	22.6 ± 0.76	21.7-23.9	3.4	0.0001		I	

Table IV-4.-(Cont.)

Age	N	Mean ± SD	Range	CV	F P	Results Duncan's	
			Condylar breadth				
I	113	16.7 ± 0.74	15.2-18.9	4.5		I	
II	23	16.5 ± 0.52	15.7-17.7	3.1	8.13***	I	
III	8	15.6 ± 0.99	14.8-17.5	6.3	0.0005		I
			Skull height				
I	115	19.3 ± 1.29	15.2-22.2	6.7		I	
II	21	19.0 ± 0.88	17.3-20.3	4.7	15.62***	I	
III	9	17.0 ± 0.96	15.5-18.8	5.7	0.0001		I
			Maximum length of C^1				
II	10	4.4 ± 0.38	3.8-5.1	8.8		I	
I	65	4.1 ± 0.43	3.0-5.2	10.7	13.93***	I	
III	3	2.8 ± 1.23	1.4-3.8	44.2	0.0001		I
			Maximum width of C^1				
II	10	2.3 ± 0.16	2.0-2.6	7.0		I	
I	65	2.2 ± 0.14	2.0-2.6	6.4	15.25***	I	
III	3	1.7 ± 0.51	1.1-2.1	29.2	0.0001		I
			Maximum width of M^3				
I	116	6.7 ± 0.66	4.4-7.7	10.7		I	
II	27	6.5 ± 0.54	5.5-7.5	8.4	5.83**	I	
III	9	5.7 ± 0.59	4.8-6.6	10.3	0.0036		I
			Greatest mandible length				
II	27	52.7 ± 1.70	49.0-55.9	3.2		I	
I	121	52.6 ± 2.36	45.2-58.1	4.5	38.85***	I	
III	8	44.9 ± 4.46	39.6-51.9	10.0	0.0001		I
			Length of mandibular toothrow				
II	28	26.6 ± 1.53	22.3-28.6	5.8		I	
I	122	26.5 ± 1.23	23.3-28.9	4.7	9.18***	I	
III	9	24.6 ± 1.39	23.0-27.1	5.7	0.0002		I
			Alveolar length of P_4-M_3				
II	28	16.9 ± 0.72	15.0-18.2	4.3		I	
I	120	16.7 ± 0.88	14.6-18.5	5.3	6.58**	I	
III	9	15.7 ± 1.12	13.8-16.8	7.1	0.0018		I

Table IV-4.-(Cont.)

Age	N	Mean ± SD	Range	CV	F P	Results Duncan's		
			Depth through coronoid process					
I	119	23.3 ± 1.26	20.6-26.2	5.4		I		
II	27	22.8 ± 1.36	20.2-26.5	6.0	110.16***	I		
III	9	16.6 ± 1.73	14.0-19.4	10.4	0.0001		I	
			Angular-condylar height					
I	122	14.1 ± 1.23	11.9-17.1	8.7		I		
II	27	14.0 ± 1.12	12.2-16.3	8.0	37.50***	I		
III	8	10.3 ± 1.23	8.2-12.3	13.0	0.0001		I	
			Maximum length of P_4					
II	26	4.2 ± 0.26	3.5-4.7	6.0	58.45	I		
I	118	4.1 ± 0.33	3.5-4.9	8.0	58.45***	I		
III	9	2.9 ± 0.31	2.5-3.4	10.6	0.0001		I	
			Maximum width of P_4					
II	26	3.3 ± 0.23	2.6-3.6	7.0		I		
I	118	3.1 ± 0.32	2.2-3.8	10.4	23.05***		I	
III	9	2.5 ± 0.39	2.1-3.4	15.8	0.0001			I
			Maximum length of M_1					
II	26	4.6 ± 0.23	4.0-5.0	5.1		I		
I	117	4.5 ± 0.28	4.0-5.1	6.3	9.45***	I		
III	9	4.1 ± 0.80	2.5-4.9	19.6	0.0001		I	
			Maximum width of M_1					
III	9	4.3 ± 0.26	3.8-4.6	6.1		I		
II	26	4.3 ± 0.24	3.7-4.7	5.8	5.67**	I	I	
I	116	4.1 ± 0.28	3.3-4.7	6.7	0.0043		I	
			Maximum length of M_2					
I	116	4.6 ± 0.25	3.9-5.4	5.5		I		
II	28	4.5 ± 0.18	4.2-4.9	4.0	29.61***	I		
III	9	3.7 ± 0.89	2.3-4.7	24.2	0.0001		I	
			Maximum width of M_2					
II	28	4.3 ± 0.21	3.7-4.7	4.9		I		
III	9	4.3 ± 0.22	3.8-4.6	5.3	5.60**	I		
I	116	4.2 ± 0.25	3.5-4.7	6.0	0.0045	I		

Table IV-4.-(Cont.)

Age	N	Mean ± SD	Range	CV	F P	Results Duncan's		
Maximum length of M_3								
II	27	5.3 ± 0.29	4.8-5.8	5.5				
I	113	5.2 ± 0.31	4.3-5.9	6.0	2.30	ns		
III	9	5.1 ± 0.39	4.3-5.6	7.8	0.1039			
Maximum width of M_3								
II	27	3.6 ± 0.19	3.0-3.9	5.4		I		
III	9	3.5 ± 0.18	3.1-3.7	5.3	4.49*	I		
I	113	3.4 ± 0.25	2.8-4.0	7.6	0.0128	I		
Total length of femur								
I	84	45.6 ± 1.94	41.0-50.4	4.3		I		
II	12	43.8 ± 2.90	38.4-47.7	6.4	43.18***	I		
III	4	35.7 ± 3.34	31.3-38.9	9.4	0.0001		I	
Maximum width of femur								
I	86	12.9 ± 0.69	11.4-14.6	5.4		I		
II	14	12.8 ± 0.65	11.5-13.7	5.2	14.94***	I		
III	4	10.8 ± 1.94	8.4-12.5	17.9	0.0001		I	
Minimum shaft width of femur								
I	87	5.1 ± 0.38	4.3-6.4	7.6				
II	15	5.0 ± 0.30	4.4-5.6	6.2	2.39	ns		
III	4	4.8 ± 0.22	4.6-5.1	4.6	0.0970			
Total length of humerus								
I	80	46.0 ± 2.28	40.6-50.7	5.0		I		
II	11	45.5 ± 2.23	41.3-48.5	4.9	24.95***	I		
III	4	37.4 ± 4.01	32.1-40.9	10.7	0.0001		I	
Maximum width of humerus								
I	84	17.5 ± 0.71	15.8-18.8	4.0		I		
II	14	17.3 ± 0.45	16.5-18.3	2.6	10.90***	I		
III	4	15.8 ± 1.28	14.4-17.3	8.1	0.0001		I	
Minimum shaft width of humerus								
I	83	5.0 ± 0.29	4.3-5.8	5.8		I		
II	14	4.7 ± 0.26	4.3-5.2	5.6	15.01***		I	
III	4	4.3 ± 0.40	3.8-4.75	9.3	0.0001			I

Table IV-4.-(Cont.)

Age	N	Mean ± SD	Range	CV	F P	Results Duncan's	
			Total length of ulna				
II	9	52.0 ± 1.91	48.9-54.2	3.7		I	
I	60	51.9 ± 2.34	40.6-58.0	4.5	15.71^{***}	I	
III	3	44.0 ± 4.65	38.6-47.1	10.6	0.0001		I
			Maximum width of ulna				
I	60	6.8 ± 0.44	5.9-7.6	6.6		I	
II	12	6.7 ± 0.33	6.2-7.3	5.0	5.56^{**}	I	
III	3	5.9 ± 0.79	5.0-6.5	13.5	0.0057		I
			Minimum shaft width of ulna				
I	60	2.0 ± 0.21	1.5-2.5	10.5		I	
II	12	1.9 ± 0.28	1.4-2.3	2.3	7.11^{**}	I	
III	3	1.6 ± 0.11	1.5-1.7	7.4	0.0015		I

Table IV-5. Helminth parasites recorded from _Solenodon paradoxus_ (Pa) and _S_. _cubanus_ (Cu).

Helminth taxa	Host	Habitat	Source
Acanthocephala			
Acanthocephala sp.	Pa	Cysts in subperitoneal muscles of pelvis, mesenteries, diaphragm, liver and pericardium	a,c
Oligacanthorynchus _O_. _thumbi_	Pa	Mesentery	b,c
Centrorhynchus sp.	Pa	Small intestine and mesentery	c
Macracanthorhynchus _M_. _hirundinaceus_	Pa	Cysts in mesentery, abdominal cavity and liver	d
Trematoda			
Brachylaemidae _Brachylaemus_ sp.	Pa	Colon	a
Cestoda			
Hymenolepidae Hymenolepidae sp.	Pa		c
Vampirolepis _V_. _wislockii_	Pa	Lower part of small intestine	a
" "	Cu		e
_V_. _almiqui_	Cu		f
Nematoda			
Trichostrongylidae _Shattuckius_ _S_. _shattucki_	Pa Cu	Duodenum	a e
Physalopteridae _Physaloptera_ sp.	Cu		g

Sources: a) Sandground (1938); b) Haffner (1939); c) this study; d) de Melgen _et al_. (1973); e) Rysavy and Barus (1970); f) Perez (1960); g) Lorenzo _et al_. (1981).

CHAPTER V

CONSERVATION STATUS

Status and Numbers

Solenodon paradoxus

The status of S. paradoxus in the Dominican Republic has been discussed recently (Ottenwalder 1985). Its present distribution is widely spread but highly fragmented. Despite the discovery of new localities where the species is still found, the prospects for survival are bleak. In most of these localities, it occurs in small isolated habitat patches and is rarely seen. More continuous habitat is only available in the Cordillera Central, in the Barahona Peninsula, and in the Boca de Yuma forest. To some extent, significant amounts of forest are also left in Sierra de Baoruco. Although not in immediate danger of extinction, Hispaniolan solenodons are declining throughout the country. Land development and the impact of exotic species are the major problems faced by S. paradoxus in the Dominican Republic. These are illustrated in the third section of this chapter (Conservations problems: People-Solenodon conflict).

Numbers are unknown. Between 1973 and 1988 I have salvaged, confiscated, collected, or obtained by various means 68 animals or their remains. Rough density estimates obtained in the Barahona Peninsula south of Oviedo, suggested two animals/km^2. The site is a fairly homogeneous transitional dry-moist Bursera forest on reef limestone at 5-80 meters elevation. The method of estimation used was direct observation during nocturnal activity in transects selected at random. The surveys were conducted for five consecutive nights between 20:00-24:00, for a total of 20 h. in four plots of one square kilometer each.

In Haiti, the species is concentrated in a single region on the remote southwestern end of the Tiburon Peninsula, the plateau of Plain Martin at Duchity. Despite the isolation of this area, human populations are high and depend on traditional agriculture and forest harvest methods. Solenodons are eaten when encountered, both by people and by dogs. Little hope has been expressed for this population (C. Woods pers. comm). Numbers are unknown.

Despite the existence of two National Parks in southwestern Dominican Republic and one in southwestern Haiti, the South Hispaniolan solenodon, S. paradoxus subspecies B, is the most endangered of the two geographic populations.

Solenodon cubanus

As of 1991, local sources estimate that only ten S. cubanus are known to have been captured throughout Cuba in the course of the century (J. de la Cruz pers. comm.).

Up to 1974, only five animals were said (Silva Taboada 1974) to have been caught (in four occasions, 1913, 1943, 1953, 1974) or observed in several localities of eastern Cuba (Cauto Arriba, La Francia, La Bayamesa, La Bayamita, Alto de Sonador, San Antonio de Duaba, Mayarí Arriba, La Melba y Monte Iberia). However, I examined two specimens obtained by C. Ramsdem in Monte Iberia, Baracoa in 1909, in the collection of the Instituto de Ecología y Sistemática of the Cuban Academy of Science (IES/ACC). Whether these are among the animals listed by Silva it could not be determined. At least three additional Cuban solenodons were captured in the wild between 1974 and 1982. According to (Varona 1983), all three (one in 1976, a female in 1981, and a juvenile in 1982) were released at the site of capture within the limits of protected areas. But Abreu *et al*. (1989), claimed it was two in 1974 from La Zoilita, and one from El Palenque in 1982, in Sierra del Cristal; the latter being the only one released. Nevertheless, I examined one specimen from Baracoa dated 1974 in the collection of the IES/ACC.

The species is believed to survive in Cuchillas de Toa (Alayon 1988), Sierra del Cristal, Gran Sierra, Cuchillas de Moa, and Cuchillas de Baracoa (Abreu et al. 1990). However, during the last fifteen years, living populations of *S. cubanus* have only been known from Sierra del Cristal, Holguin Prov, and in the mountains of Baracoa, Guantanamo Prov. Varona (1981) reported that 14 animals were sighted in Sierra Maestra during the mid 1970's, but according to a recent assessment of the threatened Cuban fauna (Cruz, in press), no observations have been recorded from this mountain range in 30 years. Thus, their present distribution is only confirmed to include the regions of Baracoa and Sierra del Cristal. In 1981, Eisenberg and Gonzalez (1985) found solid evidence of their presence and the partial skeleton of two specimens in a burrow system in Cerra La Iron, Baracoa. The situation of the species in this area was described by these authors as stable.

In Sierra del Cristal, a team of Cuban biologists searched for the animal in La Zoilita, Sierra la Boca, near Mayarí, between 1985 and 1988 (Abreu et al. 1989). The surveys were conducted as part of multidisciplinary faunal inventories organized in anticipation of government plans to develop a large scale mining operation in the area. La Zoilita region, located on the northern slopes of Sierra del Cristal, contains significant deposits of ferro-nickel. Logging of the area was started with the announcement of forthcoming mining activities, and was carried out to prepare the site for an open mine operation. In nine trips to the area, evidence of the existence of the species was reported from "all areas visited in rain forest and in pine forest near streams" (Abreu et al. 1989), but not a single animal was observed. Two animals killed by dogs were collected (Abreu et al. 1990). The investigation concluded in 1989. By 1990, the vegetation had been leveled and extraction of the mineral started (Anonymous, pers. comm.).

La Zoilita no longer exists as a Solenodon habitat. Up to 1991, no new studies or conservation programs have been developed, and because of the economical situation, there were no plans for such projects envisioned in the near future.

As in Haiti, solenodons are utilized for food by hunters in the mountains of Sierra del Cristal and Baracoa (J. de la Cruz pers. comm.). Because of their low densities, hunting of solenodons for food in these two countries is only opportunistic rather than systematic. Traditional hunting of endemic terrestrial mammals in the Greater Antilles is now restricted to the more common species of Capromys in Cuba, and to Geocapromys brownii in Jamaica. The use of dogs for subsistence hunting of terrestrial wildlife is widespread in the islands, though Jamaican hutias have been traditionally trapped.

My estimate of the totalnumber of S. cubanus captured since its discovery is about 40, with a maximum of 50 animals. There are 13 specimens in museum collections in North America, no more than 7 in Europe, and perhaps 15 in Cuba (including private collections). A number of museums had Hispaniolan specimens erroneously catalogued as S. cubanus. A review of the historical and recent literature gives a similar figure.

Whether the species is surviving at very low numbers or is just difficult to find is uncertain. The relative abundance of the two species (cubanus and paradoxus), as interpreted, is certainly contrasting. The possibility exists that isolated populations of S. cubanus might have gone undetected, as was found to be the case in the Dominican Republic (Ottenwalder 1985). However, I suspect S. cubanus is in danger of extinction.

The possible extirpation of the La Zoilita population, known to be condemned to its vanishment with anticipation, is distressing. A great opportunity for alternative conservation effort probably has been wasted. Capture and removal of individuals should have been attempted for the establishment of translocation or captive breeding programs.

Conservation Problems

Like many other wildlife species native to the West Indian islands, Solenodon populations have declined throughout their former range. The genus Solenodon indeed faces the same conservation problems that other vertebrate species of the islands are suffering: destruction of habitat by shifting agriculture and charcoal production, mining, and other development activities, predation from exotic species, and indiscriminate killing and utilization for food by humans. The major dificulties faced by the species at present and probably for the rest of their existence are illustrated briefly by a case study in the Cabrera Promontory, in northeastern Dominican Republic.

The existence of S. paradoxus was unknown in the Cabrera Promontory before 1986. Field work to investigate the status of the species in this portion of the Dominican Republic was carried out in 1986. The objectives of these surveys were to a) establish the existence of solenodons in the area; b) gather data on historical and recent distributions, relative, abundance and habitat use; and c) assess the impact of past and current land use patterns on populations, if any. I report here the results and observations obtained throughout the eastern half of the Cabrera Promontory.

Study area

The Cabrera Promontory is a well-defined physiographic division located in the northeastern region of the Dominican Republic. It is a region of reef limestone and somewhat horizontal strata characterized by low hills and plateaus of moderate relief with a maximum elevation of 451 m in Loma Siseviere. The landform assumes the shape of escalated terraces, which become less extensive as elevation increases. It is semicircular in shape, and its approximate extent is 20 by 16 km. Politically, the Promontory occupies the northeasternmost portion of the Maria Trinidad Sánchez Province. The southeastern half of the Promontory is the area surveyed and is discussed herein. It is under the municipal administration of Cabrera.

The climate is moist, with a dry season in either the first or third quarter of the year. Subtropical conditions are influenced by prevailing northeasterly tradewind patterns and modified by irregular physiography. Orographic rainfall is abundant, and the mean annual precipitation ranges from 2,145 mm along the Cabrera (east) coast, to 1,672 mm at Rio San Juan (west coast). Mean annual temperature ranges from 22° to 25°C. and is nearly uniform throughout the year. The mean annual temperature on the coast is 26°C and the minimum in the mountains is 15°C.

The dominant life zone on the slopes of the Cabrera Promontory is subtropical wet forest characterized by broadleaf evergreen forest with epiphytes and lianas, rapid growth and rapid natural regeneration. At lower elevations and along the coastal lowlands the life zone is subtropical moist forest with moderate growth that regenerates easily. Together these two life zones cover more than 60% of the total surface area of the Dominican Republic. The results of a recent study on the habitat of Solenodon (Ottenwalder 1985) concluded that approximately 86% of the 42 solenodon localities are in moist or wet forest formations. Unfortunately, these two life zones are also the most suitable for agriculture when slope and soil quality are not limiting factors.

Results

Between February and December of 1986 I recorded and confirmed the death or capture of nine solenodons in the southeastern half of the Promontory, and I also received reliable reports of two additional deaths in the study area during the same period. Dogs were involved in nine of the eleven cases. One was presumably caught and later released by a campesino. Part of the skull and post-cranial skeleton were found of one animal whose cause of death was not determined. Two bodies and one skeleton were salvaged and preserved.

The largest number of solenodons (seven) were found at two localities west of the settlement of Loma Alta (250 m). During February 1986, five solenodons were attacked at dawn by dogs accompanying campesinos on their way to milk free-ranging cows. Four animals were killed on the spot and the fifth was captured alive and taken to the campesinos' home. The animal was kept captive for four days, then reportedly escaped. The solendonwas found at 290 m elevation, about 1.2 km NW of Loma Alta, near a little valley, approximately 2000 m^2, planted with yams, yuca, sweet potato, auyama and yautia. This depression was surrounded by small hills of gradual slope. The predominant vegetation was poor pasture with scattered trees and patches of shrubs. On the eastern slopes and hilltops regeneration was underway on the upper edges of limestone, and here, narrow, but dense stands of relatively old secondary growth reached half the height of the occasional emergents more reminiscent of mature forest. Examination of the patch later confirmed with certainty that these forest fragments were the source of the solenodons.

On July 29, two campesinos and their dogs encountered a pair of adult solenodons at about 21:00 h. The campesinos had been looking for chickens 2 km SW of Loma Alta, at an altitude of about 275 m. The female succumbed to the bites of the dogs but the male was captured alive after being cornered by the dogs. Subsequently, I released the male near the capture site. The habitat was a fairly open area on a terrain of irregular topography. The ground cover was dominated by wild grasses exploited by livestock, with scattered patches of dense shrubs and small garden sites or "conucos" on lower depressions. Some of the surrounding slopes were steep and devoid of vegetation. The extensive exposure of limestone was suggestive of pronounced erosion. However, along the crest of the hilltops a long, narrow corridor of forest extended for several hundred meters. The corridor was connected to a relatively large block of younger secondary growth dominated by weedy species. This portion of the valley bottom had evidently been left to recover from overuse. The solenodons were found at an open site about 300 m from these vegetation fragments.

Another solenodon, a female, was killed by a dog in Los Hoyos (200 m), about 1 km south of La Cabirma. The site was a partially cultivated slope about 50 m from the house of a campesino family. The existence of the animal in their backyard was unknown to all family members. The solenodon was found under the base of a large tree stump in the edge of a thicket of early secondary growth. The thicket bordered on a coffee plantation shaded by old trees. Presumably the solenodon evacuated his burrow at mid-day when disturbed by the clearing of vegetation. We were also told of a capture and release of another solenodon near Los Hoyos, but were unable to confirm this.

In September, one animal was attacked and killed by dogs near El Saltadero, about 1 km east of the settlement of Caya Clara. In late November, the partial skeleton of an adult solenodon was found inside a crevice in a large limestone boulder about 40 meters from the confluence of the stream Caya Clara with the Cigua River. The vegetation in the streambeds included old trees with a canopy height of 15-20 m. This somewhat disturbed site is 1 km southwest of the coastal town of Cabrera at 50 m elevation.

During my surveys I also obtained additional evidence of the existence of the species from a number of localities within the study area. Fresh tracks and other signs were observed in the following localities:

a) 1.5 km west of Loma Alta along the vegetated slopes on the edge of cultivated fields.

b) In a relatively undisturbed forest fragment known as Los Puentes, a few hundred m north of Loma Siseviere. This area is vegetated but on a fairly steep slope, the upper ridge being about 390 m elevation. The fragment was on private property and had remained untouched by wish of the previous owner. Although the successors expressed their intention to leave the forest patch in pristine condition, they have in fact begun selective logging, and the fragment is being cleared. The fragment is about 3.8 ha of forest dominated by cacao cimarron (Sloanea berteriana). Canopy height varied from 20 m to 30 m (N=6, mean DBH >15 cm). Numerous tracks and an inactive tunnel system were found in the litter layer (ca. 35 cm depth) converging under the base of a cacao cimarron.

c) One km east of Caya Clara.

d) Los Hoyos (200m).

e) In Pozo del Higo (260 m), between La Jagua and Jina Clara (280 m).

I also received reliable reports (recorded between 1970 and 1985) of animals sighted, captured, killed, or found dead from the following localities: Media Gorra, Los Canjilones; coastal areas near Cabrera; one km southeast of Loma Siseviere; Los Puentes; Rio Cigua; Los Hicacos; Jingebrillo; Los Hoyos; and Loma de Salomón. Valuable information on the status of solenodons from the northwestern half of the Promontory was also obtained during the surveys. According to this information solenodons might still be found in the hills above Abreu, Pionia, La Cubana and El Catuán.

Socio-economic patterns

Human population estimates for the Cabrera municipality in 1986 represent only 23.2 % (28,185 inhabitants) of the total population of the Maria Trinidad Sánchez Province (121,192 inhabitants). Nevertheless, human densities for the Cabrera district are higher than the average for the

Province (121.5 vs. 92.5 inhabitants per km^2). Densities are also high when compared to the other two districts in the province, Nagua and Río San Juan (71.6 and 48.9 inhabitants per km^2, respectively).

The people of Cabrera Promontory are fundamentally rural and the economy agrarian. This is exemplified by the northeastern region of the country, known as the Cibao Oriental, where 69.4 % of the population live in rural areas and 60-65 % of the economically active population depends on agricultural activities. Subsistence agriculture on the Promontory is characterized by a rudimentary technology and by mismanagement of natural resources. Underemployment prevails, incomes are low, and quality of life is poor. Socio-economic development has been limited by several factors, including: a) inadequate use of the available natural resorces; b) primitive technology and low efficiency in the main activities of production; and c) inappropriate land tenancy practices; wherein, widespread "minifundia" (small land owners) are too small to be productive, and growing "macrofundia" (feudal farming system) concentrate on the ranching of beef cattle; and d) low literacy rates and deficient technical assistance.

The most suitable crops for the Promontory are coffee and cacao, which are perennials. Unfortunately, these crops have exhausted the soil nutrients, hence yields are low. These plantations are now being converted to pasture for livestock.

Primitive technology forces the farmer to extract as much as possible from the land, leading to soil degradation. Consequently, productivity decreases and erosion on steep slopes increases. The small farming practices are particularly damaging on the Cabrera Promontory, which has steep slopes unsuitable for seasonal crops. Furthermore, when small farms are sold to latifundia, the accretion of small parcels into larger ones disrupts the agrarian structure.

Assessment of Captive Breeding

Methods

The modern technology of captive breeding is today a recognized conservation practice for the management of endangered species. Several sources of information were investigated to assess the past contribution of captive breeding to the conservation of Solenodon. A total of 25 zoological parks, universities, and other institutions known to have held captive solenodons were contacted. Data were requested on maintenance, husbandry, behavior, reproduction, diseases, parasites, and postmortem examinations. In addition to the latter information, an effort was made to assemble the captive history of each animal, to include capture data, sex, approximate age on arrival, and dates of accession and death. This information was generated from animal collection records, published and unpublished data, and individual sources such as zoo staff, animal dealers, native hunters, and other individuals that might have been involved at some stage with animals in captive conditions. Whenever possible, the disposal of individual specimens was followed to museum collections for further information and study.

Results

Captive history

Since the arrival of a male *Solenodon cubanus* at the Philadelphia Zoo in 1886, approximately 170 solenodons were removed from the wild to be maintained in captivity in zoos and other zoological institutions in North America, Europe and the West Indies (Table V-1). With one exception, wild populations have been the source of all individuals, and nearly all of the animals known to have been held in captivity were *S. paradoxus*. The proportion of Hispaniolan-Cuban specimens recorded is approximately 10:1.

Solenodon paradoxus. The first live Hispaniolan solenodons arriving in North America were a family group of four received in 1908 by the Museum of Comparative Zoology, Cambridge, which were kept alive for a short period before their preservation as museum specimens. Approximately 50 individuals were imported into the United States by several zoos between 1910 and 1970. Solenodons were on exhibit at the Bronx Zoo as early as 1910. In total the New York Zoological Society obtained 18 animals between that year and

1967, including a pregnant female that gave birth at the park 17 days after arrival (Hornaday 1910; Bridges 1936; Crandall 1964).

In 1937 the City of New York received two solenodons from the Dominican Republic, and the animals were kept at the Staten Island Zoo (Barrett Park). Specimen labels at the American Museum of Natural History indicate that two of their preserved specimens came from the Central Park Zoo, though there are no records of these individuals in the park files. Between 1949 and 1959 eight animals arrived at the Brookfield Zoo, and the University of Puget Sound at Tacoma, Washington, obtained about 10 animals from the Dominican Republic between 1967 and 1979. Several of these were maintained in captivity and one male was sent on loan to the National Zoo in Washington, D.C. Since 1910, at least 14 animals were kept in the collection at the National Zoo, where staff recorded behavioral observations and developed a captive maintenance protocol (Eisenberg and Gould 1966; Eisenberg and Leyhausen 1972; Eisenberg 1975, 1980) that resulted in setting a longevity record of 12 years for the Hispaniolan species. The record animal was the last captive of the species in North America and died in 1976.

Approximately 53 solenodons arrived at European collections from the Dominican Republic and Haiti between 1935 and 1978 (Table 1). The largest number were imported by the Hamburg Zoological Museum. Although 11 of the 28 animals received between 1935 and 1937 arrived dead, valuable observations were published by Mohr (1936-1938) on the behavior, maintenance, and development of the species. Nine (6/3) of the solenodons received by Hamburg were eventually sent to the zoos of Leipzig (1/0), Halle (1/2), Berlin (2/1), Frankfurt (1/0) and Wroclaw (Breslau, 1/0).

Tijskens (1967) discussed the maintenance of 14 animals obtained between 1966 and 1968 by the Antwerp Zoo, Belgium. The Max Plank Institute for Brain Research imported at least 12 animals from Haiti for anatomical research. The Frankfurt Zoo recieved one of these as well as six others from elsewhere. The London Zoo had one in its collection in 1967. More recently a freelance insectivore research facility in Wien, Austria, received two males and two females on breeding loan from the Santo Domingo Zoo.

Except for collections in the Dominican Republic and Puerto Rico, there are no records of Hispaniolan solenodons in captivity in the West Indies. Nevertheless, according to Bridges (1936), A.H. Verrill received information on captive specimens in Haiti and Santo Domingo during the 1930's. The only information from Puerto Rico suggests there was a pair in the zoo at Mayaguez in 1968.

Solenodons have been maintained in captivity at several institutions in the Dominican Republic. The old zoo, Jardin Zoologico y Botanico de Santo Domingo, had solenodons on exhibit from time to time. However, the zoo did not keep organized records of its animal collection, hence it provides no relevant historical information. Perhaps 20-30 solenodons might have arrived at the collection, and at least six live animals were shipped from the park to North American zoos during the 1950's (including 2/2 to Brookfield, 1/1 to New York). The old zoo came under the supervision of ZOODOM during the final construction stage of the new zoological park in Santo Domingo and was finally closed to the public in 1974.

During 1972 and 1973 the Centro Nacional de Investigaciones Agropecuarias (CENIA), a research center of the Dominican Ministry of Agriculture, obtained seven animals for medical research. These short-term studies documented endoparasites (Ricart de Melgen <u>et</u> <u>al</u>. 1972), morphology of the gastrointestinal tract (Ricart de Melgen and Pena 1973), haematology, and sex determination using sexual chromatine (Gonzalez and de Mello, 1973). Of this group of animals, which included one newborn, two juveniles and four adults, three were euthanized and tested for rabies and parasitic infection. A planned study of artificial insemination was not undertaken. The period in captivity of these animals was from two to eighteen days.

Thirty-one solenodons (17 males, 14 females) were received in the Parque Zoologico Nacional of Santo Domingo (ZOODOM) between 1975 and 1988. The first arrived in 1975, the same year the park opened to the public. Between 1975 and 1977, fifteen animals were obtained by an acquisition program created for the development of a captive breeding colony. The observations obtained from 1975 to 1977 were summarized by Pena (1977). Inadequate housing facilities and resources, among other problems, hampered the program.

In early 1978 the acquisition program was ended, husbandry changes were implemented, and efforts and resources were concentrated on the remaining six animals. A successful captive breeding was recorded in 1979, from a pair that was housed in a large (4 x 7 m) outdoor enclosure. (Ottenwalder 1979).

The other male was released with two females in a second outdoor enclosure of approximately 7 m diameter. No artificial refugia were provided, but the animals were allowed to dig their own nesting cavities and tunnels. A foundation perimeter of 25-inch-deep cement blocks prevented underground escapes. The animals constructed a burrow under a large limestone boulder and evidence of reproduction was recorded. Between 1978 and 1988 twelve additional specimens were presented to the zoo by donors who had captured them accidentally or had attempted to keep them as pets. Nine of these arrived in poor physical condition because of trauma, weakness, starvation or stress, and lived only briefly.

At the beginning of the century, zoos exhibited solenodons as a curiosity, and little efforts were directed toward their breeding or study. With few exceptions (Eisenberg 1975, 1980; Eisenberg and Gould 1966; Mohr 1936-1938), information about their husbandry in most zoos is either poor (Hornaday 1910; Bridges 1936, 1958; Crandall 1949, 1964; Horst 1967; Tijskens 1967; Poduschka 1975) or unknown. Solenodon proved to be short-lived and difficult of maintain in captivity. As a consequence, it became customary by the end of the 1960's to maintain them in off-exhibit indoor enclosures, as study subjects. Research on captive animals had been the source of major information on the behavior, reproduction, and ontogeny of solenodons (Mohr 1936-1938; Eisenberg and Gould 1966; Eisenberg and Leyhausen 1972; Eisenberg 1975, 1980; Peña 1977; Poduschka 1977; Ottenwalder 1979; Eisenberg and Gonzalez 1985; Varona 1983).

A variety of prepared diets, natural food items and supplements has been used to keep solenodons in captivity (Appendix 1). Although captive diets have been improved and refined over time, there has apparently been no commensurate increase in survival. Seven zoos offering various diets have maintained animals for four or more years in captivity. The diet developed at the National Zoo maintained the animal with the greatest longevity recorded for solenodons (11 years and 4 months).

Mortality

The majority of deaths in captive solenodons have been associated with stress-related syndromes. Of 104 captive Hispaniolan solenodons, 16 were dead on arrival and 56 died within the first year (Table V-2). Furthermore, 48 of those 56 died within 30 days of arrival, 82 percent of the whole captive population died by the second year (Fig. V-2). Available records indicate that only about 20 of the 104 sampled animals survived two or more years. Of these, 17 survived from 2 to 8 years and one as long as 12 years and four months. Although the sample size is small, it appears that younger animals have higher survivorship than adults (Fig. V-3). However, some adults that have survived 6-7 years in captivity probably approached their maximum lifespan. Five deaths resulted from traumas, two possibly from septicemia, and four from peritonitis. Other causes include haemorragic pneumonia, bronchopneumonia, severe purulent sialadenitis, possible lipidistrophy, endometritis, osteoporosis, intestinal cancer, and colibacillosis (Table V-3). Post mortems of 58 S. paradoxus revealed the presence of endoparasites in 28 individuals, and parasites were blamed as the cause of death in 13 cases (Appendix 2).

Solenodon cubanus

Only 10 Cuban solenodons are known to have been in captivity, and very little in known about their maintenance (Table V-4). The scarcity, secretive habits, and delicate nature of the species has not been conducive to a successful program of captive maintenance.

The captive history of the species is summarized in Table V-5. One animal lived for three years in a private home at Guanabacoa (Poey 1851). Poey himself maintained two pairs, and reported that the deaths of the animals was due to infested wounds and parasites. Gundlach (1877) kept several pairs for brief periods and observed a female with two very young offspring being maintained in La Habana. In December 1886, a female from Bayamo arrived at the Philadelphia Zoo from eastern Cuba. Unfortunately there seems to be no information recorded about the maintenance of this animal, probably the only Cuban solenodon ever in captivity in a North American zoo. It survived until July 1892, a period of five years and seven months. In 1912 several animals were kept and studied in the Museo Bacardi in Santiago de Cuba (Bofill 1948).

There is no additional information on captive individuals in Cuba until 1943-44 when the Jardin Zoologico de la Habana obtained two animals from the Baracoa region. At least one of the two animals was a female that had been lactating prior to capture (Angulo 1947). They were fed crabs, earthworms, lizards, ground meat, eggs and milk (Barbour 1944, 1945). In 1953, another pair was caught in Sierra Maestra and kept in a school in Santiago de Cuba. The female died after four months, and the male survived 15 months (Cañas 1971).

In 1974 and 1975, three solenodons (one adult male, one adult female, and one juvenile female), were captured near Baracoa and sent to the Habana Zoological Garden. The discovery of the animals aroused considerable interest in Cuba and the zoo staff and members of the Cuban Academy of Sciences devoted great effort to captive breeding. The male died 11 months later, and the adult female survived for two years and two months. The juvenile female lived for 6 years and 11 months (Varona 1983), which so far represents the maximum longevity recorded for any known S. cubanus in captivity.

The animals were fed twice daily on a ration equivalent to one fifth of their body weight. It consisted of a horse meat mixture (around 100g/day each), with vitamins and mineral additives, and one raw egg. In addition they were provided with live prey such as Anolis lizards (about 14 g/day), cockroaches, and crickets. The average adult weight recorded for these three animals was 740 g. Observations on the maintenance and behavior of the last female were recorded by Eisenberg and Gonzalez (1985). The animal was kept indoors in a wooden cage measuring approximately one by two meters and was provided with a nest-box with newspapers for substrate and shredded paper for breeding. It was allowed to exercise and move around in a small patio adjacent to the building housing the cage.

Status of captive populations.

No Cuban solenodons have been in captivity since 1988. The last known Hispaniolan solenodon in captivity died in the zoo of Santo Domingo in 1990. It survived 4 years. Maintenance for this individual, a male, was as follows. It was housed in two contiguous rooms (2.3 x 3 m each) in the quarantine area of a veterinary clinic. The two rooms were connected by a ground-level opening in the dividing wall to provide enough space for activity and exercise. A nest-box

(1.2 x 0.7 x 0.5 m) was provided in one of the rooms as a sleeping chamber. Logs, rocks, and a hollow stump were placed in this room. The second room was provided with a 10 in. deep layer of soil, organic matter and litter, plus limestone rocks, a dead hardwood tree trunk with proximal sections of roots still attached and some shade-tolerant plants. The room was maintained at 26°-29°C and 84% humidity.

The animal was fed prepared foods in the first room and live invertebrates in the second room. Meats were offered in a rotation: minced or whole chick (skinned), minced mouse, baby mice, and ground horsemeat, plus raw egg twice weekly with the meat. Millipedes (about 150 g) were offered two nights a week, and earthworms, insects, mealworms, and lizards as available. Wheat germ, vitamins and mineral supplements were added to the diet twice weekly. The average weight of wild animals was about 800 g, hence this weight was considered optimal for captives. Body weight was monitored closely to prevent obesity. In captivity, most adult animals attain weights above 1000 g. within 1-2 months on the new diets, usually rich in animal fats and protein. The amount of food provided was adjusted as body weight fell below 750 g or above 950 g. Routine husbandry practices, utilized with the captive solenodon under study at the Parque Zoologico Nacional of Santo Domingo, are summarized in Appendix 3.

Conservation Measurements Taken

Legislation

Solenodons are fully protected by law in Cuba and the Dominican Republic. In Haiti, mammals are not covered by existing wildlife regulations. Furthermore, the Ministry of Agriculture has been dismantled recently by the newly elected administration. As a result, no wildlife authority or equivalent wildlife enforcement agency exists in that country. Protection is apparently effective in Cuba, but in the Dominican Republic, laws protecting Solenodon are virtually disregarded. Ignorance concerning their legal status, poor enforcement, and the prevalence of a non-positive image of the species among Dominicans are the major reasons for this situation. Despite any well intentioned efforts, effective enforcement by the government wildlife authority in the Dominican Republic is hampered by insufficient material and human resources, which reflects the poor political support natural resource management institutions have in that country. Concern for wildlife conservation has been increasingly advocated in recent presidential elections, but neglected thereafter.

Solenodons are opportunistically exploited for food in Haiti. In the Dominican Republic, this practice is unknown, but indiscriminate killing of animals by man is commmon.

Protected areas

Protected areas with confirmed or potential surviving populations of Solenodon in Cuba, Dominican Republic, and Haiti are presented in Table V-6. The presence of S. cubanus inside the boundaries of several protected areas of eastern Cuba is generally assumed by Cuban authorities. In fact, the Jaguani and Duaba Reserves were in part created for the protection of the Cuban solenodon. However, there is no information about their current status in these areas.

The existence of living populations S. paradoxus is confirmed in seven protected areas of Hispaniola, six in the Dominican Republic and one in Haiti. Their present and future status is intimately compromised with the situation of these national parks. In the Dominican Republic, a considerable list of human disturbances, incompatible with the national park criteria, threaten the integrity of these areas (Table V-7).

The J. Armando Bermudez and Jose del Carmen Ramirez national parks were established, respectively, in 1956 and 1959 to protect the boreal vegetation and fauna of the highlands which are unique in the Caribbean Basin, and the headwaters of the Yaque del Norte and Yaque del Sur rivers. Together, the two adjacent areas cover 153,000 ha. and include the highest mountain of the West Indies, Pico Duarte (3,087 meters). The low lying zones are covered by mixed coniferous woods and broadleaf forests, while highlands are covered by Pinus occidentalis and elements of colder temperate-type flora. The two parks are important reserves of native vertebrate species, and contain approximately 84 percent of the country's remaining endemic pine (*P. occidentalis*) stands, and 36 percent of the existing mixed hardwood forest. Much of the highland vegetation communities is still in its natural state. However, a great portion of the low lying zones, of greater importance to *Solenodon*, have been destroyed or altered.

Although part of the human population that lived within the park's boundaries were evicted after 1979, the people that live in adjoining areas use them for farming and cattle ranching. Coffee plantations exist inside the parks along the borders. Slash and burn has cleared the natural vegetation from many of the slopes at lower elevations. Deliberate burning and vandalism has damaged vast expanses of the forest. Continued disturbance hinders the recovery and regeneration of lowland areas. Some hunting and grazing still occurs in many areas of the parks. The problems are agravated by poor cooperation and shared authority on the parks by two government agencies. The parks have remained relatively well protected because of their remoteness and lack of access roads.

Similar problems threaten *Solenodon* populations and their habitats in the remaining National Parks of the Dominican Republic and Haiti. Furthermore, the distribution and status of *Solenodon* in these parks are still insufficiently known.

Fig. V-1

Map of eastern Cuba showing the only mountain ranges where living populations of *S. cubanus* have been known since its description in 1861. Closed circles indicate the areas where the species has been recorded during the past 10 years.

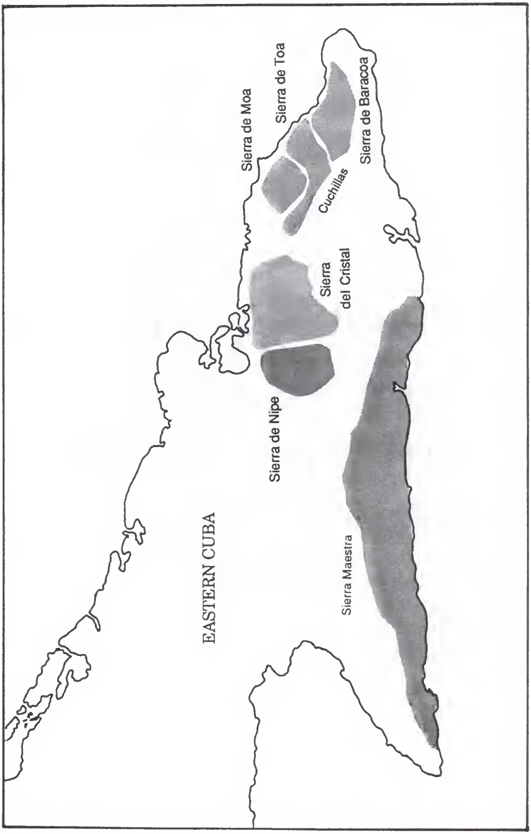

EASTERN CUBA
Sierra Maestra
Sierra de Nipe
Sierra
del Cristal
Cuchillas
Sierra de Moa
Sierra de Toa
Sierra de Baracoa

FIG. V-2

Survivorship in a sample of 104 S. paradoxus and one S. cubanus in captivity between 1886-1989.

SURVIVORSHIP IN CAPTIVITY

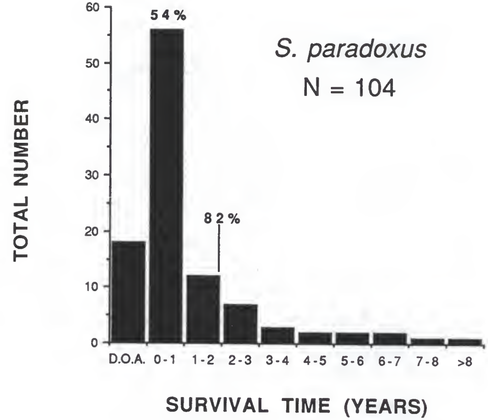


FIG. V-3

Survivorship of juvenile, subadult and adult Solenodon in captivity. Data from Table V-2.

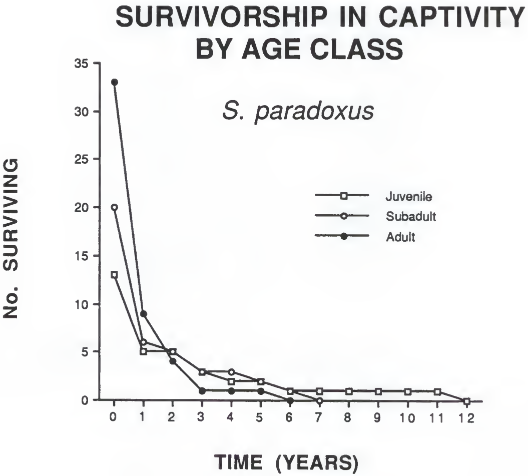

SURVIVORSHIP IN CAPTIVITY BY AGE CLASS
S. paradoxus
No. SURVIVING
TIME (YEARS)
Juvenile
Subadult
Adult
0
5
10
15
20
25
30
35
0
1
2
3
4
5
6
7
8
9
10
11
12

Table V-1. Historical review and present status of captive populations of S. paradoxus from 1908 to 1990. Time interval indicates years of first and last recorded live solenodon in each institution. Sex: male (M), female (F), unknown (U).

			Total	Total	Total	Sex			Status
Institution	From	To	arrived	transf.	kept	M	F	U	12/1990
MCZ, Harvard	1908	?	4	0	4	2.	1.	1	-
Bronx, NYZS	1910	1967	17[a]	2[b]	15	6.	8.	1	-
NZP, Wash.,DC	1910	1976	14	0	14	6.	7.	1	-
Staten Island	1937	?	2	0	2	0.	0.	2	-
Central Park,	1937	?	2	0	2	0.	0.	2	-
Brookfield, IL	1949	1959	8[c]	0	8	4.	4.	0	-
Tacoma, Wash.	1967	1970	11	1[d]	10	7.	3.	0	-
Hamburg, GER	1925	1937	28[e]	9[f]	19	9.	10.	0	-
Wroclaw, POL	1935	1942	1	0	1	1.	0.	0	-
Halle, GER	1935	?	3	0	3	1.	2.	0	-
Leipzig, GER	1936	1936	1	0	1	1.	0.	0	-
Berlin, GER	1936	1943	3	0	3	2.	1.	0	-
Frankfurt, GER	1966	1973	7[g]	0	7	3.	4.	0	-
Max-Plank, GER	1963	1970	12[h]	1[i]	?	?.	?.	?	-
Antwerp, BEL	1966	1969	14	0	14	7.	5.	2	-
London, UK	1967	?	1	0	1	1.	0.	0	-
IRC-Wien, AUS	1978	198?	4[j]	0	4	2.	2.	0	-
Old Zoo,R.D.	1950	1966	4	4[k]	?	?.	?.	?	-
CENIA, R.D.	1972	1973	7	0	7	2.	4.	1	-
ZOODOM, R.D.	1975	1990	31[l]	4	27	15.	12.	0	-
Mayaguez, P.R.	1968	?	2	0	2	1.	1.	0	-
Summary	1908-1990								

Table V-1 (Cont.)

[a] Including 0.0.1 on deposit from (27 Aug.1910 to 14 Feb. 1911) Mus. Comp. Zool., Cambridge.

[b] 1.1 (Max/Julie pair: on deposit at Bronx since April 1965) returned to NZP on Sept. 1967.

[c] Including 2.2 acquired 1949-50 as S. cubanus, but examination of these specimens at FMNH show clearly they are paradoxus.

[d] One (0.1) transferred to NZP.

[e] Eleven (11) animals were dead on arrival.

[f] According to Mohr (1936-38), nine (6.3) solenodons were distributed to Leipzig (1.0), Halle (1.2), Wroclaw (1.0), Berlin (2.1), and Frankfurt (1.0) between 1936-37.

[g] Including 0.1 on loan from Max-Plank Institute. The male presumably received from Hamburg sometime in 1936-37 is not included in Frankfurt numbers, since Frankfurt does not seem to have records of the former existence of this animal in file; reportedly, all their seven solenodons arrived only after Jan. 1966 (R.Faust *in litt*.).

[h] It is unknown whether all animals arrived alive or how long they survived afterwards.

[i] 0.1 on loan to Frankfurt

[j] 2.2 on loan from ZOODOM; 2.0 dead by Feb. 1981.

[k] 2.2 sent to Brookfield Zoo.

[l] Does not include captive born

Table V-2. Captive survivorship in a sample of 104 wild-caught *S. paradoxus* from 1910 to 1988.

SURVIVAL TIME	ESTIMATED AGE ON ARRIVAL				MORTALITY		
(years)	JUV	SUB	ADU	Unk	TOTAL	%	
DOA	1	7	4	6	18	17	
0-1	7	7	20	24	56	53.8	29 (10 days) 19 (30 days) 9 (1-4 month) 6 (4-8 month) 3 (8-12 month)
1-2	-	1	5	6	12	11.5	
2-3	2	2	3	-	7	6.7	
3-4	1	-	-	2	3	2.8	
4-5	-	1	-	1	2	1.9	
5-6	1	1	-	-	2	1.9	
6-7	-	1	1	-	2	1.9	
7-8	-	-	-	1	1	0.3	
> 8	1	-	-	-	1	0.9	Survived 12 years, months; maximum longevity record for *S. paradoxus*

AGE: Juvenile, < 5 months; subadult, 5-8 months; adult, 8 months. Established arbitrarily and based on available growth data from Mohr (1936-38), Eisenberg (1975), and this study. UNK: Animals of unknown age. DOA: Dead on arrival, or dead between removal from the wild and arrival at captive facility.

Table V-3. Causes of death in 29 captive Hispaniolan solenodons, excluding parasite-laden cases. Data are from necropsy reports and post-mortem findings recorded at zoos of Bronx, NZP, Brookfield, Wroclaw, Antwerp, Austria, and Santo Domingo.

SEX	ARRIVAL	DEATH	POST-MORTEM/ CAUSE OF DEATH
F	28-4-65	17-1-66	Severe purulent sialedenitis[a]
M	13-10-66	13-11-66	Possible septicemia[b]
F	28-4-65	17-10-66	Bronchopneumonia
F	13-10-66	23-10-66	Endometritis[c]
M	26-7-69	12-7-70	Haemmorhagic pneumonia
F	15-9-66	28-11-69	Possible lipodistrophy
M	7-12-35	31-5-42	Senility[d]
M	25-6-66	14-5-69	Undetermined[e]
M	25-6-66	3-7-66	Empty gastrointestinal tract
F	8-6-67	12-12-67	Undetermined[f]
M	14-9-68	29-12-69	Undetermined[g]
M	1-12-78	1-2-81	Intestinal cancer
M	1-12-78	6-12-79	Stomach torsion[h]
F	17-3-76	6-4-78	Colibacillosis
M	1-7-76	8-11-78	Suffocation[i]
F	1-7-76	7-7-77	Traumas
M	1-7-76	7-12-78	Osteoporosis
F	8-8-76	14-8-76	Abortion[j]
F	11-9-76	12-9-76	Traumas[k]
M	11-9-76	12-9-76	Traumas[k]
M	14-9-76	27-9-76	Traumas[l]
F	14-9-76	30-3-82	Peritonitis
M	14-9-76	23-9-76	Traumas[l]
F	23-3-77	5-3-79	Edometritis[m]
M	31-8-78	31-8-78	Traumas, stress[k]
F	14-5-79	15-5-79	Traumas, stress[k]
F	1-6-79	21-8-79	Peritonitis
M	7-4-83	8-4-83	? (dying on arrival)
M	17-2-88	14-5-88	Hepatic degeneration

---

[a] Two other animals in same group developed massive hyaline droplet necrosis of serous glands

[b] Parotid glands light in color, myocardium mottled

[c] Infection of salivary glands; pulmonary congestion & edema

[d] Adult at arrival, lived 6 1/2 years in captivity

[e] Ascites and fluid in abdominal cavity; lung congestion; symptoms of suffocation

[f] White stains on liver

[g] Red subcutaneous eruption

[h] Viscera occluded

[i] Accident caused by collapse of burrow

[j] Caused by stress of capture

[k] During capture and transport

[l] Did not eat after capture

[m] Post-partum haemorraghic congestion in lungs

Table V-4. Historical review and present status of captive populations of S. cubanus from 1886 to 1988. Time interval indicates years of first and last recorded live animal in each institution. Sex: male (M), female (F), unknown (U). All animals originated from the wild.

Institution	From	To	Total arrived	Total transf	Total kept	Sex M	F	U	Status 12/1990
Philadelphia	1886	1892	1[a]	0	1	1.	0.	0	-
Habana, CUBA	1943	1982	5	0	5	1.	2.	2	-
Santiago, CUBA	1953	1956	4	0	4	1.	1.	2	-
Baracoa, CUBA	1983	1988	1	0	1	0.	0.	1	-
Summary	1886-1988		11	0	11	3.	3.	5	-

[a] Surviving adult male of a family group of three collected in 1886 about "30 miles from Bayamo" sent by Gundlach (1895) to the United States National Museum, Wash., and from here to the Philadelphia Zoo (Allen 1942).

Table V-5. Captive history of *S. cubanus* between 1886-1988. Months abbreviated as "m", years as "y".

ZOO and SEX	DATE CAPTURED	DATE OF DEATH	TIME SURVIVED	REPORTED CAUSE OF DEATH
Philadelphia				
F (Ad)	July 1886	26.7.92	5y,7m	
Habana				
?	1943	1943	-	Parasite infestation
?	1943	1944	-	
M (Ad)	26.4.74	29.3.75	11m	Digestive problems*
F (Ad)	1.12.74	-	2y,2m	
F	July 1974	-	6y,11m	Digestive malfunction
Santiago				
M	1953	-	1y,2m	
F	1953	-	4m	
Baracoa				
?	1983(?)	Mar. 88	4y	

* Presumably due to endoparasites (Varona 1983)

Table V-6. Protected areas with confirmed or potential surviving populations of _Solenodon_ in Cuba, Dominican Republic, and Haiti. Status: present (P), unknown (U). If known, year indicates last confirmed record.

Name of protected area	Country Category	Equivalent IUCN Category	Surface area (ha)	Status of _Solenodon_
CUBA				
Cupeyal del Norte	Nt. Reserve	I	10,260	U
Jaguani	Nt. Reserve	I	4,932	U
Cuchillas del Toa	Biosphere R	IX	127,500	U
Yunque de Baracoa	Na. Monument	III		U
Sierra Maestra	Gran Parque	VIII	527,000	U
Duaba	Faunal Ref.	I		U
DOMINICAN REP.				
Armando Bermudez	Nat. Park	II	76,600	P-1990
J. Carmen Ramirez	Nat. Park	II	76,400	P-1990
Sierra Baoruco	Nat. Park	II	80,000	P-1990
Jaragua	Nat. Park	II	140,000	P-1990
Los Haitises	Nat. Park	II	20,800	P-1990
del Este	Nat. Park	II	43,000	P-1990
HAITI				
Pic Macaya	Biosphere R.	IX	5,500	P-1990

Table V-7. Human activities threatening <u>Solenodon</u> populations and their habitats inside the boundaries of protected areas in Cuba, Dominican Republic (DR), and Haiti.

Rank	Activity	Cuba	DR	Haiti
1	Habitat loss			
	Shifting cultivation	X	X	X
	Plantation agriculture	X	X	X
	Fire	?	X	X
	Charcoal production	?	X	X
	Livestock grazing	X	X	X
	Unplanned colonization	?	X	X
	Mining	X	X	-
	Unlawful logging	-	X	X
	Commercial logging	X	-	-
	River and dam impoundment	?	X	-
	Building/Road construction	X	X	?
2	Exotics			
	Predation	X	X	X
	Competition for food (?)	X	X	X
	Diseases and parasites (?)	?	?	?
3	Human predation			
	Unlawful capture and killing	X	X	X
	Subsistence hunting	X	-	X

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The geological history of the islands is certainly a key factor for the interpretation of Solenodon biogeography. Unfortunately, the evolution of the Greater Antilles is still a matter of much controversy. Nevertheless, several geological events relevant to the origin of the Greater Antillean vertebrate fauna are generally accepted (for review see Pindell and Dewey 1982, Guyer and Savaye 1986, Perfit and Williams 1989, Williams 1989, Donnelly 1990, Holcombe and Edgar 1990):

a) During the early Cenozoic, Jamaica (presumably accompanied by southern Hispaniola) was probably somewhat isolated from the remainder of the Greater Antilles. Eastward movement of these two land masses towards the other Antillean elements probably took place during the late Cenozoic.

b) Eastern Cuba and northern Hispaniola were "close together" during the late Cretaceous-early Cenozoic general movement of Antillean elements.

c) Whereas there was no general submergence for most Antillean islands, Jamaica may have been totally submerged from the middle Eocene and all of the Oligocene, not emerging until the middle Miocene. Although partially covered by limestone, submergence for Southern Hispaniola was less complete.

d) Southern and Northern Hispaniola were separated for a long time, until suturing along the Cul de Sac-Neiba Valley materialized shortly after middle Miocene. However, according to Donnelly (1990), neither the time nor the fact of the fusioning have been adequately demonstrated.

e) During middle Eocene, Puerto Rico was "attached" to southeastern Hispaniola.

The four species of *Solenodon* are fairly similar in appearance, and probably closely related. In their radiation, inter-island (Cuban and Hispaniolan) populations evolved distinctive morphological features, whereas within-island populations are separated by size presumably a response to niche partitioning and island area as major selective forces (Fig. VI-1). In Cuba, the larger island, both the large and small species (new giant form and *S. cubanus*) are larger, respectively, than the large and small species from Hispaniola (*S. paradoxus*, *S. marcanoi*), the smaller island.

In Hispaniola, it is noticeable that both south island populations of solenodons are smaller than the population of *Solenodon* on the north island. The fact that populations of the same species (*S. paradoxus*) are larger in the north and smaller in the south, to the extent that some *S. paradoxus* from southern Dominican Republic resemble S. marcanoi, is provocative. A tendency for the reduction in body size is quite obvious in the southern populations of S. paradoxus. The skull of several adult S. paradoxus from Sierra de Baoruco are almost identical to the skull of S. marcanoi in shape and in a number of dimensions (Figs. II-10, II-11, II-12).

Analysis of cranial traits for the four species of Solenodon indicate that S. marcanoi share characters of both, S. paradoxus and S. cubanus. Thus, it could be assumed that S. marcanoi either represents an intermediate form between the two lineages or is ancestral to both, which raises the old problem of primitive vs. derived characters in West Indian insectivores.

Aside from the obvious dilemma of reconciling Solenodon with Nesophontes, and recognizing that the set of characters used here is relatively reduced to attempt a meaningful interpretation of the phylogenetic relationships among the different species of Solenodon, some evolutionary patterns can be postulated.

The ancestors of Solenodon probably entered the Greater Antilles from North America or Yucatan through Cuba. In their radiation, earlier forms attained increased body size in response to an empty semi-fossorial insectivore-omnivore niche, and to the absence of carnivore predators. Genetically, ontogeny is not tightly controlled during earlier stages of ecological release due to the unspecialized nature of the invading stock. As a result, body size is highly variable. Eventually, selective pressures favor non-overlapping body sizes in the exploitation of available resources. Exclusion by size is advantageous to successful reproduction. Changes in body size and food habits impose constraints on thermoregulation and energetic adaptations. In larger (Solenodon-like, Fig. VI-1) forms, selection has favored longevity, lower rates of metabolism, smaller litters, slower growth, and therefore, lower densities. Smaller (Nesophontes-like, Fig. II-13) forms evolved towards higher rates of metabolism and growth, larger litters, shorter life span, and attained high population densities. Because of their smaller size, they had more potential predators among the vertebrate fauna of the islands. Furthermore, forced to search for food under unfavorable conditions to maintain endothermy, predation pressure is higher for smaller forms. Environmental predictability and low predation are among the key adaptative advantages evolved by the larger forms.

An opportunity for the inoculation of Hispaniola by insectivores materialized with the connection of eastern Cuba and northern Hispaniola during the late Cretaceous-early Cenozoic. Further adaptation and speciation resulted in the evolution of two large (Solenodon) and three small forms (Nesophontes) in Hispaniola. One of the two evolving

Solenodon lineages (S. marcanoi) retains traits of the older, more primitive Cuban-stock, whereas the second (S. paradoxus) departed from the Cuban-founder, and evolved into a more specialized, derived form, both morphologically and ecologically. S. paradoxus dispersed widely throughout Hispaniola, utilizing a gradient of habitats and elevations. A shift to more readily available food sources is suggested by changes in its dentition, which I interpret as specializations. While S. paradoxus appears to be somewhat resilient to environmental changes, and to survive under a moderate degree of disturbance, S. cubanus is most certainly a truly climax species. S. cubanus might also be more fossorial in habits than S. paradoxus, as the Cuban animal has been seen only on a few occasions since its discovery. S. paradoxus is active above ground with some regularity, at least seasonally.

Inoculation of Solenodon to Puerto Rico might have been prevented either by ecological barriers at the time of connection of eastern Hispaniola and Puerto Rico, or by its absence in that portion of Hispaniola during the middle Eocene. However, the conditions in eastern Hispaniola did not represent an effective barrier for Nesophontes, which inhabited lowland dry to montane rain forest, and probably expanded rapidly throughout Hispaniola because of its presumably higher growth rates. The colonization scheme hypothesized for the ancestors in Cuba may have been repeated in Puerto Rico. *Nesophontes* attained a large body size in the absence of predators and available empty niches. *S. paradoxus* is probably the culmination of the *Solenodon* radiation.

Among other factors, such as predation by exotic carnivores with higher rates of metabolism (McNab 1989), species extinction (two *Solenodon*, all *Nesophontes*) and local extirpations in *Solenodon* might be related to body size and trophic specialization. Both the largest and smallest species (*Solenodon* "new species A" and *S. marcanoi*, respectively), presumably food specialists, are extinct, whereas the two medium size species, *S. paradoxus* and *S. cubanus*, presumably food generalists, are still extant.

Patterns of speciation in West Indian insectivores would be largely determined by the subterranean environment and its insectivore-omnivore niches, which in turn determine divergent population structure. Adaptative divergent patterns involve: large vs.small body size, low vs. higher basal metabolic rates, high vs. low thermal conductances, relatively large vs. small territories, and relatively low vs. high taxonomic diversity. Development of reproductive isolation in small, isolated, and inbred populations was facilitated by insular fragmentation events of the Greater Antillean land masses. Both parapatric and allopatric speciation are suggested by cave deposits and overall distributional record.

Admittedly, the nature and sequence of the events described above are highly speculative.

Perfit and Williams (1989) hypothesized that the *Solenodon* ancestor might have entered the Greater Antilles from North America, through Cuba or Yucatan, either by vicariance or dispersal. *Solenodon* is not uncommon in cave deposits in western Cuba (See Chapter III). Judging by its femora, the giant Cuban *Solenodon* possibly attained a size similar to that of *Didelphis*, and it has been considered one of the two largest known insectivores, living or extinct (Morgan *et al*. 1980). Among other features, its humerus, as in other members of the genus, is of primitive fossorial condition. Its distribution was apparently restricted to western Cuba.

In *Nesophontes*, the molars exhibit the normal mammalian condition; chewing involves the attrition of the sculpture of the upper molar crowns against the sculpture of the lower molar talonids (McDowell 1958). In *Solenodon*, the sculpture of the teeth appears to play little if any part in the function of chewing, and it is the shear of the entire wedge of the upper molar trigon between high lower molar trigonids that pulverizes the food. According to McDowell (1958) this difference might be related to longevity. He suggested that in *Nesophontes* molar wear is similar to *Sorex*, in which molar cusps are gone at 66-72 weeks, concluding that *Solenodon* shows the culmination of the process of efficient chewing with increased longevity. Furthermore, bone remains of Nesophontes are extremely abundant in cave deposits and barn owl pellet accumulations throughout Cuba and Hispaniola, whereas Solenodon is rare in historical and Recent times.

The enlarged upper and lower premolars, and massive upper canines of Cuban solenodons are suggestive of an omnivore-insectivore ancestry whose dentition was capable of crushing and food generalism. The following characters of Cuban Solenodon might represent the primitive condition; 1) the first two lower premolars highly enlarged and inflated; 2) the frontal region much broader at the anterior edge of the orbits (Figs. II-8, II-9; 3) the upper canines are greatly enlarged and inflated and lacking anterior accessory cusps (Fig. 4). In S. paradoxus, these characters represent derived conditions; first two lower premolars laterally compressed and not lingually expanded; skull cylindrical, frontal broadening is lost (Fig. II-10); upper canine laterally compressed; accessory cusps in upper canine and premolars (Fig. II-4).

If, in fact, S. marcanoi represents an intermediate lineage between S. cubanus and S. paradoxus, and if S. marcanoi is restricted to South Hispaniola, then a connection between Cuba and South Hispaniola is missing. This latter scenario would suggest a Proto-Antillean derivation (McFadden 1980) from Yucatan via South

Hispaniola. In this case, the complete submergence of Jamaica would explain the absence of Solenodon and Nesophontes in that island. This is, however, unlikely since southern and northern Hispaniola presumably joined after the mid-Miocene, perhaps early Pliocene, and only after eastern Cuba and northern Hispaniola began to drift apart. Solenodon stock was probably already on these islands much earlier than the time South Hispaniola and Jamaica approached their current positions. The evolutionary relationships of S. cubanus, S. marcanoi and S. paradoxus are not easily interpreted because of the rampant fragmentation of islands during the Greater Antillean genesis (see Pindel and Barret 1988), and the disagreements concerning the timing of the connections among the various islands only confound the picture.

Several gaps are obvious in the distribution pattern of S. paradoxus in Hispaniola. The species is absent from northern Haiti both in the fossil and living record, and it is unknown from cave deposits in Hispaniola with the exception of one site, Rancho de la Guardia, in Sierra de Neiba. Until relatively recently, the known distribution of S. paradoxus in the Dominican Republic was fairly limited in the north and unknown in the south. Because of its presence in the Cordillera Central of the Dominican Republic, its existence in the Massif du Nord, the Haitian extension of the Dominican range, is to be expected. Solenodon is, in fact, extant in the mountains near Restauración, on the border with Haiti. Even if the species was extirpated by human activities in recent times, evidence of its historical presence must exist somewhere north of the Cul-de-Sac.

The Hispaniolan solenodon is known from Amerindian sites in the north, central, and eastern portions of the Dominican Republic, but has not been found in older, fossil deposits other than Cueva Rancho La Guardia, in Sierra de Neiba. Paleontologically, the vertebrate fauna of the Dominican Republic has been only superficially explored. I believe their apparent absence in the fossil record is due to a lack of adequate information and collection.

The same argument applies to S. marcanoi which appears restricted to the south of both Haiti and the Dominican Republic. S. marcanoi is larger in Rancho la Guardia, in the northernmost range of its distribution and north of the Neiba Valley, whereas the specimens from the Massif de la Hotte are smaller. Furthermore, the S. marcanoi material from Morne La Selle, on the south island across from the Cul de Sac-Neiba Valley strait, includes both Rancho la Guardia (larger) and La Hotte-sized (smaller) individuals. I suspect that there is a tendency towards reduction in body size in S. marcanoi from east to west and that this tendency is due to a peninsular effect at the end of the Tiburon Peninsula. This effect might have been increased by a drastic reduction of land mass in pre-Pleistocene times, when the Massif de la Hotte and the Massif de La Selle-Sierra de Baoruco block were separated by a deep marine passage along the Jacmel-Fauche depression (Marrausse *et al*. 1982; Woods 1989) (Fig. II-1). The La Selle-Baoruco block was an isolated island until at least the early late Pliocene. Re-unification of the two south Hispaniolan islands probably did not happen until late Pleistocene (Marausse and Pierre-Louis 1981). The combination of reduced island size and isolation might also account for the tendency of southern *S. paradoxus*, particulary the Baoruco-Barahona population, to be smaller in body size, and thus, for its apparent convergence towards *S. marcanoi* size. If *Solenodon* entered northern Hispaniola from southeastern Cuba, it could be predicted that larger *S. marcanoi* should be found in fossil deposits of northern Hispaniola.

The geographical range of *S. cubanus* has contracted dramatically during historical times. Evidence from cave and archeological deposits indicates that the species was widely distributed in the western and eastern ends of Cuba until the recent past. At present, there seems to be no explanation for its absence from most of central Cuba. Except for Sierra de Cubitas and Sierra del Escambray there are no indications of the existence of *Solenodon* in that portion of the island. *Solenodon* certainly moved across central Cuba, either from west to east or from east to west. This passage is supported by its presence in cave and Indian deposits in Sierra de Cubitas. Much of central Cuba is characterized by lowlands, that probably underwent submergence in Pleistocene times. It might also be possible that the two extremes of the island are better known because of the higher research opportunities and resources available in La Habana on the west, and in Santiago de Cuba on the east. The western portion is also the only known range of the giant Cuban Solenodon, which is restricted to Pinar del Rio and La Habana provinces. However, I would expect a wider distribution for this species, which should include the eastern provinces.

Throughout the Dominican Republic, the greatest threat to solenodons is environmental degradation. Their extirpation from many areas of their historical range reflects the long-term effects of the intensive exploitation of the natural forests. The situation in the Cabrera Promontory is not exceptional, and according to the data gathered during my surveys, systematic exploitation of the natural vegetation began in the 1930's. Until this time much of the Promontory was still clothed in pristine forest. Conversion of the natural wildlands by development accelerated during the following decades with a massive influx of settlers, mostly immigrants from the more densely populated Cibao region. Clearing of forest habitats for migratory and/or shifting agriculture, grazing lands, and wood and charcoal industries, have caused considerable deforestation, erosion, and water resource degradation. As a result, no sizeable blocks of undisturbed forest remain. Instead there are relatively small fragments of secondary growth representing various successional stages, perennial crops, and narrow strips of vegetation covering the reduced watersheds.

My observations suggest that solenodons were widespread on the Cabrera Promontory in the recent past. The older campesinos in particular reported that the animals were not uncommon, and were relatively frequently encountered during clear cutting and slash-and-burn activities. Solenodons are now considered very rare and only discovered by their dogs. As in most areas of the Dominican Republic where the animals survive, it is common belief among the campesinos that solenodons are obnoxious animals and that they are harmful to root crops. The foraging tracks left by solenodons as they dig for invertebrates in gardens lead the campesinos to believe that the animals feed on yuca, sweet potato, and yam. Furthermore, the tracks of rats and solenodons are easily confused by the untrained observer, hence solenodons are often blamed for damage caused by rodents.

Although legally protected, regulations safeguarding solenodons are rarely enforced. This problem is exacerbated by the lack of relevant education. In general, Dominicans consider solenodons to be of little value for food, cash, recreation, etc. Hence, most campesinos do not hesitate to kill solenodons if the opportunity exists. If not first, predation by dogs is the second most important source of mortality after habitat degradation. Having evolved on an island lacking native mammalian carnivores, solenodons lack effective anti-predatory behavior to cope with dogs, which were introduced by western man during the early colonization period. Both domestic and feral dogs are efficient predators upon solenodons. Campesinos encourage this predation and react with pride when their dogs kill a solenodon.

After centuries of colonial exploitation, mono-crop plantation systems, and itinerant agriculture, much of Cuba, Haiti, and the Dominican Republic have been left with severely damaged terrestrial wildlife, which today is under further stress because of growing human populations, deforestation, introduction of exotic species, erosion, expanding tourism, industrial activity, and waste disposal. The long history of massive human intervention in the native upland forests (Table VI-1) has fundamentally changed the islands' vertebrate fauna, and have had a profound impact on Solenodon populations.

At present, the West Indian islands are at a critical juncture. Given the current trends, aggravated by economic recession and foreign debt, the next few decades will be a period of tremendous acceleration in the growth of local industry and human population, which would result in serious environmental dilemmas and crisis. International cooperation as well as leadership from national governments and environmental experts would be required to prevent resource depletion throughout the islands. The overall goal for the conservation of the remaining biodiversity should be to promote sustainable development in the region.

Solenodon, a relict group whose only known or suspected close relatives (Nesophontidae, Apternodontidae, and Geolabididae) are all extinct, is unique in many aspects. They are also the most peculiar of all West Indian mammals. The two extant members of the genus are the only survivors of an extensive insectivore radiation that reached two genera and 12 species in the Greater Antillean islands. Both surviving species are today endangered. In all probability, at least one population of Solenodon is locally extirpated every year somewhere in Cuba, Haiti, or in the Dominican Republic. Despite this, most areas throughout their known range remain to be surveyed. The following recommendations provide directions in an effort that will be critical for immediate and long-term attempts to save Hispaniolan and Cuban Solenodon from extinction.

1. Development of an Action Plan for West Indian Insectivores

Justifications for the development of an Action Plan for the conservation of the surviving Greater Antillean insectivores have been discussed in detail in previous section of this study.

Objectives of the Action Plan:

- Emphasize the importance of Solenodon, either as important element of the islands' ecosystems, or as ancient lineages which are valuable for elucidating mammalian evolution.
- Identify species and critical habitats under threat, and document their status.
- Identify research, field conservation, and captive breeding projects needed for these species.
- Promote local and international participation in conservation projects; promote education programs and direct conservation action.
- Strengthen arguments for the protection of the species and their habitats.

2. Ranking Species Priorities

Using the recently proposed Red Data Categorization (Mace and Lande 1991), which provides quantitative criteria for the assessment of extinction threats (population size, distribution, trends, stochasticity), I propose the following ranking and status:

SPECIES/ POPULATION	PRIORITY LEVEL	RDB CRITERIA
_S_. _cubanus_	1	Critical
_S_. _paradoxus_		
a) La Hotte	2	Endangered
b) Baoruco	2	Endangered
c) North Hisp.	3	Endangered

3. Assessment of MVP's and Development of PVA's

The assessment of MVP's (Minimum Viable Population) and PVA's (Population Vulnerability Analysis) is strongly recommended, even if there are insufficient data for a full estimation. The attempt will help to define the questions that need answers and identify the direction of research and conservation priorities.

4. National Conservation Strategies

The World Conservation Strategy (WCS), jointly published in 1980 by IUCN, UNEP and WWF recommended the preparation of National Conservation Strategies (NCS). Provisions for _Solenodon_ conservation should be included in an NCS because the long-term survival of Cuban and Hispaniolan solenodons needs to be a part of overall national environmental conservation plans. Conservation and development programs need to be integrated in such a manner as to reduce conflict.

In addition to including _Solenodon_ in their National Conservation Strategies, the governments of Cuba, Haiti, and the Dominican Republic (so far only Cuba have prepared one), should develop National Solenodon Conservation and Management Strategies for each country.

5. Enforcement of Legislations Protecting Solenodon Populations and their Habitats

Existing national legislations protecting Solenodon and their habitats need to be fully enforced in Dominican Republic and Cuba. In Haiti, were government wildlife protection is unrealistic, the future survival of Solenodon is only possible if the National Park Pic Macaya could be spared from destruction. Since there is little hope for any local effort to succeed in this task, only international support could change present prospects for this AID-funded protected area.

6. Establishment of Solenodon Protected Areas

A network of protected areas (eg. Solenodon sanctuary management criteria) should be develop in each island, including both the creation of new areas, and the designation of core areas within the boundaries of existing National Parks.

7. Attenuation of Conflicts Between People and Solenodons

The Action Plan should include among the priorities the development of a strategy to minimize the conflicts between land development and Solenodon conservation.

8. Translocation of Solenodons

Solenodons may have to be translocated from areas which are being developed for mining and agriculture. Removed animals could be either released in suitable habitats within protected areas of their present and historical range, or utilized for the development of sound captive breeding programs. To minimize mortality, the release of translocated animals would only be attempted after careful assessment of environmental quality, expected survivorship and monitoring success.

9. Control of Exotic Predators

Although this is a very controversial, and perhaps somewhat unrealistic issue, the control of exotic carnivores inside protected areas is urgently needed and should be highly considered.

10. Establishment of captivity breeding programs

The development of successful captive breeding programs for Solenodon is vital to any long term conservation strategy. The purpose of captive propagation is to reinforce, not replace, wild populations. An intensive captive management approach is recommended.
Solenodons were first held in captivity as early as 1886. Studies on captive populations have played a key role in

filling some important gaps in our knowledge of solenodon biology, and the information derived from such research represents an invaluable source for the development of further programs. However, solenodons have done poorly in captivity. Few successes have been achieved in the attempts to establish captive populations, and only a single breeding has been recorded. Furthermore, zoos have been the major cause of removal from the wild. More than 50 percent of all Solenodon specimens known since their discovery were captured to be placed in captivity. Therefore, a complete evaluation of husbandry procedures should be required to prevent the failures recorded in the past.

In addition to adequate management, most of the traditional difficulties of their captive maintenance can be overcome with the new technologies available for the captive breeding of threatened wildlife. In the past, the most common problems encountered with captive solenodons were related to their social structure, inadequate facilities, and difficulty of adapting adult animals to captive conditions and diets.

If captured, family groups should be kept together. Pairs or groups are probably stressed when maintained in close confinement. Adults apparently need isolation during the stressful year subsequent to capture, and such isolation is easily disrupted. Juveniles are more easily adapted to captivity than adult individuals. The availability of relatively large outdoor enclosures (6 by 12 m) would increase chances of breeding success. Both visual and auditory disturbances can disrupt isolation. Solenodons need considerable supervision, care and medical attention to persist long in captivity. Furthermore, success in breeding solenodons is contingent upon an adequate understanding of their natural history and behavior in the wild, yet these are poorly known.

Parasite-host interactions are complex. Slight changes in the conditions host animals are subjected to can greatly influence their susceptibility to epidemics of parasites. In subterranean mammals, parasites, diseases, and food shortages have been shown to influence density-dependent mortality (Jarvis 1973). Presumably there are not "bad" parasites. Under stressful situations, however, parasitism could have negative secondary effects on the reproductive performance and physical conditions of captive solenodons. Monitoring their parasite loads should be undertaken whenever possible. Captive mortality in captive solenodons may be reduced by routine parasite checks.

11. Research

The following research priorities, in order of importance, are recognized:

a) Status surveys
b) Population size
c) Genetic variation
d) Ecology
e) Impact of exotic species
f) Diseases and parasites

12. Public Awareness

Educational programs should be carried out to educate the public concerning Solenodon, their importance and problems. Publicity should be given to agricultural, mining and hydroelectric projects where Solenodon habitat would be affected, so than possible impacts can be evaluated before their implementation.

13. Support and Implementation of the Solenodon Action Plan

Ultimately, the success of the Action Plan and conservation strategy will depend on how effectively each government implements its recommendations. Political decision and government commitment will be essential. Considering the present and future economical challenges faced by Cuba, Haiti, and the Dominican Republic, it is unlikely that conservation efforts would have any hope without international support.

FIG. VI-1

Dorsal profiles of the skull of the known species of *Solenodon* suggesting size-grades niches in the radiation of the group, and comparison of the relative size of the members of the genus with the largest species of the genus *Nesophontes*. a) *Solenodon* "new species A" (MNHNC 421/123); b) *S. cubanus* (USNM 37983); c) *Nesophontes edithae*, Puerto Rico (UK 51); d) *S. paradoxus paradoxus*, North Hispaniola (JAO 721); e) *S. paradoxus* "new subspecies B" (JAO 476); f) *S. marcanoi* (UF 128162).

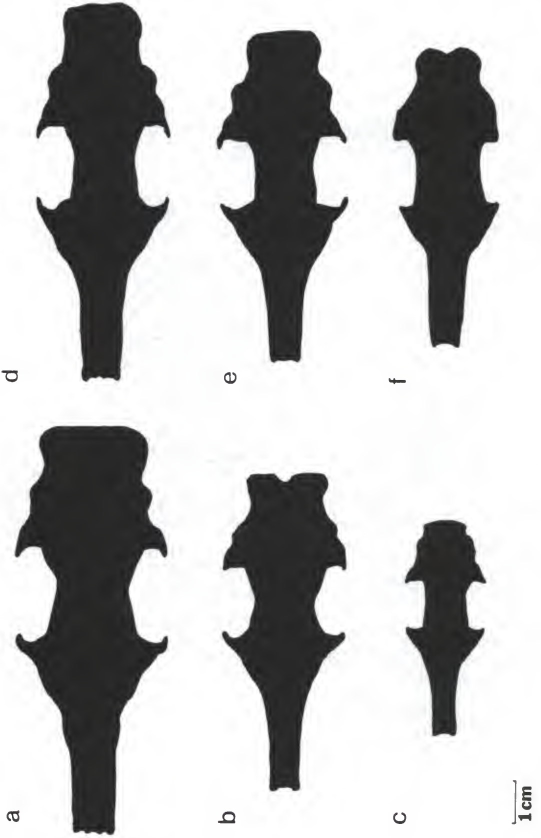

a
b
c
d
e
f
1cm

Table VI-1. Population and deforestation trends in Cuba, Haiti, and the Dominican Republic.

Enviromental Parameter	Cuba	Dominican Republic	Haiti
Surface area (km^2)	114,524	48,442	27,000
Population (in millions)	10,4	6,9	6,3
Density (h/km^2)	90.8	142.4	233.3
Growth rate (%)	1	2.4	2.8
Percent forested[1]			
1920	46	77	60
1954	-	-	8.5
1964	14.4	22.6	3.6
1970	14	23	7
1970	18	40	0
1974	11	22.7	1.8
1980	21.5	19.6	5.2

SOURCE: FAO (1975); Zon and Sparhawk (1923); Lugo *et al*. (1981).

LITERATURE CITED

Abreu, R. M., J. de la Cruz, A. Rams, and M. E. García. 1989. Vertebrados del complejo montañoso "La Zoilita", Holguín, Cuba. Poeyana 370:1-16.

Abreu, R. M., A. Rams, and J. de la Cruz. 1990. El almiqui (Solenodon cubanus). Algunos aspectos de su historia, biología y conservación. Poeyana 410:1-20.

ACC (Academia de Ciencias de Cuba). 1982. Juan C. Gundlach: Cartas a Antonio Mestre. Acad. Cien. Cuba, Editorial Academia, La Habana.

Alayón García, G. 1988. Resultados preliminares de los estudios faunísticos en la Reserva de la Biosfera "Cuchillas del Toa" (Holguin-Guantanamo) Cuba. Resumen de Trabajos. Seminario-Taller Latinoamericano sobre Manejo de Ecosistemas Protegidos de Montaña. Santiago de Cuba, junio 20-26,1988. Comisión Rectora del Gran Parque Nacional Sierra Maestra/FAO. p. 24.

Acevedo González, M., O. Arredondo, and N. Gonzalez Gotera. 1975. La cueva del Tunel. Editorial Pueblo y Educación, La Habana. 73 pp.

Aguayo, C. G. 1950. Observaciones sobre algunos mamíferos cubanos extinguidos. Bol. Hist. Nat. Soc. Felipe Poey 3:121-134.

Aguayo, C. G., and L. H. Rivero. 1954. Catálogo de la fauna Cubana. Circulares del Museo y Biblioteca de Zoología de la Habana 351:1283-1324.

Alayo, P. 1958. Lista de los mamíferos de Cuba (Vivientes y extinguidos). Museo "Charles T. Ramsden", Univ. Oriente, Santiago de Cuba. 34 pp.

Alayon García, G. 1988. Resultados preliminares de los estudios faunísticos en la Reserva de Biosfera "Cuchillas del Toa" (Holguin-Guantanamo), Cuba. Resumen de Trabajos. Seminario-Taller Latinamericano sobre Manejo de Ecosistemas Protegidos de Montaña. FAO y Comisión Rectora del Gran Parque Nacional Sierra Maestra. 20-26 Junio. Santiago de Cuba, Cuba.

Allen, G.M. 1910. Solenodon paradoxus. Mem. Mus. Comp. Zool. 40(1): 1-54.

Allen, G.M. 1918. Fossil mammals from Cuba. Bull. Mus. Comp. Zool., 62(4):133-148.

Allen, G.M. 1911. Mammals of the West Indies. Bull. Mus. Comp. Zool. Harvard 54(6):175-263.

Allen, G.M. 1942. Extinct and vanishing mammals of the Western Hemisphere. Amer. Committee Intern. Wildlife Protection. Spec. Publ. 11:1-620.

Allen, J.A. 1908. Notes on Solenodon paradoxus Brandt. Bull. Amer. Mus. Nat. Hist. 24:505-517.

Angulo, J.J. 1947. Teat location in the Cuban solenodon. J. Mamm. 28(3):298-299.

Anonymous. 1908. Annual Report of The Curator. Museum of Comparative Zoology, Cambridge, p. 6.

Anonymous. 1974. The Cuban solenodon. Jour. Fauna Preser. Soc. Oryx, Nov., p. 542.

Arredondo, O. 1955. Contribución a la paleontología de la Sociedad Espeleologica de Cuba. Bol. Soc. Espeleo. Cuba. 1(2):3-31.

Arredondo, O. 1961. Descripciones preliminares de dos nuevos géneros y especies de edentados del Pleistoceno Cubano. Bol. Grupo Exploraciones Científicas. La Habana, 1(1):19-36.

Arredondo, O. 1970. Nueva especie de ave pleistocénica del orden Accipitriformes (Accipitridae) y nuevo genero de Las Antillas. Univ. La Habana. Ser. Cien. Biol. 4(8):1-19.

Arredondo, O. 1971. Nuevo genero y especie de ave fosil (Accipitriformes: Vulturidae) del Pleistoceno de Cuba. Memor. Soc. Cien. Nat. La Salle 31 (90):309-323.

Arredondo, O. 1976. The great predatory birds of the Pleistocene of Cuba. p. 169-197. In: S.L. Olson (ed.). Collected papers in avian paleontology honoring the 90th birthday of Alexander Wetmore. Smithsonian Contrib. Paleobiology 27:1-211.

Arredondo, O. 1982. Los strigiformes fósiles del Pleistoceno Cubano. Bol. Soc. Cien. Nat. La Salle, 140:33-55.

Arredondo, O. 1984. Sinopsis de las aves halladas en depósitos fosilíferos pleisto-holocénicos de Cuba. Inst. Zool., Reporte de Investigación 17:1-35.

Arredondo, O. and L. Varona. 1974. Nuevos género y especie de mamífero (Carnivora: Canidae) del Cuaternario de Cuba. Poeyana 131:1-12.

Barbour, T. 1944. The solenodons of Cuba. Proc. New England Zool. Soc. 23:1-8.

Barbour, T. 1945. A naturalist in Cuba. Little, Brown and Co., Boston.

Beddard, F. E. 1909. Mammalia. MacMillan and Co., London.

Bofill, J. 1948. In: Boytel ed., Datos y documentos que sobre el Almiqui Solenodon cubanus Peters existen en este Museo. Publ. Occ. Mus. Munic. "Emilio Bacardi Moreau", Biol. (Secc. Hist. Nat.) 3:1-5.

Brandt, J.F. 1833. De solenodonte. Novo mammalium insectivorum genere. Mém. l'Acad. Sci. St. Petersbourg. 6(2):459-478.

Bridges, W. 1936. The Haitian Solenodon. Bull. New York Zool. Soc., 39(1):13-18.

Bridges, W. 1958. Two rare insectivores. Animal Kingdom 61(3):90-91.

Brodkorb, P. 1969. An extinct Pleistocene owl from Cuba. Quartely Jour. Florida Acad. Sci., 31(2):112-114.

Butler, P. C. 1956. The skull of Ictops and the classification of the Insectivora. Proc. Zool. Soc. of London 126:453-481.

Butler, P. C. 1972. The problem of insectivore classification. pp. 253-265. In: K. A. Joysey and T. S. Kemp (Eds.). Studies in vertebrate evolution. Oliver and Boyd, Edinburgh.

Butler, P. C. 1988. Phylogeny of the insectivores. pp. 117-141. In: Benton, M. J. (Ed.). The phylogeny and classification of tetrapods, Vol. 2: Mammals. Systematics Assoc. Spec. Vol. 35B. Clarendon Press, Oxford.

Cabrera, A. 1925. Genera mammalium. Insectivora, Galeopithecia. Madrid.

Cañas Alcober, R. 1971. The last Almiquis (Solenodon cubanus) in captivity. C. Zool. Garten (NF) 40:1-3.

Cave, A.J.F. 1968. The hyoid arch of Solenodon cubanus. J. Zool. Lond. 115:451-460.

Conisbee, L. R. 1953. Genera and subgenera of Recent mammals. British Museum (Natural History), London.

Corbet, G. B. and J. E. Hill. 1980. A world list of mammalian species. British Museum (Nat. Hist.) and Comstock Publishing Assoc., London.

Coy Otero, A., and N. Lorenzo Hernandez. 1982. Lista de los helmintos parásitos de los vertebrados silvestres cubanus. Poeyana 235:1-57.

Crandall, L.S. 1949. The Cuban Solenodon: Unprepossessing, but a zoological rarity. Animal Kingdom, 52(3):95.

Crandall, L. S. 1964. The management of wild animals in captivity. University Press, Chicago.

Cruz, J. de la. 1973. Los generos Cubanochirus y Capromylichus (Acarina:Atopomelidae). Acad. Cien. Cuba. Poeyana 205:1-28.

Cruz, J. de la. (In press). Fauna amenazada de vertebrados de Cuba.

Dobson, G.E. 1882. A monograph of the Insectivora. Systematic and anatomical. Part I. Erinacidea, Centetidae, and Solenodontidae. John Van Voorst, London

Dobson, G.E. 1884. On some peculiarities in the geographical distribution and in the habits of certain mammals inhabiting continental and oceanic islands. Annals and Magazine of Natural History 9:153-159.

Donnelly, T.W. 1990. Caribbean biogeography: Geological considerations bearing on the problem of vicariance vs. dispersal. pp. 595-609. In: Biogeographical aspects of insularity. Accademia Nazionale dei Lincei, Rome.

Eisenberg, J. F. 1975. Tenrecs and solenodons in captivity. Inter. Zoo Yearbook 15:6-12.

Eisenberg, J. F. 1980. Insectivorous mammals in captivity. Inter. Zoo Yearbook 20:47-52.

Eisenberg, J. F. 1981. The mammalian radiations. Univ. of Chicago Press, Chicago. 610 p.

Eisenberg, J. F., and E. Gould. 1966. The behavior of Solenodon paradoxus in captivity with comments on the behavior of other insectivora. Zoologica 51:49-58.

Eisenberg, J. F., and P. Leyhausen. 1972. The phylogenesis of predatory behavior in mammals. Z. Tierpsychol. 30:59-93.

Eisenberg, J. F., and N. Gonzalez Gotera. 1985. The natural history of Solenodon cubanus. Acta Zool. Fenn. 173:275-277.

Eisentraut, M. 1976. Das gaumenfaltenmuster der säugetiere und seine bedeutung fur stammesgeschichtliche und taxonomische untersuchungen. Bonner Zool. Monographien 8:1-214.

Elliot, D. G. 1905. A check list of mammals of the North American continent, the West Indies, and the neighboring seas. Field Columbian Mus. Publ. 105, Vol.6.

FAO (Food and Agriculture Organization). 1975. Inventario y fomento de los recursos forestales. Republica Dominicana, Technical Report No. 3. SF/DOM 8. Rome.

Findley, J.S. 1967. Insectivores and dermopterans. pp. 87-108. In: S. Anderson and J.K. Jones Jr. (eds.). Recent mammals of the world: A synopsis of the families. Ronald Press Co, New York.

Flower, W. H. and R. Lydekker. 1891. An introduction to the study of mammals living and extinct. Adam and Charles Black, London.

Gonzalez, N. 1981. El record subfosil mas occidental del Almiqui, Solenodon cubanus (Insectivora: Solenodontidae). Acad. Cien. Cuba. Misc. Zool. 12:2-3.

Gonzalez, V. and M. T. de Mello. Datos hematologicos y determinación del sexo de jutia, Solenodon paradoxus, por la observación de cromatina sexual. (Unpublished report).

Gregory, W. K. 1910. The orders of mammals. Bull. Amer. Mus. Nat. Hist. 27:1-524.

Gundlach, J. 1866-67. Revista y catálogo de los mamíferos Cubanos. pp. 40-56. In: F. Poey (Ed.). Repertorio fisico-natural de la Isla de Cuba. Tomo 2. La Habana.

Gundlach, J. 1872. Catalogo de los mamíferos Cubanos. An. Soc. Española Hist. Nat. Tomo 1:231-258.

Gundlach, J. C. 1877. Contribución a la mammalogía cubana. G. Montiel y Cia., La Habana. 53 pp.

Gundlach, J. C. 1895. Notes on Cuban mammals. Proc. Linnean Soc. New York 7:13-20.

Guyer, C., and J.M. Savage. 1986. Cladistic relationships among anoles (Sauria: Iguanidae). Systematic Zoology 35:509-531.

Hall, E.R. 1981. The mammals of North America. 2nd Ed. John Wiley & Sons Inc., New York.

Hall, E.R. and K.R. Kelson. 1959. The mammals of North America. The Ronald Press Co., New York.

Hartshorn, G., G. Antonini, R. DuBois, D. Harcharick, S. Heckadon, H. Newton, C. Quezada, J. Shores, and G. Staples. 1981. The Dominican Republic country environmental profile: A first study. JRB Assoc. AID/SOD/PDC-C-0247. Washington, D.C. 109 pp.

Hershkovitz, P. 1971. Basic crown patterns and cusp homologies of mammalian teeth. pp. 95-150. In: A. A. Dahlberg (Ed.). Dental morphology and evolution. Univ. Chicago Press, Chicago.

Holcombe, T.L. and N.T. Edgar. 1990. Late Cretaceous and Cenozoic evolution of Caribbean ridges and rises with special reference to paleogeography. pp. 611-626. In: Biogeographical aspects of insularity. Accademia Nazionale dei Lincei, Rome.

Honacki, J.H., K.E. Kiman, and J.W. Koeppi. 1982. Mammal species of the world: A taxonomic and geographic reference. Assoc. Syst. Collections. Lawrence, Kansas.

Horst, G.W. Gleiss. 1967. Unter robben, gnus and tigerschalngen. Chronik des Zoologischen Gartens Breslau 1865-1965. Natura et Patria Verlag, Hamburg.

Hornaday, W. T. 1910. The solenodon. New York Zoological Society Bull. 41:695.

Jaimez, E. Casimba, Bol. Grupo Espeleológico "Pedro Borrás". Año 1, No. 1. p. 5.

Koopman, K.F. and R. Ruibal. 1955. Cave-fossil vertebrates from Camaguey, Cuba. Breviora. 46:1-8.

Kowalski, K. 1976. Mammals: An outline of theriology. Polish Scientific Publ., Warszana, 1971.

Kleiman, D. G. 1977. Monogamy in mammals. Q. Rev. Biol. 52:39-69.

Kratochvil, J. 1976. Ein neuer fund von <u>Atopogale</u> <u>cubanus</u> [A rediscovery of <u>Atopogale</u> <u>cubanus</u>] (Peters) (Insectivora, Mamm.). Zoologické Listy 25(2):113-115.

Lawlor, T. E. 1979. Handbook to the orders and families of living mammals. 2nd. Ed. Mad River Press, Eureka, California.

Leche, W. 1907. Zur Entwicklungsgeschichte des Zahnsystems der Säugetiere. 2. Teil: Phylogenie, 2. Heft: Die Familien der Centetidae, Solenodontidae und Chrysochloridae. Schweizerbartsche Verlagsbuchhandlung, Stuttgart.

Lillegraven, J. A., M. C. McKenna, and L. Krishtalka. 1981. Evolutionary relationships of Middle Eocene and younger species of <u>Centetodon</u> (Mammalia, Insectivora, Geolabidae), with a description of the dentition of <u>Ankylodon</u>. Univ. Wyo. Publ. 45:1-115.

Liogier, A.H. 1974. Diccionario botanico de nombres vulgares de La Española. Jardin Botanico Dr. Rafael M. Moscoso. Universidad Nacional Pedro Henriquez Urena, Santo Domingo.

Lorenzo, N., A. Coy Otero and R. Abreu. 1981. Los helmintos que invaden a las especies del genero <u>Solenodon</u> Brandt, 1833. Acad. Cien. Cuba. Poeyana 222:1-4.

Lugo, A.E., R. Schmidt, and S. Brown. 1981. Tropical forests in the Caribbean. Ambio 10(6):318-324.

MacFadden, B.J. 1980. Rafting mammals or drifting islands? :Biogeography of the Greater Antilles insectivores <u>Nesophontes</u> and <u>Solenodon</u>. Jour. Biogeog. 7:11-22.

MacPhee, R.D.E. 1981. Auditory regions of primates and eutherian insectivores. Morphology, ontogeny and character analysis. Contrib. Primatology 18:1-281.

MacPhee, R.D.E. 1987. The shrew tenrecs of Madagascar: Systematic revision and Holocene distribution of Microgale (Tenrecidae, Insectivora). Amer. Mus. Novitates 2889:1-45.

Matthew, W. D. 1910. On the skull of Apternodus and the skeleton of a new artiodactyl. Bull. Amer. Mus. Nat. Hist. 28:33-42.

Matthew, W. D. 1918. Affinities and origin of the Antillean Mammals. Bull. Geol. Soc. Amer. 29:657-666.

McDowell, S.B. 1958. The Greater Antillean insectivores. Bull. Amer. Mus. Nat. Hist. 115(3):113-214.

McKenna, M.C. 1975. Toward a phylogenetic classification of the Mammalia. p. 21-46. In: F.S. Szalay and W.P. Luckett (eds.). Phylogeny of the Primates. Plenum Press, New York.

McNab, B.K. 1979. The influence of body size on the energetics and distribution of fossorial and burrowing mammals. Ecology 60(5): 1010-1021.

McNab, B.K. 1980. Food habits, energetics and the population biology of small mammals. Amer. Nat. 116(1):106-124.

McNab, B.K. 1983. Ecological and behavioral consequences of adaptation to various food resources. p. 664-697. In: Advances in the study of mammalian behavior. J.F. Eisenberg and D. Kleiman, (eds.). American Society of Mammalogists., Spec. Publ. No. 7.

McNab, B.K. 1989. On the selective persistence of mammals in South America. Pp. 605-614. In: K. Redford and J.F. Eisenberg (eds.). Advances in Neotropical Mammalogy. Sandhill Crane Press, Gainesville, Florida.

Menzel, K. H. 1979. Morphologische Untersuchungen an der vorderen nasenregion von Solenodon paradoxus (Insectivora). Med. den. Diss., Frankfurt M., 1-51.

Miller, G.S., Jr. 1924. List of North American Recent mammals, 1923. U. S. Natl. Mus. Nat. Bull. 128:1-673.

Miller, G.S., Jr. 1929a. A second collection of mammals from caves near St. Michel, Haiti. Smithsonian Misc. Coll. 81(9):1-30.

Miller, G.S., Jr. 1929b. Mammals eaten by indians, owls and Spaniards in the coast region of the Dominican Republic. Smithsonian Misc. Coll. 82(5):1-16.

Miller, G.S., Jr. and R. Kellogg. 1955. List of North American Recent mammals. U. S. Natl. Mus. Bull. 205. Smithsonian Institution, Washington, DC.

Mills, J.R.E. 1966. The functional occlusion of teeth of the Insectivora. J. Linnean Soc. (Zool.) 47:1-25.

Mivart, St. G. 1867. Notes on the osteology of the Insectivora. J. Anat. Physiol., Lond. 1:281-312.

Mivart, St. G. 1868. Notes on the osteology of the Insectivora. J. Anat. Physiol., Lond. 2:117-154.

Miyamoto, M. M., and M. Goodman. 1986. Biomolecular systematics of eutherians mammals: phylogenetic patterns and classification. Syst. Zool. 35(2):230-240.

Mohr, E. 1936. Biologische Beobachtungen an Solenodon paradoxus Brandt in Gefangenschaft. I. Zool. Anz. 113:177-188.

Mohr, E. 1936. Biologische Beobachtungen an Solenodon paradoxus Brandt in Gefangenschaft. II. Zool. Anz. 116:65-76.

Mohr, E. 1937. Biologische Beobachtungen an Solenodon paradoxus Brandt in Gefangenschaft. III. Zool. Anz. 117:233-241.

Mohr, E. 1938. Biologische Beobachtungen an Solenodon paradoxus Brandt in Gefangenschaft. IV. Zool. Anz. 122:132-143.

Moreno, A. 1966. La fauna de Cuba III: Los mamíferos. Bol. Jardín Zool. La Habana 1(5-6):13-15.

Morgan, G.S., C.E. Ray, and O. Arredondo. 1980. A giant extinct insectivore from Cuba (Mammalia: Insectivora: Solenodontidae). Proc. Biol. Soc. Wash. 93(3):597-608.

Morgan, G. and C. A. Woods. 1986. Extinction and the zoogeography of West Indian land mammals. Biol. J. Linnean Soc. 28:167-203.

Muñoz, A.R. 1974. Captura trabajador del INDAF un almiquí en la Sierra del Cristal. Granma, 2 de diciembre, p. 3, La Habana.

Novacek, M. J. 1982. Information for molecular studies from anatomical and fossil evidence on higher eutherian phylogeny. pp. 3-41. In: M. Goodman (Ed.). Macromolecular sequences in systematic and evolutionary biology. Plenum Press, New York.

Novacek, M. J. 1990. Morphology, paleontology, and the higher clades of mammals. pp. 507-543. In: H. H. Genoways (Ed.). Current mammalalogy. Plenum Press, New York.

Novacek, M. J., M. C. McKenna, N. A. Neff, and R. L. Cifelli. 1983. Evidence from the earliest known erinaceomorph basicranium that insectivorans and primates are not closely related. Nature 306:683-684.

Novak, R. M., and J. L. Paradiso. 1983. Walker's Mammals of the world. 4th Ed. John Hopkins Univ. Press, Baltimore.

Ottenwalder, J. A. 1979. Hispaniolan solenodon born at Santo Domingo Zoo. Int. Zoo News 26:46-47.

Ottenwalder, J. A. 1985. The distribution and habitat of Solenodon in the Dominican Republic. Master Sc. thesis, University of Florida, Gainesville. Pp. 128.

Ottenwalder, J. A., and E. Rupp. 1990. The status and distribution of the Hispaniolan solenodon in the Cabrera Promontory: the balance between economic development vs. natural resources. A case study. In: E. Bolay (ed.). Ecology of the Dominican Republic. Margraf Scientific Publications, Frankfurt.

Oviedo, F.G. de. 1535. La historia general de las Indias: Sumario de la historia natural y general de las Indias Islas y Tierra Firme del mar oceano. Seville.

Palmer, T. S. 1904. Index genera mammalium. North American Fauna 23. Government Printing Office, Washington.

Patterson, B. 1956. Early Cretaceous mammals and the evolution of mammalian molar teeth. Fieldiana Geol. 13:1-105.

Patterson, B. 1962. An extinct solenodontid insectivore from Hispaniola. Breviora 165:1-11.

Paula Couto, C. 1979. Tratado de paleomastozoologia. Acad. Brasileira Cienc., Rio de Janeiro.

Peña, F. M. 1977. Hábitos nutritivos del Solenodon paradoxus Brandt y el program de reproducción en cautividad. Zoodom 1:11-25.

Perez Vigueras, I. 1960. Nota sobre algunos cestodos encontrados en Cuba. Sec. Educ. Publ., Esc. Nac. Cien. Biol., Mexico, D.F.

Perfit, M.R., and E.E. Williams. 1989. Geological constrains and biological retrodictions in the evolution of the Caribbean sea and its islands. pp. 47-102. In: C.A. Woods (ed.). Biogeography of the West Indies: Past, present, and future. Sandhill Crane Press, Gainesville, Florida.

Peters, W. H. 1861. Note in Monatsber. K. Akad. Wiss. Berlin 1861:169.

Peters, W. H. 1863. Die Säugethier-Gattung Solenodon. Abh., Königl. Akad., Wiss. Berlin 1-22.

Pindell, J., and J.F. Dewey. 1982. Permo-Triassic reconstruction of Western Pangea and the evolution of the Gulf of Mexico/Caribbean Region. Tectonics 1(2):179-211.

Poduschka, W. 1975. Solenodon story. Wildlife 17:108-111.

Poduschka, W. 1977. Insectivore communication. p. 600-633. In: T.A. Seboek (Ed.). How animals communicate. Indiana Univ. Press, Bloomington.

Poduschka, W., and Ch. Podushcka. 1983. The taxonomy of the extant Solenodontidae (Mammalia: Insectivora): A synthesis. Aus den Sitzungsberichte der Osterr. Akad. Wissenschaften Mathem-naturw. Abt I (192):225-238.

Poduschka, W., and C. Wemmer. 1986. Observation on chemical communication and its glandular sources in selected Insectivora. pp. 609-616. In: D. Duvall, D. Muller-Schwarze and R. M. Silverstein (Eds.). Chemical signals in vertebrates 4. Plenum Publ. Corp., New York.

Poey, F. 1851. Memorias sobre la historia natural de la isla de Cuba. Barcina, Habana 1:1-463.

Pregill, G.K., and S.L. Olson. 1981. Zoogeography of West Indian vertebrates in relation to Pleistocene climatic cycles. Ann. Rev. Ecol. Syst. 12:75-98.

Rabb, G. B. 1959. Toxic salivary glands in the primitive insectivore Solenodon. Chicago Acad. Sci., Nat. Hist. Misc. 170:1-3.

Ralls, K. 1977. Sexual dimorphism in mammals: Avian models and unanswered questions. Amer. Nat. 111(981):917-938.

Ricart de Melgen, A. M. y B. Peña. 1973. Nota sobre la morfologia externa del tubo gastrointestinal de jutia Solenodon paradoxus. Bol. Lab. Vet. 1(1):41-43.

Ricart de Melgen, A. M., B. Peña and M. T. de Mello. 1973. Ciclo erratico de acantodefalo en jutia, Solenodon paradoxus, Bol. Lab. Vet. 191:1-8.

Riedman, M. L. 1982. The evolution of alloparental care and adoption in mammals and birds. Q. Rev. Biol. 57(4):405-435.

Rivero, M. and O. Arredondo. 1991. Paralouatta varonai, a new Quaternary platyrrhine from Cuba. J. Hum. Evol. 21:1-11.

Rysavy, B., and V. Barus. 1970. The worms from hosts of the genus Solenodon Brandt, 1833 (Insectivora). Folia Parasitol. 17:89-90.

Saban, R. 1954. Phylogénie des insectivores. Bull. Mus. Natl. Hist. Nat., Paris, Ser. 2 26:419-432.

Sagra, R. Historia física, política y natural de la Isla de Cuba. Segunda Parte, Historia Natural, Tomo 3ro, Paris.

Sanderson, I.T. Caribbean Treasure. Viking Press, New York. 292 pp.

Sandground, J. H. 1938. Some parasitic worms in the helminthological collections of the Museum of Comparative Zoology. Bull. Mus. Comp. Zool. 85(2):36-39.

Schlaikjer, E. M. 1934. A new fossil zalambdodont insectivore. Amer. Mus. Novitates 698:1-8.

Schrivastava, R. K. 1963. The deltoid musculature of the Insectivora. Acta Zoologica 44:131-143.

Schwartz, A. 1980. The herpetogeography of Hispaniola, West Indies. Stud. Fauna Curacao and Carib. Islands 189:86-127.

Segall, W. 1970. Morphological parallelisms of the bulla and auditory ossicles in some insectivores and marsupials. Fieldiana 150(15):169-205.

Silva Taboada, G. 1974. Las especies amenazadas de vertebrados Cubanos. Reporte sin publicar, Acad. Cien. Cuba, La Habana. 32 pp.

Simpson, G. G. 1945. The principles of classification and a classification of mammals. Bull. Amer. Mus. Nat. Hist. 85:1-350.

Simpson, G.G. 1956. Zoogeography of West Indian land mammals. Amer. Mus. Novitates 1759:1-28.

Starck, D., and W. Poduschka. 1982. Über die ventraldrüse von Solenodon paradoxus Brandt, 1833 (Mammalia: Insectivora). Z. Säugetierkunde 47:1-12.

Steadman, D. W., G. K. Pregill, and S. L. Olson. 1984. Fossil vertebrates from Antigua, Lesser Antilles: evidence for late Holocene human-caused extinctions in the West Indies. Proc. U. S. Nat. Acad. Sci. 81:4448-4451.

Szalay F. S. 1975. The origins of primate higher categories; an assessment basicranial evidence. pp. 91-123. In: W. P. Luckett and F. S. Szalay (Eds.). Phylogeny of the primates: a multidisciplinary approach. Plenum Press, New York.

Thornback, J. 1983. Towards a mammal conservation strategy. Report to the 59th SSC Meeting, Inter. Union Conser. Nature. Harare, Zimbabwe. 11 p.

Thornback, J. and M. Jenkins. 1982. The IUCN Mammal Red Data Book. Part 1. Unwin Brothers Ltd., Surrey, U.K.

Tijskens, J. 1967. Solenodon paradoxus Brandt. Zoo Antwerp Soc. Roy. de Zool. d'Anvers 142-144.

True, F.W. 1884. A provisional list of the mammals of North and Central America and the West Indian islands. Proc. U. S. Natl. Mus., Vol. 7, Appendix, pp. 3-27.

Van Valen, L. 1966. Deltatheridia, a new order of mammals. Bull. Amer. Mus. Nat. Hist. 132(1):1-126.

Van Valen, L. 1967. New Paleocene insectivores and insectivore classification. Bull. Amer. Mus. Nat. His. 135(5):217-284.

Varona, L.S. 1974. Catálogo de los mamiferos vivientes y extinguidos de las Antillas. Academia de Ciencias, Cuba.

Varona, L.S. 1980. Protection in Cuba. Oryx 15:282-284.

Varona, L. S. 1983. Remarks on the biology and zoogeography of the Solenodon (Atopogale) cubanus Peters, 1861 (Mammalia, Insectivora). Bijdragen tot de Dierkunke 53(1):93-98.

Varona, S., and O. Arredondo. 1979. Nuevos taxones fosiles de Capromyidae (Rodentia: Caviomorpha). Poeyana 95:1-51.

Verrill, A.H. 1907. Notes on the habits and external characters of the solenodon of San Domingo (Solenodon paradoxus). Amer. Journ. Sci. 4(24):55-57.

Vrydagh, J. M. 1954. Le Solenodon de Cuba. Pp. 107-112. In: Los fossiles de domain, Paris.

Walker, E. P. 1975. Mammals of the World. 3rd Ed. John Hopkins Univ. Press, Baltimore.

Webber, M. 1928. Die säugetiere. Gustav Fisher, Jena.

Williams, E.E. 1989. Old problems and new opportunities in West Indian biogeography. Pp. 1-46. In: C.A. Woods (ed.). Biogeography of the West Indies: Past, present, and future. Sandhill Crane Press, Gainesville, Florida.

Winge, H. 1941. The interrelationships of the mammalian genera. C. A. Reitzels Forlag, Copenhagen vol. 1, 418 pp.

Wislocki, G.G. 1940. The placentation of _Solenodon paradoxus_. Jour. Anat. 66:497-531.

Woods, C.A. 1976. _Solenodon paradoxus_ in Southern Haiti. J. Mamm. 57(3):591-592.

Woods, C.A. 1981. Last endemic mammals in Hispaniola. Oryx 16:146-152.

Woods, C.A. 1983. Biological survey of Haiti: Status of the endangered birds and mammals. Nat. Geographic Soc. Resear. Rep. 15:759-769.

Woods, C.A., J.A. Ottenwalder and W.W. Oliver. 1986. Lost mammals of the Greater Antilles. Dodo, J. Jersey Wildlife Preservation Trust, 22:23-42.

Woods, C. A. 1986. The mammals of the national parks of Haiti. Report to USAID/Haiti of project 521-0169-C-003083-00. 73 p.

Woods, C. A. 1989. A new capromyid rodent from Haiti: The origin, evolution, and extinction of West Indian rodents and their bearing on the origin of the New World hystricognaths. pp. 59-89. _In_: C.C. Black and M.R. Dawson (eds.). Papers on fossil rodents: In honor of Albert Elmer Wood. Natural History Museum of Los Angeles County, Science Series 33.

Woods, C. A. 1990 The fossil and Recent land mammals of the West Indies: An analysis of the origin, evolution, and extinction of an insular fauna. pp. 641-680. _In_: Biogeographical aspects of insularity. Accademia Nazionale dei Lincei, Rome.

Woods, C. A., and J. F. Eisenberg. 1989. The land mammals of Madagascar and the Greater Antilles: Comparison and analysis. Pp. 799-826. _In_: C.A. Woods (ed.). Biogeography of the West Indies: Past, present, and future. Sandhill Crane Press, Gainesville, Florida.

Yates, T. L. 1984. Insectivores, elephant shrews, tree shrews, and dermopterans. pp. 117-144. _In_: S. Anderson and J. K. Jones (Eds.). Orders and families of Recent mammals of the world. John Wiley & Sons, New York.

Zeveloff, S. I., and M. S. Boyce. 1980. Parental investment and mating systems in mammals. Evolution 34(5):973-982.

Zon, R. and W.N. Sparhawk. 1923. Forest resources of the world. McGraw-Hill, New York.

APPENDIX 1

FOOD ITEMS AND DIET SUPPLEMENTS OF SOLENODON IN CAPTIVITY.

Food item	Hispaniolan						Cuban
	BRO	NZP	DOM	HAM	ANT	FRA	HAB
Horsemeat (ground)	X	X	X			X	X
Minced beef				X		X	
Brain				X			
Kidney				X			
Liver				X			
Heart						X	
Mice (newborn)		X	X		X		
Mice (adult, skinned)		X	X			X	
Chicks (2-3 day old)		X	X			X	
Frankfurt						X	
Earthworms		X	X				X
Mealworms	X					X	
Millipedes (live)			X				
Crickets		X			X		X
Crabs							X
Lizards		X	X				X
Egg				X	X		
Egg yolk (raw)	X	X	X	X			X
Milk	X					X	X
Milk (powdered)		X					
Milk (evaporated)	X						
Dog food (ground)		X	X				
Mirra coat			X				
Wheat germ			X				
Cod liver oil	X						
Bone meal	X		X				
Iodized salt		X					
Fruits	X				X		
Banana	X					X	
Lettuce	X					X	
Vitamins		X	X			X	X
Minerals			X				
Calcium						X	

* BRO=Bronx, New York
NZP=National Zoological Park, Washington D. C.
DOM=Santo Domingo, Dominican Republic
HAM=Hamburg, Germany
ANT=Antwerp, Belgium
FRA=Frankfurt, Germany
HAB=Habana Zoo, Cuba

APPENDIX 2

PARASITISM AND PARASITE-RELATED MORTALITY (MARKED WITH ASTERISKS) IN <u>SOLENODON</u> <u>PARADOXUS</u> (N=28). DATA AS RECORDED IN POST-MORTEM EXAMINATIONS. SEE TEXT FOR INSTITUTION ACRONYMS. SEX: M, MALE; F, FEMALE. LOAD: H, HEAVY; M, MODERATE, L, LOW.

Zoo/ Sex	Post-mortem findings	Load
Bronx		
*1M, *2F	Parasites in stomach and peritoneum caused acute peritonitis.	H
1F	Tapeworms in middle half of intestine, 1-2 mm width, 15 cm lenght.	L
1M	Elongated, rice grain size, withish nodules in the omentum and posterior ventral abdominal musculature; skeletal muscle adjacent to epididymis containing remnants of large parasites with thick walls and resembling cyst forms containing larvae.	H
Cenia		
*1M	■ 200 nodules, small, rice grain size, white color encysted in liver, mesentery and abdominal cavity; ■ "large" number of taenias obstruding intestine.	H
1F	cysts of acanthocephala in liver	L
1F	cysts of acanthocephala in spleen	L
1M	nodules of acanthocephala in abdominal muscles and mesentery.	M
Antwerp		
1M	"parasites in abdominal cavity.	?
*1M	larvae and tapeworms in belly muscles, stomach, diaphragm, and mesentery.	H

*1F	■ worm tubercules in peritoneum and omentum; ■ tapeworms in abdominal cavity, stomach and intestines.	H
1M	isolated stage of tapeworms	?
1F	plecercoidic larvae of mesocestoides in epiplon and diaphram.	?
Frankfurt		
*1M	attack by filaria.	?
1F	acanthocephaliasis and infection by <u>Pseudomonas aureoginosa</u>.	?
1M	enteritis caused by taeniasis and salmonellosis	?
*1M, *1F	infestation with acanthocephala and tapeworms	H
*1F	encysted nematodes, tapeworm infestation, infection by <u>Salmonella</u> <u>typhymurinum</u>.	H
Brookfield		
1M	parasitism in intestine	L
*1M	■ small white nodules in intestine; ■ large numbers of small tapeworms in areas of haemorragic enteritis in small intestine; ■ "many cysts" in musculature of diafragm, intercostal and abdominal muscles.	H
*1F	■ small pin-head, white nodules on wall of stomach and mesentery; ■ tiny worms in stomach wall; ■ <u>Micrococcus</u> infection	H
Zoodom		
*1M	parasitary hepatitis-white nodules in mesentery, larvae in liver surface	
*1M	white cysts in diaphragm, mesentery, and abdominal muscles and in liver.	H
1F	nodules of acanthocephala in mesentery and abdominal muscles.	H
1F	taenias in intestine and and acanthocephala in mesentery.	L
1M	acanthocephala in stomach and mesentery	L

APPENDIX 3

SUMMARY OF HUSBANDRY PROCEDURES FOR CAPTIVE SPECIMEN OF S. PARADOXUS BETWEEN DECEMBER 1986 AND DECEMBER 1990*.

Daily:

- physical condition and general appearance of animal check
- amount of food offered and consumed recorded
- max-min temperature recorded
- rooms cleaned; nest-box substrate changed
- soil and air humidity check
- food offered at 17:00 h.

Weekly:

- body weight recorded
- exposed skin areas treated with A-D oinment

Monthly:

- faecal samples examined for parasites
- bath to remove dirt particles and treat skin dryiness; first three months bathed under mild anestesia to minimize stress.
- dentition cheched for wear and tartar and cleaned up if required.

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* Only the investigator and a trained keeper are involved in the supervision, maintenace and handling of the animal.

BIOGRAPHICAL SKETCH

Jose Alberto Ottenwalder was born in Santo Domingo, Dominican Republic on 14 October 1949. Sex came at early age, but maturity only much later. He concluded Pre-med studies at the Universidad Nacional Pedro Henriquez Ureña in 1970. The same year he entered the Universidad Autonoma de Santo Domingo where he received the degree of Licenciado in biology. The subject of his thesis was the population status of sea turtles in the Dominican Republic. He began graduate school at the University of Florida in August 1982, and received a Master Science degree in Wildlife Ecology in 1985. His thesis was about the habitat and distribution of the _Solenodon paradoxus_ in the Dominican Republic. Still, he feels the toughest and most rewarding school is life. He keeps saying he plans to retire after the doctoral degree. He thinks he knows what he wants. And he thinks he is going to get it. He thinks life is indeed wonderful. He wants it all.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John F. Eisenberg

John F. Eisenberg
Katharine Ordway Chair
of Ecosystem Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Charles A. Woods
Professor of Zoology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

F. Wayne King

F. Wayne King
Professor of Forest
Resources and Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Melvin Sunquist
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the School of Forest Resources and Conservation in the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December 1991

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