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Complementary areas for conserving avian diversity on Hispaniola

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Abstract

Hispaniola has been identified as a global priority for avian conservation. However, little quantitative information has been available to help guide optimal strategies for conservation action on the island. Here, the first broad-scale look has been assembled of the distribution of species of conservation concern among protected areas in Haiti and the Dominican Republic and their occurrences have been analysed to determine where conservation activities might be focused to serve avian conservation interests. An iterative, heuristic complementarity approach was used, such that the most highly ranked reserve is that which protects the greatest number of species of conservation concern and subsequently ranked reserves are those that add the most species of conservation concern that are not included in the first reserve. Parks are prioritised by the presence/absence of species of concern and prioritised a second time with individual species first being weighted by species-specific extinction risks and then by uniqueness in terms of endemism at the island or regional level. Parks of highest importance are the Sierra de Bahoruco National Park and Jaragua National Park, but the importance of other protected areas to avian conservation is also documented and discussed.

INTRODUCTION

The island of Hispaniola (48 442 km^2) supports more bird species than any other Caribbean island except Cuba. Of the more than 300 species of birds recorded on the island (Keith *et al*., 2003), 285 are native residents (Ottenwalder, 2000). With as many as 30 species considered endemic (Raffaele *et al*., 1998; Keith *et al*., 2003), birds have a 10.5% rate of endemism on the island. The island's two nations, Haiti and the Dominican Republic, contain 16 species considered by BirdLife International (2000) to be vulnerable or threatened with extinction, six species that are considered to be near-threatened, as well as important habitat for many more species of conservation concern nationally (SEA/DVS, 1990; Latta & Lorenzo, 2000) and internationally (NAS, 2002; USFWS, 2002). In addition to permanent resident species, the Dominican Republic harbours a large percentage of the wintering populations of many North American breeding birds, e.g. at least 17 species of wood warblers winter in significant numbers in the country (Wunderle & Waide, 1993; Keith *et al*., 2003).

Hispaniola's contribution to global biodiversity has earned the island the highest ranking of importance in a worldwide assessment of protection priorities (Stattersfield *et al*., 1998). Although several habitats of Hispaniola are vital to the survival of many endemic and migrant bird species, their rate of loss is alarming. Haitian forests are almost entirely denuded (Paryski, Woods & Sergile, 1989; Ottenwalder, 2000) and conservation in Haiti is embryonic (Paryski *et al*., 1989; Keith *et al*., 2003). In the Dominican Republic recent estimates place forest loss at greater than 90% (FAO, 1991; Ottenwalder, 2000) and most currently forested areas are fragmented and under continuing heavy pressure. In response to this crisis, the Dominican government has created 40 protected areas under the national park system covering 13 164 km^2. Approximately 7915 km^2 or 16.2% of the country is designated as protected terrestrial ecosystems (Ottenwalder, 2000). The Directorate of National Parks (DNP) has management plans written for 10 national parks, of which six have been implemented (Ottenwalder, 2000). Out of the 40 protected areas, 24 have personnel; in addition, a number of non-governmental organisations assign personnel to parks under co-management agreements with the DNP. For example, Valle Nuevo is managed by Fundación Moscoso Puello and the Jaragua National Park is co-managed by Grupo Jaragua.

Because limited financial resources available for conservation often dictate that choices be made in the degree of attention provided to management units, efficiency in selecting priority areas for action is a requirement for the conservation of biodiversity (Ehrlich, 1992; Williams

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et al., 1996). One such method is the use of sets of complementary areas (Williams *et al*., 1996; Dobson *et al*., 1997; Komar, 2002), with areas selected on the basis of numbers of endangered species (Dobson *et al*., 1997), endemic species (Peterson, Ball & Brady, 2000), greatest combined species richness (Williams *et al*., 1996), or species-specific extinction risks (Root, Akçakaya & Ginzburg, 2003). Analyses of complementarity (Pressey, Possingham & Margules, 1996; Williams *et al*., 1996; Peterson *et al*., 2000; Komar, 2002) use an iterative approach that maximises otherwise unrepresented species among the species occurring in a set of protected areas (Vane-Wright, Humphries & Williams, 1991; Williams *et al*., 1996) in order to prioritise management units for conservation.

Here, an analysis is presented of complementary areas for conserving avian diversity in the Dominican Republic and Haiti. In this analysis, avian diversity is represented by those species that have appeared on lists nationally and internationally as endangered, threatened, or as species of special conservation concern. In addition, diversity is represented by species unique to the island or the region, including Hispaniolan endemic species or subspecies, and species that are endemic to the Caribbean Basin. Complementary areas are built for each of these criteria using presence/absence scores and scores indexed for a species' estimated threat of extinction and contribution to global diversity. Using results combined from these complementary analyses, protected areas are prioritised in terms of their importance to protecting avian biodiversity.

METHODS

Selection of parks

Thirteen national parks were selected for inclusion in the analysis (Table 1, Fig. 1) based on their geographical distribution, relatively large size and availability of bird species lists. Ten sites in the Dominican Republic covering $> 85\%$ of the total area of non-marine parks in the country were analysed (Table 1), including the Monte Cristi National Park, the twin parks of the Cordillera Central (Armando Bermúdez National Park and José del Carmen Ramírez National Park, hereafter treated as a single protected area), the Juan B. Pérez Rancier National Park (commonly referred to as Valle Nuevo), the Los Haitises National Park, the Parque del Este National Park, the Sierra de Neiba National Park, the Laguna de Cabral Scientific Reserve, the Sierra de Bahoruco National Park and the Jaragua National Park. In Haiti, there are only three national parks, all of which are included in this analysis: the Citadelle National Historic Park, the Pic Macaya National Park and the La Visite National Park.

Selection of species

Analyses presented here include all identified species of conservation concern. Species of conservation concern included (1) species or subspecies endemic to Hispaniola (Clements, 2000; Keith *et al*., 2003), or (2) species endemic to the Caribbean Basin (Clements, 2000; Keith *et al*., 2003). In addition, species of conservation concern included those considered to be threatened or endangered by (1) the Dominican Department of Wildlife (SEA/DVS, 1990), (2) the National Workshop on Avian Conservation (Latta & Lorenzo, 2000) or (3) BirdLife International (BirdLife International, 2000). Neotropical migratory birds wintering on Hispaniola and breeding residents with populations in North America, were also included as species of conservation concern if they were (1) wintering Neotropical migrants whose range is restricted primarily to the Caribbean Basin (Wunderle & Waide, 1994), (2) listed as a species of concern by the National Audubon Society (NAS, 2002) or (3) listed as a species of concern by the US Fish and Wildlife Service (USFWS, 2002). The NAS's '*WatchList 2002*' relies on 'objective, scientific analyses of trend, population size, and other factors,' including threats on both the breeding and wintering grounds, to assess threats to a species. The WatchList also reflects species of concern as identified by BirdLife International and Partners in Flight. The USFWS's '*Birds of Conservation Concern 2002*' identifies birds of the highest priority for conservation with the goal of focusing attention on species well in advance of the plausible need to consider their listing as threatened or endangered species.

The presence or absence of species at each national park was determined through published and unpublished records and consultation with local experts (Table 1). Species rarely recorded from a protected area were considered to be absent from the reserve since they were not likely to be a regular component of the local avifauna. The exception to this criterion for determining presence/absence was globally rare species that may not be commonly seen in any locale and so were considered present even if recorded infrequently at a site.

Analyses

Species' occurrences were counted for each protected area. Similarities among protected areas were summarised using Jaccard's similarity index (Magurran, 1988). Prioritisation of protected areas for conservation attention was carried out using an iterative, heuristic complementarity algorithim (Pressey *et al*., 1996; Williams *et al*., 1996; Peterson *et al*., 2000; Komar, 2002) to maximise the representation of sets of species. Complementarity refers to the degree to which a protected area contributes otherwise unrepresented species to a set of protected areas (Vane-Wright *et al*., 1991; Williams *et al*., 1996). The first reserve selected was the one that protected the greatest number of species of conservation concern. The second reserve selected was the one that added the most species of conservation concern that were not included in the first reserve. This step was then repeated until all reserves had been prioritised or no more species could be added. Ties were not broken by alternate measures and are reported as ties.

Table 1. The land area, elevational range, principal native habitat types and primary published sources of species-occurrence data for 12 protected areas of Hispaniola

			Major habitats represented									
Protected area	Area (km^2)	Elevation (m)	Salt lagoon	Fresh lagoon	Mangrove	Scrub	Dry forest	Karst	Humid broadleaf	Pine forest	Cloud forest	Principle data sources
DOMINICAN REPUBLIC												
Monte Cristi	561	0–239	X		X	X						Sociedad Ornitológica Hispaniola (unpublished results)
Cordillera Central	1530	1200–3175							X	X		Ottenwalder (1988)
Valle Nuevo	657	1000–2500							X	X	X	Núñez (2003)
Los Haitises	1375	0–50			X	X		X	X			Sociedad Ornitológica Hispaniola (unpublished results)
Parque del Este	430	0–70	X		X	X						Anderson (1980); Faaborg (1980)
Sierra de Neiba	407	900–2279							X	X	X	Rimmer *et al*. (1998), (2003)
Laguna de Cabral	240	20		X								Club de Observadores de Aves Annabelle Dod (1997), (1998)
Sierra de Bahoruco	800	300–2367							X	X	X	Klein *et al*. (1998); Latta (1998); Latta *et al*. (2003)
Jaragua	1374	0–234	X		X	X	X					Ottenwalder (1979), (1981); Faaborg (1980); Wiley & Ottenwalder (1990)
HAITI												
Citadelle	2.5	500–875				X	X					Woods & Ottenwalder (1983)
Pic Macaya	55	950–2347						X	X	X		Vuilleumier (1981); Woods & Ottenwalder (1983), (1986), (1992)
La Visite	20	1900–2268						X	X	X		Vuilleumier (1981); Woods & Ottenwalder (1983), (1986), (1992); Dávalos & Brooks (2001)

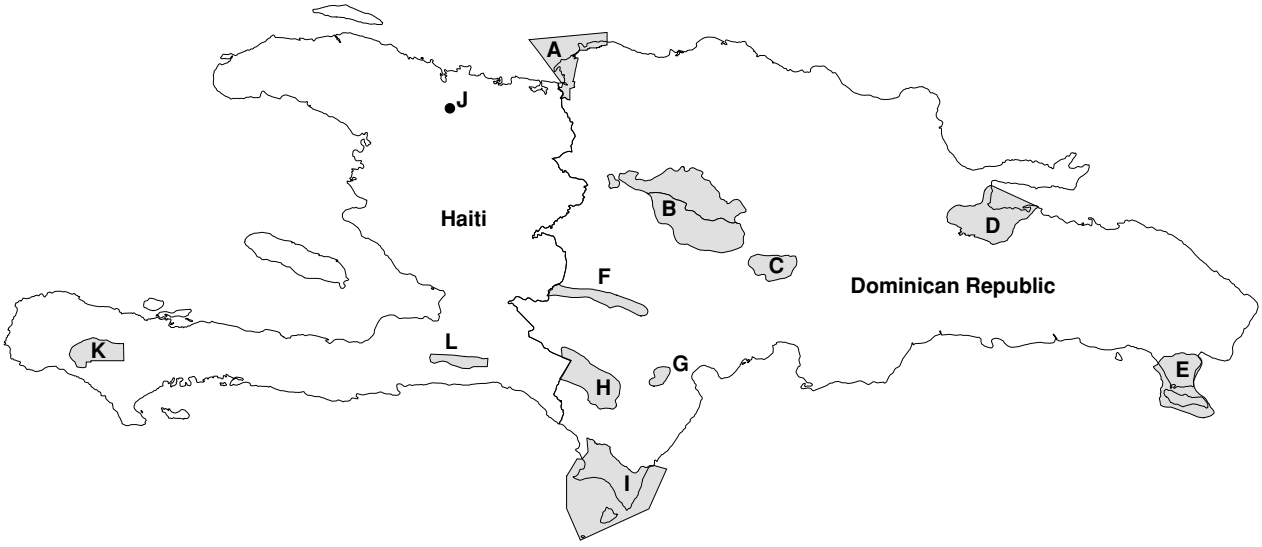

Fig. 1. Map of Hispaniola showing the location of 12 protected areas (composed of 13 national parks) in Haiti and the Dominican Republic: (A) Monte Cristi National Park, (B) parks of the Cordillera Central (including Armando Bermúdez National Park and José del Carmen Ramírez National Park), (C) Valle Nuevo or Juan B. Pérez Rancier National Park, (D) Los Haitises National Park, (E) Del Este National Park, (F) Sierra de Neiba National Park, (G) Laguna de Cabral Scientific Reserve, (H) Sierra de Bahoruco National Park, (I) Jaragua National Park, (J) Citadelle National Historic Park, (K) Pic Macaya National Park and (L) La Visite National Park.

Table 2. Threat and uniqueness categories and the integer values used as an estimate of the species' risk of extinction and the species' value in terms of global biodiversity, respectively

	Source	Value
	Threatened species	
Threat level		
Endangered or threatened	BirdLife International (2000) Latta & Lorenzo (2000)	3
Threatened	SEA/DVS (1990)	2
Species of concern	NAS (2002)	1.5
	USFWS (2002)	1.5
No specific threat		1
	Unique species	
Uniqueness category		
Island endemic	Keith *et al*. (2003)	2
Endemic subspecies	Keith *et al*. (2003) Clements (2000)	1.5
Caribbean endemic	Clements (2000)	1.5
Not a regional endemic		1

Parks were prioritised a second time and in a similar manner except that prior to the complementarity analysis individual species were weighted by species-specific extinction risks multiplied by their uniqueness in terms of endemism at the island or regional level (Root *et al*., 2003). The value of a particular protected area then reflects the importance and magnitude of the threats facing the species occurring in the reserve and the uniqueness of those species in terms of global biological diversity (Table 2). Thus, an integer value was assigned to each species based on the level of risk of extinction, such that species listed as endangered (BirdLife International, 2000; Latta & Lorenzo, 2000) received a risk value of 3, those listed as threatened (SEA/DVS, 1990) received a value of 2, species listed as meriting conservation concern (NAS, 2002; USFWS, 2002) received a risk value of 1.5, as did species classified as 'data-deficient' by BirdLife International (2000) since it was assumed that appearance on the BirdLife list was an indication that there was increased concern for the species. Those species that were not listed as at risk, but were considered species of conservation concern based on other criteria, were assigned a value of 1. Similarly, scoring was carried out to index unique species in terms of global biodiversity, so that more priority was given to the protected areas in which they reside (Table 2). Hispaniolan endemic species were assigned a value of 2 (Keith *et al*., 2003), Hispaniolan endemic subspecies and Caribbean endemics (Clements, 2000; Keith *et al*., 2003) were assigned a value of 1.5, while all other species were assigned a value of 1. Using this scoring system, species received an index score of 1–6, with the highest score received by island endemics, such as the Ridgway's hawk, *Buteo ridgwayi*, which also occur on lists of threatened or endangered species. Parks were then ranked, with the parks of highest conservation-priority being those with the highest total scores of those species present. Index scores for all species appear in the Appendix.

RESULTS

The distribution of 123 bird species among protected areas in Haiti and the Dominican Republic is summarised in the Appendix. Of these, 101 are breeding residents and 22 are winter-resident Neotropical migrants (Table 3). The highest number of breeding resident species was found in the Sierra de Bahoruco (55 species), followed by the Jaragua National Park (54 species) and the Parque del Este

Table 3. Taxonomic, abundance and residence status of birds inhabiting 12 protected areas of Hispaniola

Protected area	Total species ($n = 123$)	Hispaniolan endemic species ($n = 30$)	All endemic species and subspecies ($n = 67$)	Threatened/ endangered species ($n = 60$)	Resident breeders ($n = 101$)	Neotropical migrants ($n = 22$)
Parque del Este	69	12	30	29	54	15
Jaragua	68	11	31	31	54	14
Sierra de Bahoruco	64	26	50	30	55	9
Cordillera Central	53	22	40	20	45	8
Laguna de Cabral	53	6	21	18	39	14
Monte Cristi	51	8	23	23	44	7
Los Haitises	45	11	29	20	40	5
Pic Macaya	43	15	33	14	36	7
La Visite	42	19	33	16	36	6
Valle Nuevo	41	18	32	19	36	5
Sierra de Neiba	32	16	26	15	28	4
Citadelle	25	12	19	7	21	4

(54 species). Of the 22 species of non-breeding, winter residents, most were found at lower-elevation sites, including the Parque del Este (15 species), the Jaragua National Park (14 species) and the Laguna de Cabral (14 species). In contrast, most Hispaniolan endemic species occurred at higher elevations, such as the Sierra de Bahoruco (26 species), the Cordillera Central (22 species) and the La Visite (19 species). Similarly, when endemic subspecies and Caribbean regional endemics are added, high numbers were reported from the Sierra de Bahoruco (50 species), the Cordillera Central (40 species) and the La Visite and Pic Macaya parks (33 species each). Finally, threatened or endangered species were found most often in the Jaragua National Park (31 species), the Sierra de Bahoruco (30 species) and the Parque del Este (29 species).

Ranking based on the presence or absence of all species (Table 4) showed that the Parque del Este was the highest priority park, with 69 species of concern (56% of total) reported from the area. In the iterative process to determine the second highest priority park, the Sierra de Bahoruco entered with 28 additional species protected (79% of total), followed by the Jaragua National Park with 10 more species (87% of total). When rankings were made on the basis of more refined criteria, however, the Parque del Este fell out of the top three priority parks. Based on the number of Hispaniolan endemic species protected, or the number of endemic species, subspecies and regional endemics, the Sierra de Bahoruco was first (87% of Hispaniolan endemics; 75% of all endemics), followed by the Jaragua National Park (cumulative 93% of Hispaniolan endemics, 87% of all endemics), followed by a tie between the Sierra de Neiba, Cordillera Central and Valle Nuevo parks. Based on the number of threatened and endangered species protected, the Jaragua National Park was first (52% of total), followed by the Sierra de Bahoruco (85% of cumulative total) and then a tie between the Sierra de Neiba, Cordillera Central, Valle Nuevo and Laguna de Cabral parks.

Rankings based on index scores consistently placed the Sierra de Bahoruco and the Jaragua National Park as the first and second most important parks, respectively, in all criteria for protection (Table 4). The Sierra de Bahoruco protected 52% of all species of conservation concern, 87% of Hispaniolan endemics, 75% of all endemic species and 50% of threatened and endangered species. Adding the Jaragua National Park in step two of the iterative process resulted in the protection of 83% of all species of conservation concern, 93% of Hispaniolan endemics, 87% of all endemic species and 85% of threatened and endangered species. The third most important protected area varied depending on the criteria, but was the Laguna de Cabral when all species were considered, a tie between the Sierra de Neiba, Cordillera Central, Valle Nuevo and Pic Macaya parks for Hispaniolan endemics, and a tie between the Sierra de Neiba, Cordillera Central and Valle Nuevo parks for all endemic species and threatened and endangered species.

Jaccard similarity indices indicated essentially two groups of parks on Hispaniola defined by elevational range (Table 5). One group of higher elevation parks consists of the Cordillera Central, Valle Nuevo, Sierra de Neiba, Sierra de Bahoruco, Pic Macaya and La Visite. These parks share a similar suite of species that is somewhat distinct from that found in the lower elevation parks of Parque del Este, Jaragua National Park, Monte Cristi National Park and Laguna de Cabral. The Citadelle is not included in either group, probably due to its small size and smaller species list. But, interestingly, the only park dominated by limestone karst habitat, Los Haitises, seems not to share a close similarity in avifauna with any other park.

Finally, the analyses highlight several species of concern that do not occur in any protected area, or appear in a single park only (Appendix 1). Species not represented in any park include three rails (the black rail, *Laterallus jamaicensis*, the yellow-breasted crake, *Porzana flaviventer*, and the spotted rail, *Pardirallus maculatus*), the northern pintail (*Anas acuta*), the double-striped thick-knee (*Burhinus bistriatus dominicensis*)

Table 4. Ranking of conservation importance (number of species added with each iteration) of 12 protected areas in Hispaniola

Protected area	All species	Hispaniolan endemics	All endemics	Threatened/ endangered species
		Presence/absence		
Monte Cristi (MC)	6 (1)			4 (1)
Cordillera Central (CC)	5 (2)	3 (1)	3 (2)	3 (2)
Valle Nuevo (VN)	5 (2)	3 (1)	3 (2)	3 (2)
Los Haitises (LH)		2 (2)		
Parque del Este (PE)	1 (69)		4 (1)	
Sierra de Neiba (SN)	5 (2)	3 (1)	3 (2)	3 (2)
Laguna de Cabral (LC)	4 (4)		4 (1)	3 (2)
Sierra de Bahoruco (SB)	2 (28)	1 (26)	1 (50)	2 (20)
Jaragua (JG)	3 (10)	2 (2)	2 (8)	1 (31)
Citadelle (CT)				
Pic Macaya (PM)	6 (1)	3 (1)	4 (1)	4 (1)
La Visite (LV)				
		Index scores		
Monte Cristi (MC)				
Cordillera Central (CC)	4 (3)	3 (1)	3 (2)	3 (2)
Valle Nuevo (VN)	4 (3)	3 (1)	3 (2)	3 (2)
Los Haitises (LH)		2 (2)		
Parque del Este (PE)			6 (1)	
Sierra de Neiba (SN)		3 (1)	3 (2)	3 (2)
Laguna de Cabral (LC)	3 (6)		5 (1)	4 (2)
Sierra de Bahoruco (SB)	1 (64)	1 (26)	1 (50)	1 (30)
Jaragua (JG)	2 (38)	2 (2)	2 (8)	2 (21)
Citadelle (CT)				
Pic Macaya (PM)	5 (1)	3 (1)	4 (1)	5 (1)
La Visite (LV)				

Table 5. Jaccard similarity indices (*Cj*) based on species presence/absence in 12 protected areas of Hispaniola

	MC	CC	VN	LH	PE	SN	LC	SB	JG	CT	PM
Monte Cristi (MC)	1.00										
Cordillera Central (CC)	0.18	1.00									
Valle Nuevo (VN)	0.15	0.65	1.00								
Los Haitises (LH)	0.33	0.32	0.28	1.00							
Parque del Este (PE)	0.52	0.34	0.24	0.50	1.00						
Sierra de Neiba (SN)	0.12	0.52	0.66	0.20	0.19	1.00					
Laguna de Cabral (LC)	0.60	0.23	0.18	0.38	0.54	0.16	1.00				
Sierra de Bahoruco (SB)	0.19	0.70	0.57	0.38	0.37	0.45	0.22	1.00			
Jaragua (JG)	0.65	0.25	0.20	0.35	0.61	0.18	0.57	0.29	1.00		
Citadelle (CT)	0.23	0.39	0.38	0.27	0.27	0.39	0.24	0.37	0.26	1.00	
Pic Macaya (PM)	0.18	0.57	0.53	0.35	0.32	0.44	0.26	0.57	0.25	0.45	1.00
La Visite (LV)	0.15	0.61	0.60	0.28	0.23	0.57	0.22	0.63	0.22	0.43	0.63

and the grasshopper sparrow (*Ammodramus savannarum intricatus*), the latter two being inhabitants of open savannas and grasslands at low elevations, and two species with very restricted distributions in Haiti but wider Caribbean distributions (the thick-billed vireo, *Vireo crassirostris tortugae*, and the tawny-shouldered blackbird, *Agelaius humeralis humeralis*). Species represented in a single park include the white-tailed tropicbird (*Phaethon lepturus)*, northern shoveler (*Anas clypeata*), ring-necked duck (*Aythya collaris*), Caribbean coot (*Fulica caribea*), piping plover (*Charadrius melodus*), short-eared owl (*Asio flammeus domingensis*), least pauraque (*Siphonorhis brewsteri*), pearly-eyed thrasher (*Margarops fuscatus*), Swainson's warbler (*Limnothlypis swainsonii*) and the Haitian endemic, grey-crowned palm-tanager (*Phaenicophilus poliocephalus*).

DISCUSSION

Hispaniola has been identified as a top global priority for avian conservation (Stattersfield *et al*., 1998); however, little quantitative information has been available to help guide optimal strategies for conservation action on the island. Here, the first broad-scale look at the distribution of species of conservation concern among protected areas on the island has been assembled and their occurrences analysed to determine where conservation activities might be focused to serve avian conservation interests.

Prominence in the analyses presented here is given to the high elevation national park of the Sierra de Bahoruco. The importance of the Bahorucos to avian conservation lies in the large number of endemic, threatened and endangered species that have been recorded there, together with the presence of relatively extensive pine, cloud and mixed-broadleaf forests. These are among the most threatened habitats on the island (Tolentino & Peña, 1998; Latta & Lorenzo, 2000) and are of high importance to Hispaniolan endemics (Ricklefs & Cox, 1972; Latta, Rimmer & McFarland, 2003). Because the southern peninsula of Hispaniola, including the Sierra de Bahoruco, was periodically separated from the northern portion of Hispaniola by rising ocean levels during the Pleistocene (Woods & Ottenwalder, 1992), speciation events often occurred in isolation on the peninsula. This is reflected in the Bahorucos representation as one of the five most important centres of plant diversity and endemism on the island (Davis *et al*., 1997). For example, the Sierra de Bahoruco contains 52% of 319 orchid species, 32 of which are endemic to the Bahorucos (Grupo Jaragua, Inc, 1994).

Despite the ranking of the Sierra de Bahoruco National Park as a top priority in almost all measures, the park is now under extreme pressure. Forests that dominate park habitats are under threat from illegal forestry, gathering of firewood, cattle grazing and agricultural encroachment (Ottenwalder, 2000). But the most severe problem facing the Bahorucos is uncontrolled fires; at the current rate of burning, forests will be reduced by half in the next 50 years (Latta, Sondreal & Brown, 2000). As a result of these threats, a management plan for the park based on sound science is critically needed. A preliminary evaluation of the natural resources of the park was made in 1994 (SEA/DVS, 1994), but further efforts at management planning have not borne fruit.

Like the Sierra de Bahoruco National Park, the Jaragua National Park also figured prominently in all analyses presented here (Table 4). The high ranking of the Jaragua reflects the diverse habitats of the park, the inclusion of the offshore islands and their important colonial seabirds and the contrast in habitats between the montane Sierra de Bahoruco National Park and the coastal Jaragua National Park. The importance of the Jaragua National Park has been recognised by many entities (Grupo Jaragua, Inc, 1994), resulting in the development of a management plan and a successful co-management agreement between the DNP and the non-profit Grupo Jaragua.

The status of the Jaragua and Sierra de Bahoruco National Parks was greatly increased when the biological uniqueness of these protected areas was recognised by the United Nations in the creation of a UNESCO Biosphere Reserve (UNESCO, 2002). The Jaragua–Bahoruco–Enriquillo Biosphere Reserve, designated in late-2002, covers a 500 000 ha mosaic of habitats, ranging from Enriquillo Lake lying 40 m *below* sea level, through the lagoons and coastal habitats of the Jaragua National Park, to the montane pine and cloud forests of the Sierra de Bahoruco. This first biosphere reserve on the island reflects international recognition of the unique nature of the site and the responsibility to steward the reserve for sustainability. Unfortunately, the biosphere reserve and all of the national parks continue to be seriously threatened by legislative attempts to fragment the parks by allowing mining concessions, the sale of key parcels for real estate and tourism developments and other economic development activities (BirdLife International, 2004).

Additional parks figuring prominently in these analyses are other high elevation sites on Hispaniola: the Sierra de Neiba National Park, the parks of the Cordillera Central including Valle Nuevo and the Pic Macaya in Haiti. These parks also correspond with three out of the five most important centres of plant diversity and endemism on the island (Davis *et al*., 1997). The Sierra de Neiba and the Cordillera Central have a 25% level of plant endemism (Davis *et al*., 1997), while 28% of the plants in the Pic Macaya are endemic (Woods & Ottenwalder, 1992). The Pic Macaya is of particular interest as the most highly ranked of the Haitian parks because it contains rich, mesic broadleaf vegetation and pine forests and associated populations of forest birds (Woods & Ottenwalder, 1992). The Sierra de Neiba National Park is arguably one of the most threatened parks on Hispaniola. Forests below 1600 m, and those within 1 km of roadways are essentially gone (Rimmer *et al*., 2003), and 70–80% of the park has been severely disturbed by grazing, cutting and clearing for agriculture (Rimmer, Goetz & McFarland, 1998). Only remnant solitary hardwood trees and isolated forest fragments remain at these elevations and pressure on the remaining forests is high. The park has recently benefitted, however, from increased attention paid by DNP staff and the non-governmental Programa Ambiental Transfronterizo, resulting in reductions in deforestation and cattle grazing (Rimmer *et al*., 2003) and offering hope that forests may recover.

Aside from the Jaragua National Park, the only other low elevation site that was ranked moderately highly was the Laguna de Cabral, which was the only freshwater habitat among the parks assessed. Cabral is noted for the prominence of migratory birds, especially waterfowl, which although dramatically reduced in numbers from historical highs (Keith *et al*., 2003), nevertheless still winter at Cabral. Cabral continues to be threatened by over-fishing, shooting and encroachment by grazing cattle, despite the efforts of conservationists and park personnel to limit such activities (pers. obs.).

Although not highly ranked, it is important to note that other protected areas in the national park system are still vital to avian conservation planning efforts since these parks are part of a broader effort by the DNP to protect

samples of all habitats on the island. Although protection of representative ecosystems by the park system has not been rigorously studied, the list presented here of bird species found in no park, or in a single park, suggests a need for more reserves in marshland and grassland habitats that are highly impacted by coastal development and by sugar and rice production (Ottenwalder, 2000). This contrasts with an inventory completed by the Wildlife Department (SEA/DVS, 1990) that concluded 26 types of ecosystems were adequately represented in protected areas. More recently, a diverse team of conservationists and managers present at a national workshop for avian conservation planning concluded, again without quantitative data, that there were no significant gaps in the habitats represented by protected areas (Latta & Lorenzo, 2000). In the future it would be instructive to use recently available habitat classifications and GIS databases such as those assembled by Tolentino & Peña (1998) to quantify hectares of each habitat-type represented within national protected areas, to examine the distribution of those parcels and to determine if sufficient habitat is protected to insure viable populations of bird species of conservation concern. Such a study would also benefit from additional surveys of bird populations using new distance sampling techniques to better estimate population size and density (Buckland *et al*., 2001; Norvell, Howe & Parrish, 2003).

As well as protecting habitats, parks that may not be highly ranked may also be of value in protecting individual species that are under-protected elsewhere. For example, the endemic subspecies of the short-eared owl is reported only for the Parque del Este, the Haitian endemic grey-crowned palm-tanager only occurs in the Pic Macaya and the range of Ridgway's hawk has been reduced almost exclusively to Los Haitises, which did not figure prominently in this analysis.

Conservationists should also be aware of the demographically important measures of reproductive success and survival rates of species of conservation concern. Because presence/absence, and even abundance, may be misleading indicators of habitat suitability (Van Horne, 1983), demographic studies are needed to show how fitness may vary between habitats and sites. Several such studies have been made with migratory birds wintering in native and anthropogenic habitats of Hispaniola (Wunderle & Latta, 2000; Latta & Faaborg, 2001, 2002). Currently a study is underway to assess the reproductive success of breeding birds in four habitats in the Sierra de Bahoruco (C. C. Rimmer & S. C. L., unpublished results); this will give us a first look at reproductive success for any Hispaniolan passerines. In addition, more detailed efforts at prioritisation and evaluation of parks might also take into account autecological studies of threatened bird species (i.e. Latta *et al*., 2000), seasonal variation in habitat-use, source–sink dynamics (Pulliam, 1988; Hanski & Gilpin, 1991) and population genetics (Meffe & Carroll, 1997), to assess how well Hispaniolan parks are protecting avian populations.

Finally, results of this analysis would be strengthened by complementary analyses made using other taxa. Birds are useful as indicators of ecosystem function because birds are diverse and cost-effective to monitor, easily and commonly recorded and are frequently assessed for threatened or endangered status at various geographical levels. In addition, on Hispaniola, recent summaries of species' distributions and abundance have been made (Keith *et al*., 2003; Latta *et al*., 2003) allowing easier access to relevant data. Similar studies using reptiles and amphibians, plants, or other biota would be of interest in supporting or amending this prioritisation scheme, since reserve prioritisations made on the basis of one taxa are not necessarily valid for other taxa (Dobson *et al*., 1997; Andelman & Fagan, 2000). Nevertheless, these data provide a broad-scale look at how avian species of conservation concern are distributed among Hispaniola's protected areas and focuses conservation activities on priority parks to maximise avian conservation interests. These data suggest that the Hispaniolan reserve system is relatively complete in giving minimal protection to the majority of its diverse avifauna. However, the responsibility for protection of birds is placed overwhelmingly on the national park system of the Dominican Republic where an exemplary 16.2% of national territory lies in protected areas (Ottenwalder, 2000). The task now is to support the DNP and their Haitian counterparts with the necessary resources to improve the effectiveness of these parks. Combined with recently published data on habitat associations of many of these species (Latta *et al*., 2003), we now have available quantitative information to direct conservation activities focused on the broad-scale question of which parks are important and the finer-scale question of which habitats are important for birds of conservation concern.

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APPENDIX 1. Presence/absence of 123 species of threatened and endangered birds or species of concern, in 12 protected areas of Hispaniola.

Species name	English common name	Status[1]	Lists[2]	Threats[3]	Score[4]	MC	CC	VN	LH	PE	SN	LC	SB	JG	CT	PM	LV
Tachybaptus dominicus	Least Grebe			FG	1.0	X				X							
Podilymbus podiceps	Pied-billed Grebe			F	1.0	X			X	X		X					
Pterodroma hasitata	Black-capped Petrel	RE	ABCDE	F	4.5								X	X		X	X
Phaethon lepturus	White-tailed Tropicbird		E		1.5									X			
Sula leucogaster	Brown Booby		DE		2.0					X				X			
Pelecanus occidentalis	Brown Pelican		D	FG	2.0	X			X	X		X		X			
Fregata magnificens	Magnificent Frigatebird		DE	F	2.0	X			X	X		X		X			
Ardea herodias	Great Blue Heron		D	F	2.0	X			X	X		X		X			
Egretta caerulea	Little Blue Heron		E	G	1.5	X	X			X		X		X			
Egretta rufescens	Reddish Egret		CDE	F	2.0	X			X	X		X		X			
Eudocimus albus	White Ibis		D	FH	2.0	X				X		X		X			
Plegadis falcinellus	Glossy Ibis		D		2.0	X						X		X			
Platalea ajaja	Roseate Spoonbill		D	FH	2.0	X				X		X		X			
Phoenicopterus ruber	Greater Flamingo		D	F	2.0	X				X		X		X			
Dendrocygna arborea	West Indian Whistling-Duck	RE	ABCDE	FGH	4.5	X						X		X			
Anas americana	American Wigeon	NM		FGH	1.0							X		X			
Anas discors	Blue-winged Teal	NM		FGH	1.0	X						X		X			
Anas clypeata	Northern Shoveler	NM		FGH	1.0							X					
Anas bahamensis	White-cheeked Pintail		E	FGH	1.5	X				X		X		X			
Anas acuta	Northern Pintail	NM		FGH	1.0												
Aythya collaris	Ring-necked Duck	NM		FGH	1.0	X											
Nomonyx dominicus	Masked Duck		DE	FGH	2.0	X						X					
Oxyura jamaicensis	Ruddy Duck		E		1.5					X		X		X			
Accipiter striatus striatus	Sharp-shinned Hawk	SE		GH	1.5		X						X				X
Buteo ridgwayi	Ridgway's Hawk	HE	ABD	FGH	6.0				X					X			
Buteo jamaicensis	Red-tailed Hawk			GH	1.0		X	X	X	X	X	X	X	X	X	X	X
Laterallus jamaicensis	Black Rail		ACE	F	3.0												
Rallus longirostris	Clapper Rail		D	FGH	2.0	X								X			
Porzana flaviventer	Yellow-breasted Crake		DE	FGH	2.0												
Pardirallus maculatus	Spotted Rail		D	F	2.0												
Porphyrio martinica	Purple Gallinule			FG	1.0				X			X					
Fulica caribea	Caribbean Coot	RE	ACE	FGH	4.5							X					

APPENDIX 1. Continued

Species name	English common name	Status[1]	Lists[2]	Threats[3]	Score[4]	MC	CC	VN	LH	PE	SN	LC	SB	JG	CT	PM	LV
Aramus guarauna	Limpkin		DE	FGH	2.0				X	X	X		X	X			
Burhinus bistriatus dominicensis	Double-striped Thick-knee	SE	BD	FGI	4.5												
Charadrius alexandrinus	Snowy Plover		CE	F	1.5	X				X		X		X			
Charadrius wilsonia	Wilson's Plover		E		1.5	X				X		X		X			
Charadrius melodus	Piping Plover	NM	C	F	1.5									X			
Calidris pusilla	Semipalmated Sandpiper	NM	E		1.5	X				X		X		X			
Calidris himantopus	Stilt Sandpiper	NM	E		1.5	X				X		X		X			
Limnodromus griseus	Short-billed Dowitcher	NM	CE	F	1.5					X		X		X			
Larus atricilla	Laughing Gull		D	I	2.0	X			X	X		X		X			
Sterna maxima	Royal Tern	NM	D	I	2.0	X			X	X		X		X			
Sterna dougallii	Roseate Tern		D	FGHI	2.0					X				X			
Sterna antillarum	Least Tern		DE	FI	2.0	X				X				X			
Sterna anaethetus	Bridled Tern		D	HI	2.0	X				X				X			
Sterna fuscata	Sooty Tern		D	FGHI	2.0	X								X			
Anous stolidus	Brown Noddy		D	FGHI	2.0	X				X				X			
Columba squamosa	Scaly-naped Pigeon	RE	BD	FGH	4.5		X	X	X				X	X	X	X	X
Columba leucocephala	White-crowned Pigeon	RE	BCDE	FGH	4.5				X	X			X	X			
Columba inornata	Plain Pigeon	RE	ABCD	FGH	4.5	X		X	X	X		X	X	X		X	
Zenaida aurita	Zenaida Dove	RE		H	1.5	X		X	X	X		X	X	X			
Geotrygon chrysia	Key West Quail-Dove	RE	BDE	FGH	4.5		X		X	X			X				
Geotrygon leucometopius	White-crowned Quail-Dove	HE	ABD	FGH	6.0		X	X					X				
Geotrygon montana	Ruddy Quail-Dove		B	FGH	3.0		X	X	X	X			X				
Aratinga chloroptera	Hispaniolan Parakeet	HE	ABD	FGH	6.0	X	X	X			X	X	X	X	X		X
Amazona ventralis	Hispaniolan Parrot	HE	ABD	FGH	6.0		X	X		X	X		X	X	X	X	
Saurothera longirostris	Hispaniolan Lizard-Cuckoo	HE		G	2.0	X	X		X	X		X	X	X	X	X	X
Hyethornis rufigularis	Bay-breasted Cuckoo	HE	ABD	FGH	6.0		X						X				
Tyto alba	Barn Owl			H	1.0		X	X	X	X			X		X	X	X
Tyto glaucops	Ashy-faced Owl	HE		GH	2.0		X		X				X				X
Athene cunicularia troglodytes	Burrowing Owl	SE	E	H	2.3	X							X	X			
Asio stygius noctipetens	Stygian Owl	SE	BD	FH	4.5		X		X				X				
Asio flammeus domingensis	Short-eared Owl	SE	CE	F	2.3					X							
Chordeiles gundlachii	Antillean Nighthawk	RE	CD	FI	3.0	X				X		X	X	X			
Siphonorhis brewsteri	Least Pauraque	HE	ABD	FGI	6.0								X				
Caprimulgus carolinensis	Chuck-will's-widow	NM	E		1.5								X	X			
Caprimulgus ekmani	Hispaniolan Nightjar	HE	D	FGI	4.0		X			X			X				
Nyctibius jamaicensis abbotti	Northern Potoo	SE	BD	FH	4.5				X	X			X				X
Cypseloides niger	Black Swift		CE	F	1.5		X	X					X			X	X
Tachornis phoenicobia	Antillean Palm Swift	RE		G	1.5	X			X	X		X		X		X	
Anthracothorax dominicus dominicus	Antillean Mango	SE, RE			1.5	X	X	X	X	X		X	X	X	X	X	
Chlorostilbon swainsonii	Hispaniolan Emerald	HE		FG	2.0		X	X			X		X			X	X
Mellisuga minima vielloti	Vervain Hummingbird	SE, RE		G	1.5	X	X	X	X	X		X	X	X	X	X	X
Priotelus roseigaster	Hispaniolan Trogon	HE	AD	FG	6.0		X	X			X		X			X	X
Todus subulatus	Broad-billed Tody	HE			2.0	X	X		X	X		X	X	X	X	X	X
Todus angustirostris	Narrow-billed Tody	HE		G	2.0		X	X			X		X		X	X	X
Nesoctites micromegas	Antillean Piculet	HE	D	FGH	4.0				X	X			X		X	X	
Melanerpes striatus	Hispaniolan Woodpecker	HE			2.0	X	X	X	X	X	X	X	X	X	X	X	X
Elaenia fallax cherriei	Greater Antillean Elaenia	SE, RE		FG	1.5		X	X	X		X		X			X	X
Contopus hispaniolensis	Hispaniolan Pewee	HE			2.0		X	X	X	X	X		X		X	X	X

APPENDIX 1. Continued

Species name	English common name	Status[1]	Lists[2]	Threats[3]	Score[4]	MC	CC	VN	LH	PE	SN	LC	SB	JG	CT	PM	LV
Myiarchus stolidus dominicensis	Stolid Flycatcher	SE, RE		G	1.5	X	X	X	X	X	X		X	X	X	X	
Tyrannus caudifasciatus gabbii	Loggerhead Kingbird	SE, RE		G	1.5		X			X			X			X	
Vireo crassirostris tortugae	Thick-billed Vireo	SE			1.5												
Vireo nanus	Flat-billed Vireo	HE	D	F	4.0				X	X			X				
Corvus palmarum	Hispaniolan Palm Crow	HE	ABD	FGH	6.0	X	X	X			X		X	X	X		X
Corvus leucognaphalus	White-necked Crow	HE	ABD	FGH	6.0	X			X	X				X	X		
Progne dominicensis	Caribbean Martin	RE			1.5	X	X			X			X	X			
Tachycineta euchrysea sclateri	Golden Swallow	SE, RE	AB	FG	4.5			X			X		X		X	X	X
Myadestes genibarbis montanus	Rufous-throated Solitaire	SE, RE		FG	1.5		X	X	X		X		X			X	X
Catharus bicknelli	Bicknell's Thrush	NM	ACE	F	3.0		X	X	X	X	X		X			X	X
Turdus swalesi	LaSelle Thrush	HE	ABD	FG	6.0			X			X		X				X
Turdus plumbeus	Red-legged Thrush	RE		G	1.5		X	X	X	X	X	X	X	X		X	X
Margarops fuscatus	Pearly-eyed Thrasher	RE			1.5									X			
Dulus dominicus	Palmchat	HE		G	2.0	X	X	X	X	X	X	X	X	X	X	X	X
Parula americana	Northern Parula	CM			1.0		X	X		X			X	X		X	X
Dendroica petechia albicollis	Yellow Warbler	SE	D	F	3.0	X			X	X		X		X			
Dendroica tigrina	Cape May Warbler	CM			1.0		X			X		X	X	X	X	X	X
Dendroica caerulescens	Black-throated Blue Warbler	CM	E		1.5		X	X	X	X	X	X	X		X	X	X
Dendroica pinus chrysoleuca	Pine Warbler	SE	D	FG	3.0		X	X			X		X			X	X
Dendroica discolor	Prairie Warbler	CM	CE	F	1.5		X			X	X	X	X	X	X	X	X
Dendroica palmarum	Palm Warbler	CM			1.0	X	X	X		X	X	X	X	X	X	X	X
Protonotaria citrea	Prothonotary Warbler	NM	CE	F	1.5					X		X					
Helmintheros vermivorus	Worm-eating Warbler	NM	CE	F	1.5		X		X	X		X	X			X	
Limnothlypis swainsonii	Swainson's Warbler	NM	CE	F	1.5								X				
Seiurus noveboracensis	Northern Waterthrush	NM	E		1.5	X			X	X		X		X			
Seiurus motacilla	Louisiana Waterthrush	NM	E		1.5		X	X		X							
Microligea palustris	Green-tailed Warbler	HE	D	FG	4.0		X	X		X	X		X	X			X
Xenoligea montana	White-winged Warbler	HE	ABD	FG	6.0		X	X			X		X			X	X
Coereba flaveola bananivora	Bananaquit	SE			1.5	X	X	X	X	X	X	X	X	X	X	X	X
Phaenicophilus palmarum	Black-crowned Palm-Tanager	HE		G	2.0	X	X	X	X	X	X	X	X	X	X		X
Phaenicophilus poliocephalus	Grey-crowned Palm-Tanager	HE	A	G	6.0											X	
Calyptophilus tertius	Western Chat-Tanager	HE	ABD	FG	6.0								X			X	X
Calyptophilus frugivorus	Eastern Chat-Tanager	HE	ABD	FG	6.0		X	X			X						
Spindalis dominicensis	Hispaniolan Spindalis	HE		G	2.0		X	X			X		X			X	X
Euphonia musica musica	Antillean Euphonia	SE, RE	D	FG	3.0		X	X			X	X	X			X	X
Loxigilla violacea affinus	Greater Antillean Bullfinch	SE, RE		G	1.5	X	X			X	X	X	X	X	X	X	X
Ammodramus savannarum intricatus	Grasshopper Sparrow	SE	E	FG	2.3												
Zonotrichia capensis antillarum	Rufous-collared Sparrow	SE	D	F	3.0		X	X			X						
Agelaius humeralis humeralis	Tawny-shouldered Blackbird	SE, RE		FG	1.5												
Quiscalus niger niger	Greater Antillean Grackle	RE, SE			1.5	X			X	X		X		X		X	X

APPENDIX 1. Continued

Species name	English common name	Status[1]	Lists[2]	Threats[3]	Score[4]	MC	CC	VN	LH	PE	SN	LC	SB	JG	CT	PM	LV
Icterus dominicensis dominicensis	Greater Antillean Oriole	SE		FG	1.5	X	X		X	X		X		X		X	
Loxia megaplaga	Hispaniolan Crossbill	HE	ABD	FG	6.0		X	X					X			X	X
Carduelis dominicensis	Antillean Siskin	HE	D	FG	4.0		X	X			X		X				X

The list includes only the regularly occurring species, and excludes introduced species and all transient species, except those that occur during migratory stopovers in large numbers. Protected areas include: MC, Monte Cristi National Park, including the Islas Siete Hermanos; CC, includes Armando Bermúdez National Park and José del Carmen Ramírez National Park; VN, Valle Nuevo; LH, Los Haitises National Park; PE, Del Este National Park, including Saona Island; SN, Sierra de Neiba National Park; LC, Laguna de Cabral; SB, Sierra de Bahoruco National Park; JG, Jaragua National Park, including Laguna de Oviedo and Alto Velo and Beata Islands; CT, Citadelle National Historical Park; PM, Pic Macaya National Park, Haiti; LV, La Visite National Park, Haiti.

[1] HE, species (or proposed species) endemic to Hispaniola (Keith *et al*., 2003; Latta *et al*. in press); SE, subspecies endemic to Hispaniola and associated islands (Clements, 2000); RE, regionally endemic species (Clements, 2000); WM, Neotropical migrant wintering on Hispaniola; CM, wintering migrants restricted primarily to the Caribbean Basin (Wunderle & Waide, 1994).

[2] A, species listed as threatened or endangered in BirdLife International (2000); B, species listed as threatened or endangered in Latta & Lorenzo (2000); C, species listed in Audubon WatchList (NAS, 2002); D, species listed as threatened by Wildlife Department (SEA/DVS, 1990); E, species listed as Birds of Conservation Concern (USFWS, 2002).

[3] F, species that are sensitive to habitat destruction because they are habitat specialists, available habitat is limited, or disturbance of habitat is identified as a problem (Keith *et al*., 2003); G, species known or suspected to have suffered population declines (USFWS, 2002; Keith *et al*., 2003); H, species subject to excessive hunting or commercialisation (Keith *et al*., 2003); I, species thought to suffer excessive predation from introduced animals (SEA/DVS, 1990; Keith *et al*., 2003).

[4] Score is based on an estimate of a species' risk of extinction and value to global biodiversity (see the text and Table 2).