

Biodiversity of Sierra del Cristal, Cuba: first insights

J. E. Fa, J. P. Soy, R. Capote, M. Martínez, I. Fernández, A. Avila, D. Rodríguez, A. Rodríguez, F. Cejas and G. Brull

Abstract Cuba has the highest combined animal and plant diversity, and the highest degree of endemism, in the West Indies. In 1998 we undertook the first major biodiversity survey of the Sierra del Cristal National Park, in the Holguín province in eastern Cuba, to address the need for baseline data on the wildlife of the forest habitats of this biologically important mountain range. This area was chosen because it is known to be a major stronghold of the endemic Cuban solenodon *Solenodon cubanus* (Insectivora, Solenodontidae). The project initiated and supported field activities of two Cuban institutions involved in nature conservation. The study focused on indicator taxonomic groups. We recorded a total of 220 species of plants, 53 spiders, 28 molluscs, 10 amphibians,

19 reptiles, 51 birds, and three species of mammal. The highest number of species were recorded in montane forest. Thirty-five percent of the taxa recorded are endemic to the area or to Cuba. Information gathered during the study will form the basis for developing long-term management plans for habitats and resident species, in conjunction with the authorities responsible for environmental conservation.

Keywords biodiversity assessment, Cuba, endemic species, forest, Sierra del Cristal, *Solenodon cubanus*.

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Introduction

Cuba is the largest island (110,922 km²) in the Caribbean, and has the richest biodiversity in the region, with an estimated 6,200 species of flowering plants, 628 vertebrates and 7,500 insects and arachnids (Santana, 1991). The island has also the highest degree of endemism in the West Indies, with c. 50% of the flora and 32% of the vertebrate fauna unique to the island (IES/CENBIO, 1998). Approximately two-thirds of the total land area of Cuba is plains (*llanuras*), and the remainder is foothills and highlands, comprising isolated groups of mountains, the highest of which is the Sierra Maestra in the east (MINAG, 1991). The fertile soil of the lowlands supports extensive sugar

cane, rice and coffee plantations. Most of the island was originally forested, but deforestation since the Spanish conquest and especially after independence, when the lowlands were converted to sugar cane plantations, has left only c. 15% of the island's original vegetation cover intact.

Since 1959, Cuban institutions have striven for the implementation of effective conservation policies via legislation and creation of protected areas, of which there are currently 236 (CNAP, 2000). However, although advances have been made in documenting biodiversity, some areas, particularly mountainous massifs such as the eastern highlands, are poorly known (IES/CENBIO, 1998).

Together with western Hispaniola, the mountains in eastern Cuba (Sierra Maestra and the Nipe-Sagua-Baracoa range) are remnants of ancient crustal upthrusting and are the most prominent centre of speciation in the Antilles (Garrido & Jaume, 1984; Schwartz & Hedges, 1991; Rodríguez Schettino, 1993; Borhidi, 1996). They are also important centres of origin for over 24 Caribbean plant genera, and more than 1,500 plant species are endemic to the eastern Cuban highlands (Capote *et al.*, 1989; Borhidi, 1996). Because of their variable geology, topography and climate, together with anthropogenic effects, these mountains are a mosaic of vegetation types ranging from lowland seasonal rainforest to montane formations (Borhidi, 1996).

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Information from biodiversity inventories and monitoring, and the expertise to analyse these data, are essential for identifying key biodiversity policy and management goals for these regions. In this paper we describe the results of field studies carried out in an area of the Sierra del Cristal, in the Holguín province, by a multidisciplinary team from the Empresa Nacional para la Protección de la Flora y Fauna (ENPFF, Cuba) and the Instituto de Ecología y Sistemática (IES, Cuba), in collaboration with the Durrell Wildlife Conservation Trust (Jersey, UK). The study area was chosen because it is known to be an important stronghold for the endemic Cuban solenodon *Solenodon cubanus* (Insectivora, Solenodontidae). The ENPFF is the national bureau for nature protection and employs personnel in 46 protected areas throughout the island. The IES is a leading institution, within the Ministry of Science and Technology, dedicated to scientific research on Cuban flora and fauna. The principal aim of the project was to collect baseline biodiversity information within the Sierra del Cristal National Park. We focused on representative taxa, namely plants, spiders, molluscs and vertebrates, that could act as indicators of overall biodiversity (di Castri *et al.*, 1992).

Study area

Cuba lies within the Neotropical region, just south of the Tropic of Cancer. The climate is tropical with hot summers and mild winters (Núñez Jimenez, 1972). The dry season is in the winter, with 1–2 dry months at the mountain fringes, but with permanently humid rainforest in the interior (Borhidi, 1996). Annual precipitation is 1,600–2,300 mm (Borhidi, 1996). Cyclones are frequent, particularly in September and October. Within the study area, climate is affected by elevation, distance from the ocean and presence of vegetation. Temperatures may be highly variable, from a minimum of *c.* 9°C to a midday maximum of *c.* 29°C. Relative humidity is high, ranging from 55% at midday to 95% before dawn (Eisenberg & Gonzalez Gotera, 1985).

Sierra del Cristal forms part of the Nipe-Sagua-Baracoa mountain range in eastern Cuba (Fig. 1). This massif consists of deeply inclined conical hills and sharp ridges. The lower sections are covered by ferralitic soils, and by yellowish-red montane clays above 700 m (Borhidi, 1996). The Sierra is situated between two main river valleys: the Río Mayarí valley in the west and Sagua de Río Tanamo valley in the east. The Sierra is an almost circular massif *c.* 40 km across. The only main road into the area is along the north of the Sierra (Núñez Jimenez, 1972).

Sierra del Cristal was the first protected area in Cuba. Through Decreto No. 487, the area then known as

El Cristal, Realengo del Cristal or Sierra del Cristal, was declared a National Park on 24 April 1930. Approximately 26,000 ha within the Municipal sectors of Mayarí and Sagua de Tanamo were dedicated to nature protection. However, protection did not become effective until 23 November 1992, when jurisdiction and management of the Sierra were granted to the ENPFF (Resolución No. 454, Ministry of Agriculture). In the 1992 legislation only 15,000 ha were protected from hunting and extraction of natural resources. The park has a buffer zone, but zoning is incomplete. The ENPFF manages the protected area, through staff at the Unidad Territorial de Holguín in Mayarí. The park staff consists of a Chief of Personnel and 15 wardens based within the park.

The Sierra del Cristal region and adjoining areas have been affected by centuries of human occupation and use. Humans have hunted animals, especially hutias (Rodentia, Capromyidae), logged the forests, and extracted a variety of non-timber products. However, there is an elevational limit to human occupation, with no settlements above 400 m. The five main villages in the area (El Culebro, Limoncito, El Palenque, Baconal and La Zanja) are in the foothills of the Sierra (Fig. 1). During the study period, Baconal and El Palenque, which are within the park's buffer zone, had a combined population of 32 people, within eight households. Most of the men were employed by the ENPFF or by the regional agricultural agency (Empresa Municipal Agropecuaria).

Agricultural land is confined to small patches surrounding habitation. Most families cultivate cacao and coffee to sell to state-run industries, and grow root crops such as malanga *Xanthosoma sagittifolium* (Family Araceae), as well as plantain *Musa paradisiaca* and cassava *Manihot esculenta* for their own consumption. About 30% of the inhabitants raise some pigs and chickens, and a smaller proportion keeps goats. Extraction of timber and non-timber forest products is limited, but fronds from the palms *Roystonea regia* and *Calyptrogyne occidentalis* are used extensively for roofing.

According to recent classifications (Capote *et al.*, 1989; Borhidi, 1996) the vegetation of Sierra del Cristal is of four main types: (1) scrub forest, which is a dry and relatively depauperate scrub vegetation typical of areas of serpentine rock; (2) montane forest, which is the climax vegetation type over altitudes of 400–900 m (Borhidi, 1996); (3) evergreen forest, which is a moist forest type associated with lowland areas; and (4) pine forest, which is a formation of endemic pines patchily distributed along the mountainous regions of eastern Cuba.

Methods

Before the fieldwork commenced we organized a three-day workshop to introduce all team members to the

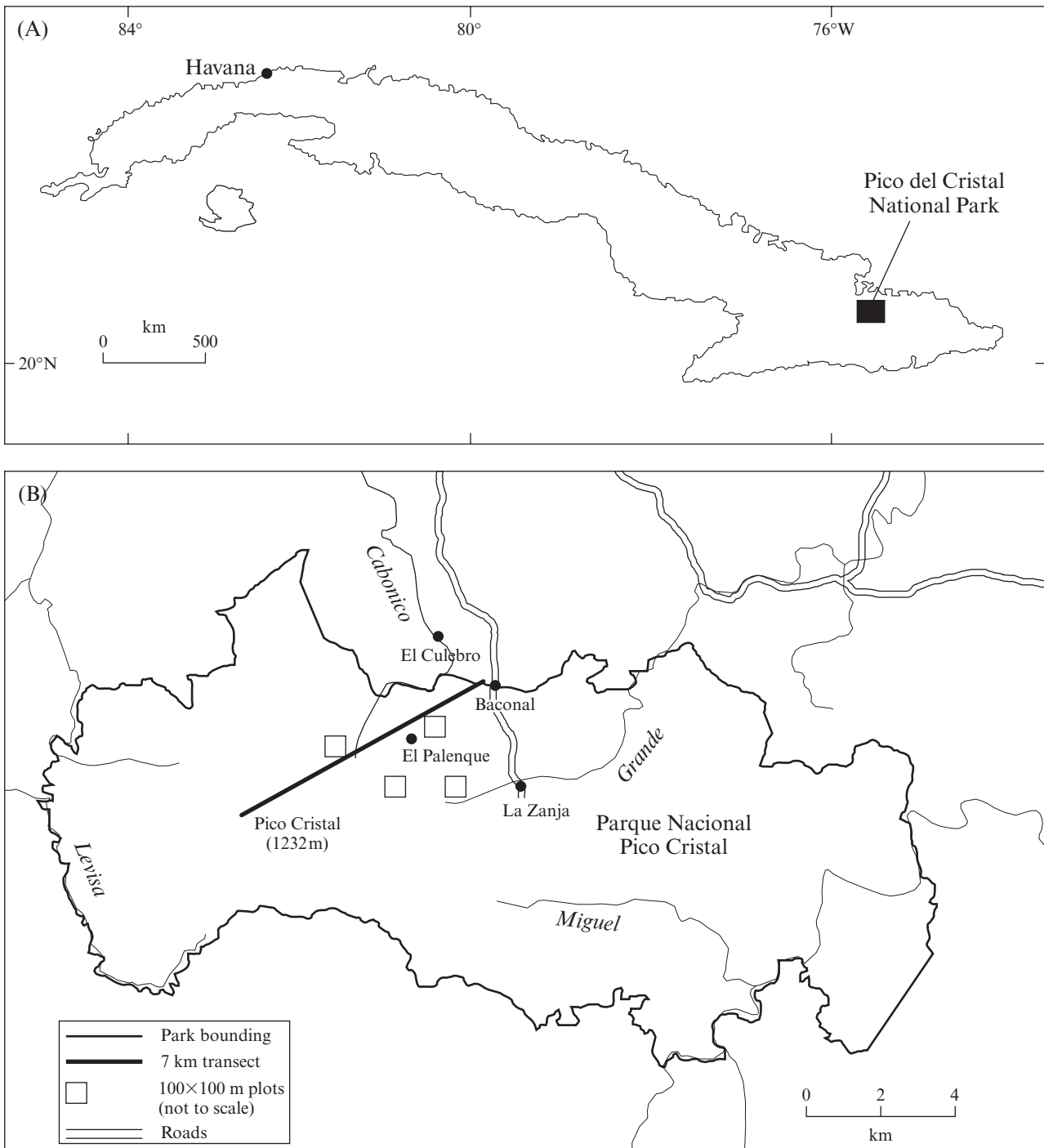


Fig. 1 (A) Cuba, illustrating the location of the Sierra del Cristal National Park, and (B) detail of the study area with localities mentioned in the text, the 7 km transect and four 100 × 100 m plots used for the flora survey, and major rivers.

ecological planning process and field studies. The workshop consisted of instruction and discussion around principles of conservation biology and conservation project management. Aerial photographs were used to

identify the main vegetation types within the study area. Fieldwork was undertaken during August-September and November-December 1998, in an area of 48 km². We undertook habitat inventories, including plant species

collection and vegetation community analyses, and conducted surveys for the presence of selected animal groups – spiders, molluscs, and terrestrial vertebrates (amphibians, reptiles, birds and mammals) – in three of the four vegetation types (evergreen, montane and scrub forest). The team comprised three botanists, six zoologists and five field assistants.

We set up a 7 km transect covering the representative habitats of the area, and collected plants at 21 points between 370 and 600 m altitude (Fig. 1). We also surveyed four 100 × 100 m plots to describe the vegetation in more detail.

Spiders were sampled daily throughout the study period using sweep netting and collection of individuals in the tree, shrub and ground vegetation layers. Some sporadic night-time sampling was also carried out. Terrestrial molluscs were sampled daily, from trees, shrubs and ground layers.

Extensive searching for amphibians was undertaken throughout the study area every day and night using standard techniques (Jones, 1986; Heyer *et al.*, 1994). Frogs were located at night by inspecting suitable sites with the aid of flashlights, and by listening to advertisement calls of vocally active species. Microhabitats that are known to be diurnal refuges for anurans, such as epiphytes, fallen logs, loose bark, tree buttresses and rock crevices, were extensively searched during the day. Reptile species were recorded along two line transects (250 × 4 m) per habitat, i.e. a total of eight transects. All counts were carried out during 08.00–12.00.

Birds were surveyed using general searching, point counts, and mist netting (Bibby *et al.*, 1992). Sixty point counts were made in total, during the morning or afternoon, at intervals of 100–150 m along trails in montane, evergreen and scrub forest. On each 10-min count all birds heard or seen were recorded.

Trap-lines for mammals were set within 11 sites in montane forest. In each line 100 Tomahawk single door live traps (82 × 23 × 23 cm) were placed at 10 m intervals. Tinned sardines were used as bait. Each line was operated for 5–10 nights for a total of 1,477 trap-nights.

Results

A total of 220 species of plants (Appendix 1), 53 species of spiders (Appendix 2), 28 species of molluscs (Appendix 3), 10 species of amphibians (Appendix 4), 19 species of reptiles (Appendix 5) and 51 species of birds (Appendix 6) was recorded (Table 1). Overall, the greatest number of species was found within montane forest, and the lowest in scrub forest, although there were differences in this respect between the various groups (Table 1). We recorded four bird species (*Accipiter gunlachi*, *Amazona leucocephala*, *Aratinga euops* and *Myadestes elisabeth*) and one mammal (*Solenodon cubanus*) that were listed as threatened in the 2000 IUCN Red List (Hilton-Taylor, 2000).

Of the vascular plant species recorded 86 (39%) are endemic, 130 (59%) are native species, and two are introduced taxa (1%) (Appendix 1). Differences between vegetation formations are structural as well as compositional, and plant communities above 600 m have poorly developed lower canopy and understorey.

Amongst the spiders (Appendix 2), two individuals of the family Hahniidae were discovered, which were new records for Cuba (Avila Calvo, 2000). In both cases only females were found, which made it impossible to identify the species. Amongst the molluscs (Appendix 3), *Coryda*, *Emoda* and *Veronicella* were the most common genera in montane forest, while *Subulina*, *Obeliscus*, *Coryda* and *Caracolus* were the most common genera in

Table 1 Number of species, endemic species (%), species in the three vegetation types, and species on the 2000 IUCN Red List (Hilton-Taylor, 2000) recorded in the seven taxonomic groups surveyed in the Sierra del Cristal, Cuba. For further details, see text and Appendices 1–6.

Taxonomic group	Appendix	No. species recorded	No. endemic species (%)	No. species in each vegetation type			No. Red List species
				Evergreen forest	Montane forest	Scrub forest	
Vascular plants	1	220	86 (39)	65	134	20	0
Spiders	2	53	4 (8)	31	18	24	0
Molluscs	3	28	14 (50)	20	20	4	0
Amphibians	4	10	9 (90)	7	6	0	0
Reptiles	5	19	11 (58)	9	15	6	0
Birds	6	51	10 (20)	46	37	15	4
Mammals		3	1 (33)	2	3	2	1
Total		384	135 (35)	181	231	72	5

evergreen forest. Molluscs were scarce in scrub forest, where only the genera *Emoda*, *Caracolus* and *Coryda* were recorded. The endemic freshwater mollusc *Pachylus nigratus* was recorded in the Río Cabonico, and a new species of slug *Veronicella* sp. was discovered in montane forest.

Amongst the amphibians (Appendix 4), an unrecognized species of *Eleutherodactylus*, possibly a new species of the subgenus *Euhyas*, was discovered close to human habitation. No evidence was found of the introduced American bullfrog *Rana catesbeiana*, which is otherwise present throughout Cuba.

We recorded eight species of bird in addition to those reported from the only other bird study in Sierra del Cristal (Abreu *et al.*, 1989). Three endemic genera (*Teretistris*, *Priotelus* and *Xiphidiopicus*) and 10 endemic species were recorded; i.e. 67% of all Cuban endemic bird species. The most abundant species (Appendix 6) were the Cuban emerald *Chlorostilbon ricardii*, Cuban bullfinch *Melopyrrha nigra*, Cuban solitaire *Myadestes elisabeth* (categorized as Lower Risk, near threatened on the IUCN Red List; Hilton-Taylor, 2000), Oriente warbler *Teretistris fornsi*, Cuban crow *Corvus nasicus* and Red-legged thrush *Turdus plumbeus*. The Cuban parrot *Amazona leucocephala*, categorized as Lower Risk, near threatened on the IUCN Red List (Hilton-Taylor, 2000), appeared to be common in the area, with flocks of up to 24 individuals observed regularly. The Cuban parakeet *Aratinga euops*, categorized as Vulnerable on the IUCN Red List (Hilton-Taylor, 2000), was less abundant, with only two flocks, of 17 and 11 individuals, recorded.

Three species of mammals were trapped in montane forest: one Cuban solenodon *Solenodon cubanus*, 15 black rats *Rattus rattus*, and one feral cat *Felis catus*. Rats were active during the daytime and were observed taking the bait from traps without springing them; the number trapped is therefore not representative of the numbers present. Black rats and feral cats were also observed in evergreen and scrub forest.

Discussion

Although there have been some studies of the wildlife of Sierra del Cristal (Abreu *et al.*, 1989) this is the first detailed biodiversity survey of the area. Our work has indicated that substantial areas of natural habitat still exist in the region, and that within the Eastern Highlands the forest of Sierra del Cristal is important because of both its extent and the relatively low level of human disturbance. The region has been protected for over 70 years and is not currently subject to major pressures of deforestation or wildlife extraction. Our results demonstrated the importance of the area as a reservoir for

species that are restricted to montane habitats in Cuba, and for endemic species, which made up 35% of the total recorded. Amongst the groups surveyed, endemism of molluscs, amphibians and reptiles was particularly high (Table 1).

Together with the Philippines, Cuba is an important global centre of molluscan evolution (de la Torre & Bartsch, 1938), with 1,405 species so far described, and Cuba has the highest species richness of reptiles in the Caribbean (Estrada & Ruibal, 1999). Eastern Cuba is a refuge for a number of important mammal species, especially the solenodon (Barbour, 1944; Abreu *et al.*, 1989; Woods & Eisenberg, 1989), and this species could be used as a flagship species (Entwistle, 2000; Bowen-Jones & Entwistle, 2002) for furthering conservation efforts in the region. The solenodons are a relict family of primitive insectivores, currently surviving only in Cuba and Hispaniola (MacFadden, 1980). Claims have been made that the species is declining (Varona, 1980) and its range contracting, but this is as yet unconfirmed.

As on many islands throughout the world, the black rat has become firmly established, and its interference was a major problem during trapping for mammals. Black rats have been linked to the extinction or decline of avian and reptile species through predation of eggs, nestlings and juveniles, and the rats are potential competitors with ground mammals (Atkinson, 1985).

Local inhabitants confirmed the presence of feral dogs and feral pigs, but we found no direct evidence of either species in the areas that we surveyed. Despite reports that the small Indian mongoose *Herpestes javanicus* is widespread in Cuba, as on other Caribbean islands (Pimentel, 1955; Nellis & Everand, 1983), no evidence of its presence was found in Sierra del Cristal, and some residents claim that the species does not occur (Varona, 1983).

We did not survey the bats of the region, but Abreu *et al.* (1989) reported three bat species, *Artibeus jamaicensis*, *Macrotus waterhousei*, and *Molossus molossus* in the area. Studies of chiropteran diversity need to be undertaken. Abreu *et al.* (1989) also documented the presence of the hutias *Capromys pilorides*, *C. prehensilis*, *C. melanurus* and *C. arboricolous*. We found faecal deposits of *C. pilorides*, and one individual of *C. melanurus* was seen in the evergreen forest. Our lack of success in catching or observing hutias could be an indication of their low numbers. All hutia species in the area have been extensively hunted, especially in the lowland areas.

ENPFF is now carrying out further studies on vegetation ecology in the area, and more detailed research on the fauna. We recommend that further studies of the distribution, abundance and ecology of Red List species, such as the solenodon, are undertaken both within the study area and in other regions of

eastern Cuba. A full assessment of the Red List status of all species is also required, especially for the endemic species. The potential impact of black rats on birds and the solenodon requires attention and further study. Successful conservation of the biota within the Sierra del Cristal area requires that the National Park guards be supported, and both national and visiting scientists be encouraged to train and mentor students. Information gathered during this study will form the basis for developing long-term management plans for habitats and resident species, in conjunction with the authorities responsible for environmental conservation.

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Appendices 1–6

The appendices for this article are available online at <http://journals.cambridge.org>

Biographical sketches

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Appendix 1

Species of vascular plant recorded in Sierra del Cristal, Cuba.

Family	Species	Family	Species
Acanthaceae	<i>Oplonia</i> sp.	Blechnaceae	<i>Blechnum fragile</i>
Annonaceae	^E <i>Annona cristalensis</i> <i>Guatteria blainii</i> <i>Guatteria</i> sp.	Boraginaceae	<i>Cordia</i> sp. <i>Ehretia tinifolia</i>
Apocynaceae	<i>Asketanthera fischeri</i> ^E <i>Forsteronia corymbosa</i> ^E <i>Neobrassa valenzuelana</i> ^E <i>Plumeria filifolia</i> <i>Plumeria obtuse</i> ^E <i>Rauwolfia salicifolia</i>	Bromeliaceae	<i>Catopsis</i> sp. ^E <i>Pitcairnia cubensis</i> <i>Tillandsia balbisiana</i> <i>Tillandsia bulbosa</i> <i>Tillandsia valenzuelana</i> <i>Vriesea</i> sp.
Aquifoliaceae	<i>Ilex macfadyenii</i> <i>Ilex repanda</i>	Buxaceae	^E <i>Buxus marginalis</i>
Araceae	<i>Philodendron lacerum</i> <i>Philodendron</i> sp.	Caesalpiniaceae	^E <i>Senna gundlachii gundlachii</i>
Araliaceae	<i>Dendropanax arboreus</i> ^E <i>Dendropanax nervosus</i> <i>Schefflera morototoni</i>	Campanulaceae	<i>Lobelia</i> sp.
Arecaceae	^E <i>Bactris cubensis</i> <i>Calyptrotona</i> sp. <i>Coccothrinax</i> sp.	Celastraceae	<i>Torrabasia cuneifolia</i>
Asclepiadaceae	^E <i>Matelea bayatensis</i> ^E <i>Matelea bicolor</i>	Chloranthaceae	^E <i>Hedyosmum grisebachii</i>
Asteraceae	^E <i>Baccharis scoparioides</i> ^E <i>Grisebachianthus lantanifolius</i> <i>Koanophyllon polystictum</i> <i>Koanophyllon villosum</i> <i>Mikania</i> sp. ^E <i>Senecio pachylepis</i> <i>Senecio plumbeus</i> ^E <i>Senecio rivalis</i> ^E <i>Spaniopappus hygrophilus</i> ^E <i>Vernonia aceratoides</i> ^E <i>Vernonia cubensis</i> ^E <i>Vernonia hieracioides</i> ^E <i>Vernonia sagraeana</i> ^E <i>Vernonia segregata</i> <i>Vernonia</i> sp.	Chrysobalanaceae	<i>Hirtella triandra</i> ^E <i>Calophyllum utile</i>
Bignoniaceae	^E <i>Jacaranda arborea</i> <i>Tabebuia caleticana</i> ^E <i>Tabebuia dubia</i> ^E <i>Tabebuia pachyphylla</i> ^E <i>Tabebuia shaferi</i> <i>Tabebuia</i> sp.	Clusiaceae	^E <i>Clusia callosa</i> ^E <i>Clusia grisebachiana</i> <i>Clusia minor</i> <i>Clusia rosea</i> ^E <i>Gracinia moaensis</i>
		Combretaceae	<i>Buchenavia tetraphylla</i> ^E <i>Terminalia orientensis</i> <i>Terminalia</i> sp.
		Convolvulaceae	<i>Ipomoea carolina</i> <i>Ipomoea</i> sp.
		Cyatheaceae	<i>Cnemidaria horrida</i> <i>Cyathea arborea</i> <i>Cyathea parvula</i>
		Cyperaceae	^E <i>Machaerina cubensis</i> <i>Rhynchospora pruinosa pruinosa</i>
		Cyrillaceae	<i>Cyrilla nipensis</i> <i>Cyrilla racemiflora</i> <i>Purdiaea</i> sp.
		Dennstaedtiaceae	<i>Odontosoria scandens</i> <i>Odontosoria</i> sp.
		Dilleniaceae	<i>Doliocarpus dentatus</i>
		Dioscoreaceae	<i>Dioscorea</i> sp.
		Dryopteridaceae	<i>Polystichum echinatum</i>
		Elaeocarpaceae	<i>Sloanea amygdalina</i>
		Ericaceae	^E <i>Lyonia glandulosa</i> var <i>revolutifolia</i> ^E <i>Lyonia myrsinefolia</i> ^E <i>Vaccinium shaferi</i>

Appendix 1 continued

Family	Species	Family	Species
Erythroxylaceae	^E <i>Erythroxylum coriaceum</i> ^E <i>Erythroxylum longipes</i> <i>Erythroxylum</i> sp.	Myrsinaceae	<i>Myrsine coriacea</i> <i>Myrsine cubana</i>
Euphobiaceae	<i>Ditita myricoides</i> <i>Drypetes serrata</i> ^E <i>Euphorbia helenae helenae</i> <i>Gymnanthes albicans</i> ^E <i>Hyeronima ovata</i> ^E <i>Leucocroton obovatus</i> <i>Mettenia acutifolia</i> ^E <i>Moacrotroton gynopetalus</i> <i>Moacrotroton trigonocarpus</i> <i>Pera ovalifolia</i> <i>Phyllanthus juglandifolius</i> <i>juglandifolius</i> ^E <i>Phyllanthus microdictyus</i> ^E <i>Platygyne hexandra</i> ^E <i>Sapium cubense</i> ^E <i>Savia cuneifolia</i>	Myrtaceae	<i>Calycolpus</i> sp. ^E <i>Eugenia scaphophylla</i> <i>Guapira rufescens</i> ^E <i>Ouratea revolute</i> <i>Ouratea striata</i> <i>Chionanthus domingensis</i>
Fabaceae	^E <i>Brya subinermis</i> <i>Desmodium incanum</i> var <i>incanum</i> <i>Teramnus uncinatus</i>	Nyctaginaceae	<i>Epidendrum jamaicense</i> <i>Oeceoclades maculata</i> <i>Phaius tankervilleae</i> ^E <i>Pleurothallis bovilabia</i> <i>Polystachya concreta</i> <i>Vanilla dilloniana</i> <i>Vanilla wrightii</i>
Flacourtiaceae	^E <i>Casearia sylvestris</i> var <i>myricoides</i> ^E <i>Lunania cubensis</i>	Ochnaceae	<i>Passiflora rubra</i> <i>Passiflora</i> sp. <i>Passiflora suberosa</i> <i>Passiflora tulae</i>
Gentianaceae	^E <i>Macrocarpaea pauciflora</i>	Oleaceae	<i>Peperomia guadalupensis</i> <i>Peperomia hernandiifolia</i> ^E <i>Piper wrightii</i>
Gesneriaceae	^E <i>Gesneria duchartreoides</i> <i>Gesneria</i> sp.	Orchidaceae	^E <i>Arthrostylidium fimbriatum</i> <i>Pharus lappulaceus</i> ^E <i>Podocarpus angustifolius</i> <i>Podocarpus aristulatus</i> <i>Securidaca virgata</i> ^E <i>Coccoloba caesia</i> <i>Coccoloba costata</i> <i>Coccoloba diversifolia</i> ^E <i>Coccoloba retusa</i> ^E <i>Coccoloba shaferi</i> <i>Coccoloba</i> sp.
Gleicheniaceae	<i>Dicranopteris flexuosa</i>	Podocarpaceae	<i>Pteridium aquilinum</i> <i>Thelypteris londiodes</i>
Hymenophyllaceae	<i>Hymenophyllum</i> sp. <i>Trichomanes scandens</i>	Polygalaceae	^E <i>Colubrina glandulosa nipensis</i> ^E <i>Rhamnidium nipense</i> ^E <i>Rhamnidium shaferi</i> <i>Prunus occidentalis</i> ^E <i>Antirhea maestrensis</i> ^E <i>Antirhea scrobiculata</i> <i>Chiococca alba</i> ^E <i>Chiococca cubensis</i> <i>Coccocypselum herbaceum</i> ^E <i>Exostema rotundatum</i> <i>Lasianthus lanceolatus</i> ^E <i>Machaonia microphylla</i> <i>Psychotria berteriana</i> <i>Psychotria cuspidate</i> ^E <i>Psychotria ossaena</i> <i>Psychotria revolute</i> <i>Psychotria</i> sp. <i>Schradera cephalophora</i> ^E <i>Suberanthus canellifolius</i> ^E <i>Helietta glaucenscens</i> <i>Spathelia</i> sp. <i>Zanthoxylum</i> sp.
Lauraceae	<i>Ocotea foeniculacea</i> <i>Ocotea leucoxydon</i> <i>Ocotea nemodaphne</i>	Polygonaceae	
Liqceae	<i>Cladonia</i> sp. <i>Usnea barbata</i>	Polyodiaceae	
Lomariopsidaceae	<i>Elaphoglossum wrightii</i>	Rhamnaceae	
Lycopodiaceae	<i>Lycopodium</i> sp.	Rosaceae	
Magnoliaceae	^E <i>Talauma minor oblongifolia</i>	Rubiaceae	
Malpighiaceae	^E <i>Byrsonima biflora</i> <i>Byrsonima coriacea</i> ^E <i>Byrsonima orientensis</i> <i>Byrsonima</i> sp. <i>Stigmaphyllon sagraeanum</i> <i>Triopteris rigida</i>		
Malvaceae	<i>Pavonia fruticosa</i>		
Marattiaceae	<i>Danaea elliptica</i>		
Marcgraviaceae	^E <i>Marcgravia evenia</i>		
Melastomataceae	<i>Calycogonium</i> sp. <i>Mecranium purpurascens</i> <i>Mecranium</i> sp. ^E <i>Miconia baracoensis</i> <i>Miconia dodecandra</i> <i>Miconia prasina</i> <i>Ossaea</i> sp.		
Moraceae	<i>Cecropia schreberiana</i> <i>Ficus</i> sp.		

Appendix 1 continued

Family	Species	Family	Species
Sapindaceae	^E <i>Allophylus cristalensis</i>	Solanaceae	<i>Cestrum laurifolium</i>
	<i>Matayba domingensis</i>		<i>Solandra</i> sp.
	<i>Matayba oppositifolia</i>		^E <i>Solanum moense</i>
Sapotaceae	<i>Serjania diversifolia</i>	Theaceae	^E <i>Laplacea cristalensis</i>
	<i>Chrysophyllum</i> sp.		^E <i>Laplacea moaensis</i>
	^E <i>Manilkara jaimiqui jaimiqui</i>	Ulmaceae	<i>Trema micrantha</i> var <i>mollis</i>
	^E <i>Micropholis polita</i>		Verbenaceae
^E <i>Sideroxylon jubilla</i>	Zingiberaceae	^E <i>Clerodendrum anafense</i>	
Schizaeaceae		<i>Anemia coriacea</i>	<i>Clerodendrum</i> sp.
		<i>Lygodium oligostachyum</i>	^E <i>Renealmia amoena</i>
Smilacaceae	<i>Smilax balbisiana</i>		

^E Endemic species

Appendix 2

Species of spider recorded in Sierra del Cristal, Cuba, with their occurrence in evergreen, montane and scrub forest.

Family	Species	Habitat type		
		Evergreen forest	Montane forest	Scrub forest
Barychelidae	^E <i>Trichopelma cubana</i>	X		
Dipluridae	^E <i>Ischmothele longicauda</i>	X		X
Theraphosidae	<i>Citharacanthus</i> sp.		X	
Anyphaenidae	<i>Hibana velox</i>		X	X
	<i>Wulfila longipes</i>		X	
Araneidae	<i>Araneus pegnia</i>		X	X
	<i>Argiope argentata</i>	X		X
Araneidae	<i>Cyclosa walckenaeri</i>	X	X	
	<i>Cyrtophora nympha</i>	X	X	
	<i>Eriophora ravilla</i>	X	X	
	^E <i>Micrathena cubana</i>		X	
	<i>Micrathena horrida</i>		X	
	<i>Micrathena militaris</i>	X		
	<i>Verrucosa arenata</i>			X
Clubionidae	<i>Clubiona</i> sp.			X
Ctenidae	<i>Ctenus vernalis</i>	X	X	X
Dinopidae	<i>Dinopis lamia</i>	X		
Gnaphosidae	Unidentified species			
Hahniidae	<i>Hahnia ernesti?</i>			X
Heteropodidae	<i>Heteropoda venatoria</i>	X		
Lycosidae	<i>Lycosa fusca</i>	X		X
Linyphiidae	<i>Frontinella</i> sp.	X		
Ochyroceratidae	<i>Theotima</i> sp.	X		
Oonopidae	<i>Heteronops</i> sp.	X		
	<i>Oonops cubanus</i>	X		
Oxyopidae	<i>Peucetia viridans</i>			X
Pholcidae	<i>Bryantina cubana</i>	X	X	
	<i>Modisimos</i> sp.	X	X	
	<i>Physocyclus globosus</i>	X		X
Pisauridae	<i>Dolomedes triton</i>	X		
Salticidae	<i>Corythalis aurata</i>	X	X	X
	<i>Hentzia antillana</i>			X
	<i>Lyssomanes antillanus</i>	X		X
	<i>Sarinda</i> sp.			X
Scytodidae	<i>Synemosina smithi</i>			X
	<i>Scytodes fusca</i>			X
	<i>Scytodes longipes</i>	X		
	<i>Scytodes</i> sp.	X		

Appendix 2 continued

Family	Species	Habitat type		
		Evergreen forest	Montane forest	Scrub forest
Selenopidae	<i>Selenops aequalis</i>	X		X
Tetragnathidae	<i>Leucauge regny</i>	X	X	X
	<i>Alcimosphenus licinus</i>	X		X
	<i>Nephila clavipes</i>		X	
Theridiidae	<i>Tetragnatha elongata</i>	X		
	<i>Argyrodes elevatus</i>		X	
	<i>Argyrodes mexicanus</i>	X		
	<i>Latrodectus mactans</i>			X
	<i>Steatoda erigoniformis</i>			X
Theridiosomatidae	<i>Theridion rufipes</i>			X
	<i>Wemdigarda clara</i>		X	
	<i>Misumenops</i> sp.			X
Thomisidae	^E <i>Miagrammopes cubanus</i>	X		
Uloboridae	<i>Philoponella semiplumosa</i>	X		
	<i>Uloborus glomosus</i>	X		

^E Endemic species**Appendix 3**

Species of terrestrial (with one exception, indicated) mollusc recorded in Sierra del Cristal, Cuba, with the number of localities in which each species was recorded, and their occurrence in evergreen, montane and scrub forest.

Family	Species	No. of localities	Habitat type		
			Evergreen forest	Montane forest	Scrub forest
Helicinidae	^E <i>Helicina</i> sp.	3		X	
	^E <i>Emoda caledoniensis</i>	5		X	X
	<i>Emoda submarginata</i>	6	X	X	X
	^E <i>Lucidella granullum</i>	5		X	
	<i>Alcacia minima</i>	2		X	
	^E <i>Alcacia neebiana</i>	1		X	
	^E <i>Ceratodiscus</i> sp.	7	X	X	
Cyclophoridae	^E <i>Crociodopoma</i> sp.	3	X		
Annulariidae	^E <i>Chondropoma</i> sp.	9		X	
Veronicellidae	<i>Veronicella cubensis</i>	8	X	X	
	^E <i>Veronicella</i> sp.	3		X	
Helminthoglyptidae	^E <i>Coryda alauda</i>	14	X	X	X
	<i>Plagyopticha</i> sp.	13	X	X	
	^E <i>Cysticopsis</i> sp.	9	X	X	
Sagdidae	<i>Hojeda boothiana</i>	11	X	X	
	Unidentified species	10	X	X	
Zonitidae	<i>Hawaiia</i> sp.	1	X		
	<i>Guppya gundlachi</i>	5	X	X	
Pleuroceriidae	<i>Pachychilus nigratus</i>	1	X (aquatic)		
Camaenidae	^E <i>Zachrysia</i> sp.	4		X	
	^E <i>Caracolus sagemon</i>	9	X	X	X
Succineidae	<i>Succinea</i> sp.	3	X		
Subulinidae	<i>Obeliscus</i> sp.	15	X	X	
	^E <i>Obeliscus</i> sp.	4	X		
	<i>Subulina octona</i>	4	X		
	<i>Opeas pumillum</i>	1	X		
Oleacinidae	<i>Oleacina solidula</i>	8	X	X	
	<i>Oleacina straminea</i>	1	X		

^E Endemic species

Appendix 4

Species of amphibian collected in Sierra del Cristal, Cuba, with the number of individuals found of each species and whether or not vocalizations were recorded.

Family	Species	No. of individuals	Vocalizations recorded
Hylidae	<i>Osteopilus septentrionalis</i>	2	
Bufonidae	^E <i>Bufo taladai</i>	4	X
Leptodactylidae	^E <i>Eleutherodactylus atkinsi</i>	16	X
	^E <i>Eleutherodactylus auriculatus</i>	12	X
	^E <i>Eleutherodactylus dimidiatus</i>	6	
	^E <i>Eleutherodactylus ionthus</i>	1	X
	^E <i>Eleutherodactylus cuneatus</i>	16	X
	^E <i>Eleutherodactylus limbatus</i>	2	
	^E <i>Eleutherodactylus</i> sp. nov.	10	X
	^E <i>Eleutherodactylus varleyi</i>	4	X

^E Endemic species

Appendix 5

Species of reptile collected in Sierra del Cristal, Cuba, with their occurrence in evergreen, montane and scrub forest.

Family	Species	Habitat type		
		Evergreen forest	Montane forest	Scrub forest
Anguidae	^E <i>Diploglossus delasagra</i>		X	
Gekkonidae	<i>Sphaerodactylus celicelicara</i>	X		
Polychrotidae	<i>Anolis angusticeps</i>		X	
	^E <i>Anolis allogus</i>	X	X	
	^E <i>Anolis alutaceus</i>	X	X	
	^E <i>Anolis argenteolus</i>	X	X	
	<i>Anolis homolechis</i>			X
	^E <i>Anolis isolepis</i>		X	X
	^E <i>Anolis porcatus</i>	X	X	X
	<i>Anolis sagrei</i>	X	X	X
	^E <i>Anolis</i> sp.nov. (c.f. <i>alutaceus</i>)		X	
	<i>Anolis smallwoodi?</i>		X	
Tropiduridae	^E <i>Leiocephalus macropus</i>		X	X
	^E <i>Leiocephalus cubensis</i>	X		
Teiidae	<i>Ameiva auberi</i>		X	X
Colubridae	<i>Alsophis cantherigerus</i>		X	
	^E <i>Antillophis andreae</i>	X	X	
Tropidophidae	^E <i>Tropidophis melanurus</i>	X		
Typhlopsidae	<i>Typhlops lumbricalis</i>		X	

^E Endemic species

Appendix 6

Species of bird collected in Sierra del Cristal, Cuba, with their status, and occurrence in evergreen, montane and scrub forest.

Family	Species	Status	Habitat type		
			Evergreen forest	Montane forest	Scrub forest
Ardeidae	<i>Bubulcus ibis</i>	S	X		
	<i>Nyctanassa violacea</i>	C	X		
Cathartidae	<i>Cathartes aura</i>	C	X	X	X
Accipitridae	<i>Accipiter striatus</i>	R		X	
	^E <i>Accipiter gundlachi</i>	C	X	X	
	<i>Buteo platypterus</i>		X	X	
	<i>Buteo jamaicensis</i>	C	X	X	X
Falconidae	<i>Falco sparverius</i>	R	X		
Aramidae	<i>Aramus guarana</i>	C	X		
Columbidae	<i>Columba squamosa</i>	S	X	X	X
	<i>Zenaida asiatica</i>	C	X		
	<i>Geotrygon caniceps</i>	R		X	
	<i>Geotrygon montana</i>	S	X	X	
Psittacidae	<i>Amazona leucocephala</i>	S	X	X	
	^E <i>Araucaria euops</i>	S	X	X	
Cuculidae	<i>Sauromera merlini</i>	C	X	X	X
	<i>Crotophaga ani</i>	C	X		
Strigidae	<i>Tyto alba</i>	S		X	
	^E <i>Otus lawrencii</i>	S	X	X	
	^E <i>Glaucidium siju</i>	C	X	X	
	<i>Asio stygius</i>	R	X	X	
Apodidae	<i>Cypseloides niger</i>	R		X	
Trochilidae	<i>Chlorostilbon ricordii</i>	C	X	X	X
Trogonidae	^E <i>Priotelus temmurus</i>	C	X	X	X
Todidae	^E <i>Todus multicolour</i>	C	X	X	X
Alcedinidae	<i>Ceryle alcyon</i>	R	X		
Picidae	<i>Sphyrapicus varius</i>	S		X	
	^E <i>Xiphidiopicus percussus</i>	C	X	X	
	<i>Colaptes auratus</i>	C	X	X	
Tyrannidae	<i>Contopus caribaea</i>	C	X	X	X
	<i>Myiarchus sagrae</i>	S	X		
	<i>Tyrannus caudifasciatus</i>	C	X	X	X
Corvidae	<i>Corvus nasicus</i>	C	X	X	
Muscicapidae	^E <i>Myadestes elisabeth</i>	C	X	X	
	<i>Turdus plumbeus</i>	C	X	X	X
Emberizidae	<i>Parula americana</i>	C	X	X	
	<i>Dendroica tigrina</i>	S	X		
	<i>Dendroica caerulescens</i>	C	X	X	X
	<i>Dendroica dominica</i>	S	X		
	<i>Mniotilta varia</i>	C	X	X	
	<i>Setophaga ruticilla</i>	C	X	X	X
	<i>Seiurus aurocapillus</i>	S	X	X	
	<i>Seiurus motacilla</i>	C	X	X	
	^E <i>Teretistris fornsi</i>	C	X	X	X
	<i>Cyanerpes cyaneus</i>	R	X		
	<i>Spindalis zena</i>	R	X		
	<i>Melopyrrha nigra</i>	C	X	X	X
	<i>Tiaris olivacea</i>	C	X	X	X
	Icteridae	^E <i>Dives atrovioleacea</i>	C	X	
<i>Quiscalus niger</i>		C	X	X	
<i>Icterus dominicensis</i>		C	X		

^E Endemic species

Status: C common, S seasonal migrant, R rare.