ORNITOLOGIA NEOTROPICAL 16: 405–417, 2005

EFFECTS OF HURRICANE GEORGES ON HABITAT USE BY CAPTIVE-REARED HISPANIOLAN PARROTS (*AMAZONA VENTRALIS*) RELEASED IN THE DOMINICAN REPUBLIC

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Resumen. – Efectos del huracán Georges sobre el uso de hábitat de Cotorras Dominicanas (*Amazona ventralis*) criadas en cautiverio y liberadas en la República Dominicana. – Colocamos radiotransmisores en 49 Cotorras Dominicanas (*Amazona ventralis*) criadas en cautiverio, y las liberamos en el Parque Nacional del Este (PNE), República Dominicana en 1997 y 1998. El objetivo primordial era desarrollar un programa de restauración centrado en el uso de aves criadas en cautiverio para fomentar la recuperación de la Cotorra de Puerto Rico (*A. vittata*). El huracán Georges pasó por el área de estudio el 22 de Septiembre de 1998 con vientos sostenidos de 224 km/h, proveyendo una oportunidad única para cuantificar la respuesta de las cotorras a ese tipo de perturbación. Información cuantitativa al respecto es rara para cualquier ave, particularmente para especies de *Amazona*, muchas de la cuales están en peligro de extinción y distribuidas en áreas propensas a huracanes en el Caribe. El rango de vivienda de 18 cotorras aumentó ($P = 0.08$) de 864 ha (IC = 689–1039 ha) a 1690 ha (IC = 1003–2377 ha) después del paso del huracán. El área total recorrida por todas las cotorras aumentó > 300%, de 4884 ha (pre-huracán) a 15,490 ha (post-huracán). Antes del huracán, las cotorras estaban concentradas en matorral costero, bosque latí foliado alto, y parcelas agrícolas baldías (i.e., "conucos"). Después del paso del huracán, las cotorras concentraron sus actividades en áreas de bosque latífoliado alto y conucos baldíos. Los accidentes topográficos, principalmente en la forma de abras o sumideros, resultaron ser "reservorios de recursos" donde las cotorras y otros frugívoros se alimentaban después del huracán. Los patrones de uso de hábitat y de movimientos exhibidos por las cotorras liberadas resaltan la importancia de considerar cuidadosamente los efectos de estacionalidad, topografía, y tamaño del área de liberación cuando se planifican reintroducciones de psittacidos en áreas vulnerables a huracanes.

Abstract. – We radio-tagged and released 49 captive-reared Hispaniolan Parrots (*Amazona ventralis*) in Parque Nacional del Este (PNE), Dominican Republic, during 1997 and 1998. Our primary objective was to develop a restoration program centered on using aviary-reared birds to further the recovery of the critically endangered Puerto Rican Parrot (*A. vittata*). Hurricane Georges made landfall over the release area on 22 September 1998 with sustained winds of 224 km/h, providing us with a unique opportunity to quantify responses of parrots to such disturbances. Quantitative data on such responses by any avian species are scarce, particularly for *Amazona* species, many of which are in peril and occur in hurricane-prone areas throughout the Caribbean. Mean home ranges of 18 parrots monitored both before and after the

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hurricane increased (P = 0.08) from 864 ha (CI = 689–1039 ha) pre-hurricane to 1690 ha (CI = 1003–2377 ha) post-hurricane. The total area traversed by all parrots increased > 300%, from 4884 ha pre-hurricane to 15,490 ha post-hurricane. Before Hurricane Georges, parrot activity was concentrated in coastal scrub, tall broadleaf forest, and abandoned agriculture (conucos). After the hurricane, parrots concentrated their activities in areas of tall broadleaf forest and abandoned conucos. Topographic relief, primarily in the form of large sinkholes, resulted in "resource refugia" where parrots and other frugivores foraged after the hurricane. Habitat use and movement patterns exhibited by released birds highlight the importance of carefully considering effects of season, topography, and overall size of release areas when planning psittacine restorations in hurricane-prone areas. *Accepted 30 April 2005.*

Key words: *Amazona ventralis*, *Amazona vittata*, captive-reared, Caribbean, Dominican Republic, habitat, home range, hurricanes, parrots, Puerto Rico, restoration.

INTRODUCTION

Hurricanes are stochastic, albeit common, natural disturbances in Caribbean ecosystems (Walker *et al.* 1991). In recent decades, hurricanes have played a determinant role in arresting population growth of several Caribbean *Amazona* species (Christian *et al.* 1996, Reillo 2001, Wiley *et al.* 2004). This threat, along with the higher overall extinction rates faced by small populations (Ewens *et al.* 1987), mandates increasing growth and geographic distribution of remnant insular *Amazona* populations to safeguard against such natural disturbances (Wiley *et al.* 2004). Losing wild populations and their associated biological culture would require recovery efforts based on captive-reared individuals alone, a considerably more daunting task even with species for which substantial captive populations exist (Derrickson & Snyder 1992, Wiley *et al.* 1992, Christian *et al.* 1996, Wiley *et al.* 2004).

An illustrative example of a hurricane-prone species is the endemic Puerto Rican Parrot (*Amazona vittata*). Once abundant and widely distributed in Puerto Rico, this critically endangered species has been confined to the montane rainforests of eastern Puerto Rico for over 60 years, where it has demonstrated serious vulnerability to hurricanes (Rodriguez-Vidal 1959, Snyder *et. al.* 1987, Vilella & Garcia 1995, Wiley *et al.* 2004). In 1989, Hurricane Hugo reduced the wild Puerto Rican Parrot population by half; from an estimated 47 individuals pre-hurricane to around 23 post-hurricane (United States Fish and Wildlife Service 1999). Intensive conservation efforts have kept the species from becoming extinct, but have failed to promote population growth beyond 50 individuals (USFWS 1999). Presently, the wild population is estimated at approximately 28–31 individuals, with nearly 160 additional parrots held at two *in situ* captive breeding facilities (Wiley *et al.* 2004).

In furtherance of conservation goals for the Puerto Rican Parrot (Snyder *et al.* 1987, USFWS 1999), our general objective was to explore the efficacy of a psittacine restoration program based on using aviary-reared birds to address two fundamental conservation objectives: supplementing an existing wild population, and restoring additional wild populations in new areas. Specifically, we sought to develop effective protocols for using captive-reared parrots to demographically augment the Puerto Rican Parrot (Colla-zo *et al.* 2003). Because of the critically endangered status of the Puerto Rican Parrot, we used the closely related Hispaniolan Parrot (*Amazona ventralis*) as an experimental surrogate (see Lambert *et al.* 1992, Collazo *et al.* 2003). In 1997 and 1998, we translocated, radio-tagged and released 49 Hispaniolan Parrots reared at aviary facilities in Puerto Rico to Parque Nacional del Este, a coastal limestone forest of the Dominican Republic. Hurricane Georges made landfall over the release area on 22 September 1998 with sustained winds of 224 km/h (Collazo *et al.* 2003), placing it in Category 4 on the Saffir-Simpson scale (1–5). The hurricane passed directly over the release area in a northwesterly direction, with total duration of approximately 8 h (White pers. observ.). After the hurricane, food abundance was drastically reduced and most trees were bare of leaves and fruits for up to 4 months (Collazo *et al.* 2003). Its occurrence during the experimental releases provided us, to our knowledge, with the first opportunity to quantify responses of an *Amazona* species to such a disturbance (see Collazo *et al.* 2003). Past reports of hurricane effects on avian populations largely have been based either on anecdotal accounts or estimates of changes in species' occurrence or relative abundance (e.g., Askins & Ewert 1991, Lynch 1991, Will 1991, Wunderle *et al.* 1992). Because hurricanes are stochastic phenomena, opportunities to acquire empirical "before and after" data with marked (e.g., radio-tagged) individuals are serendipitous, at best. Such data, however, can provide rare insights into how avian species are affected by these powerful natural disturbances (Waide 1991, Wiley & Wunderle 1993).

Herein we report home ranges and habitat use by captive-reared Hispaniolan Parrots before and after a major hurricane. Our objective was to quantify landscape-level responses of released captive-reared parrots to such a disturbance. We also report food items consumed by released parrots. Further, we discuss the relevance of our findings to population restoration efforts for psittacines in hurricane-prone areas. All common and scientific names of avian species follow American Ornithologists' Union (1998).

STUDY AREA

We conducted this study in Parque Nacional del Este (18°20'N, 68°45'W), Province of La Altagracia, in southeastern Dominican Republic. Parque Nacional del Este (PNE) covers 42,000 ha of subtropical dry and subtropical moist forests (Holdridge 1967). PNE has an average annual precipitation of 135 cm, with most (72%) occurring from May–November (Abreu & Guerrero 1997). Mean annual temperature is 27°C with a relative humidity of 79%. Topography is generally level, with elevations ranging from sea level to approximately 70 m. Although most of PNE is primary forest, small areas (≤ 2 ha) of both active and abandoned subsistence agriculture exist in the forest, primarily near its northern boundary. Detailed descriptions of the geology, flora, fauna, and land use of PNE are provided by Abreu & Guerrero (1997).

For logistical reasons, we chose the northwestern quadrant of PNE (5892 ha) as the general release area and, hence, the actual study area. Most (55%) of the study area was medium-height semihumid broadleaf forest, characterized by a canopy height of 10–12 m and canopy cover of 40–60% (Abreu & Guerrero 1997). Tall semihumid broadleaf forest, with an irregular canopy ranging from 10–20 m in height with canopy cover of 40–100%, covered 36% of the study area. Principal overstory species included *Clusia rosea*, *Bucida buceras*, *Bursera simaruba*, *Sideroxylon foetidissimum*, *Coccoloba diversifolia*, *Guaiacum sanctum*, *Ottoschulzia rhodoxylon, Metopium brownei*, and *Spondias mombin* (Abreu & Guerrero 1997). Active subsistence agriculture (i.e., "conucos" planted with pigeon peas, papayas, plantains, and cassava), abandoned conucos, pastures, coastal scrub forest, coconut plantations, and human settlements covered 9% of the study area.

Prior to releases, a network of trails and canopy-level observation platforms was constructed to facilitate data collection on radio-

TABLE 1. Tree species used for foraging by captive-reared Hispaniolan Parrots (*Amazona ventralis*) released in Parque Nacional del Este, Dominican Republic, 1997-1999.

Families	Species	Items consumed	Common names
Zygophyllaceae	*Guaiacum sanctum*[1]	Fruit	Vera
	Guaiacum officinale	Fruit	Guayacán
Anacardiaceae	*Spondias mombin*[1]	Fruit	Jobo de puerco
Polygonaceae	*Coccoloba diversifolia*[1]	Fruit	Uva de sierra
	Coccoloba pubescens[1]	Fruit	Hoja ancha
Burseraceae	*Bursera simaruba*[1]	Fruit/flowers	Almácigo
Combretaceae	*Bucida buceras*[1]	Fruit/flowers	Gri-gri
Clusiaceae	*Clusia rosea*[1]	Fruit/leaves	Cupey
Mimosaceae	*Adenanthera pavonina*	Fruit/leaves	Peronilla
	Acacia macracantha[1]	Fruit	Bayahonda
	Pithecellobium arboreum	Fruit	Gína
Sapotaceae	*Sideroxylon foetidissimum*[1]	Fruit	Caya
Sapindaceae	*Melicoccus bijugatus*[1]	Fruit	Limoncillo

[1]Fruits of these species were offered to parrots during pre-release acclimation.

tagged birds. The network encompassed areas within PNE and adjacent private lands, providing telemetry coverage of approximately 8950 ha. To limit unauthorized human access to certain areas of PNE (e.g., archaeological sites), locations of all new trails received prior approval by park administrators.

METHODS

Pre-release training and acclimation. From the aviaries in Puerto Rico, we selected 49 captive-reared Hispaniolan Parrots for translocation and release. We used young parrots (45 of 49 birds were < 2 years old) because they tend to exhibit fewer maladaptive traits (e.g., human dependency) associated with prolonged exposure to captive conditions (Derrickson & Snyder 1992, Wiley *et al.* 1992). Training of the captive-reared Hispaniolan Parrots prior to release was extensive (Collazo *et al.* 2003). Birds supplied from both aviaries were first kept in a large flight cage at the Rio Abajo Aviary in Puerto Rico. After approximately 5 months in the flight cage, parrots were shipped to the Dominican Republic where they were placed in six release cages located within PNE and in areas frequented by resident wild parrots (Collazo *et al.* 2003). At release sites, parrots were acclimated to their surroundings and underwent conditioning routines (Collazo *et al.* 2003), including daily exposure to native foods (Table 1). Prior to release, each bird was fitted with a transmitter with a unique frequency within 164–165 mHz. We used Holohil (Carp, Ontario, Canada) model SI-2C transmitters based on a design and attachment by Meyers (1996).

Parrots were released in seven groups over a period of 12 months (i.e., September 1997–September 1998; Collazo *et al.* 2003). Release groups were either four or eight birds, with the exception of the last group, which was made up of nine birds (Collazo *et al.* 2003). Supplemental feeders were suspended from trees at release sites and maintained for 2 to 3 weeks following release, or until parrots ceased visitation. During supplemental feeding, feeders were relocated approximately 50–100 m every 3 to 4 days to encourage birds to search for food in different locations.

Radiotelemetry and spatial analyses. Following release, parrots were tracked five to six times per week from the telemetry station network. Daylight hours were divided into three equal sampling periods. The initial period sampled each week was randomly selected, with the other periods sampled in turn. Thus, each sampling period was sampled at least once weekly. However, after Hurricane Georges, parrots were also tracked biweekly from a Robinson R-44 helicopter. We maintained a minimum flight altitude of >100 m AGL and speed of 60 knots to minimize flushing parrots and potentially influencing their movements. Tracking equipment consisted of a Telonics (Mesa, Arizona) TR-2/TS-1 receiver/scanner coupled with a hand-held Telonics RA-14 2-element Yagi antenna. Bearings to transmitters were determined using the loudest signal method (Springer 1979) and acquired using a Suunto hand-held compass. Declination (10 degrees westerly) was adjusted by computer during data analysis. Mean angular telemetry error (2.4°, SE = 0.4) was determined by radiolocation (n = 20) of active transmitters by observers unaware of the true location (White & Garrot 1990). These estimated bearings were then compared to the actual bearing to transmitters. Locations of all telemetry stations and test transmitters were determined using a Garmin 45 Geographic Positioning System (GPS). Aerial locations determined using the helicopter navigational GPS were also referenced to known transmitter locations and found to differ by < 100 m.

Using ArcView 3.1 (ESRI, Inc. 1996), all telemetry stations and parrot telemetry locations were projected on a georeferenced digital habitat map for PNE (Abreu & Guerrero 1997). We used false-color infrared photographs of PNE to classify habitats outside park boundaries that were also used by radiomarked parrots. These additional habitat coverages were also verified by ground-truthing and digitally appended to existing habitat coverages for the park. We then overlaid and classified telemetry locations by habitat type.

Home ranges. Minimum Convex Polygon (MCP) home ranges (White & Garrott 1990) were calculated using the Animal Movement Module within ArcView (ESRI, Inc. 1996). We used 100% MCPs to avoid excluding outlying locations resulting from long-distance movement. We recognize the bias inherent with this method (Worton 1987, White and Garrott 1990); however, use of 100% MCPs was justified for three reasons. First, the method uses all available movement data for any given individual. This was important following the hurricane when parrots became more dispersed (Collazo *et al.* 2003). Secondly, the method includes information on long-distance movements that may promote survival in areas of dispersed resources (see Collazo *et al.* 2003). Conversely, such movements may also subject birds to greater mortality (see White *et al.* 2005). Finally, knowledge of total extent of movements may aid in assessing size of areas required for population restorations, particularly in areas subject to frequent hurricanes. We also calculated 50% and 95% fixed kernel home ranges (Worton 1989) to identify core-use areas for all parrots combined. Data on pre- and post-hurricane home ranges and habitat use were examined separately because of habitat changes caused by the hurricane. We tested for differences in pre- and post-hurricane MCP home ranges for 18 individuals with pre- and post-hurricane home ranges each having a minimum of six locations using a paired t-test (SAS 1992). Data were log-transformed to meet normality and homogeneity of variances assumptions (Shapiro-Wilk, $R > 0.93$; Levene's test, $P > 0.10$; SAS 1992). Because of high variability and associated reduced statistical power, we considered differences significant at $P \leq 0.10$ to reduce Type II error (Sokal & Rohlf 1981, Taylor & Gerro-

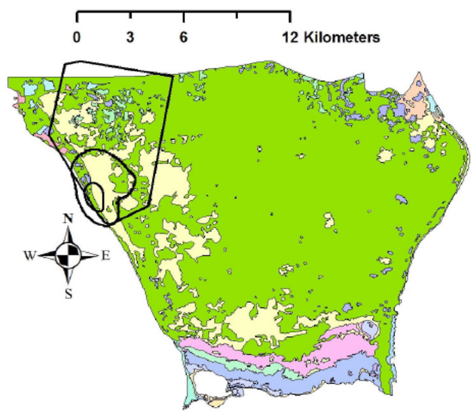

FIG. 1. Composite home ranges before Hurricane Georges for all captive-reared Hispaniolan Parrots released in Parque Nacional del Este, Dominican Republic. Outer polygon is the 100% MCP. Larger ellipse is the 95% core-use area. Smaller ellipse is the 50% core-use area.

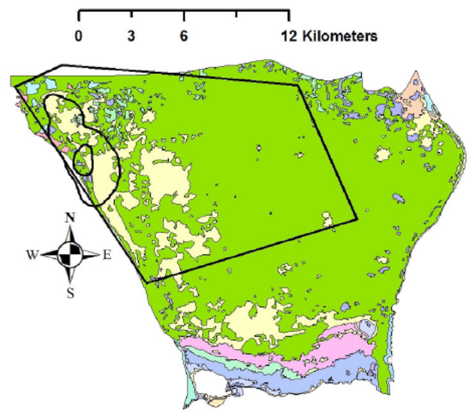

FIG. 2. Composite home ranges after Hurricane Georges for all captive-reared Hispaniolan Parrots released in Parque Nacional del Este, Dominican Republic. Outer polygon is the 100% MCP. Larger ellipse is the 95% core-use area. Smaller ellipse is the 50% core-use area.

dette 1993). Means are reported with their 90% confidence intervals.

Habitat use and preference. For assessments of habitat preference, we ran an algorithm using MATLAB (MathWorks, Inc. 1997) software that randomized (10,000 iterations) the number of locations collected on each parrot in the habitat types/period (see Carlo *et al.* 2003). On each iteration, random numbers between zero and one were generated *n* times, *n* being the total number of observations collected for each parrot in the particular habitat type. According to its value, each randomly generated number was then assigned to the habitat type whose abundance interval category contained the random number. We determined the number of times a simulated value was greater than or equal to the empirical value, which, divided by the number of iterations (10,000), yielded the *P*-value (Manly 1991). These *P*-values were interpreted as the probability of observing an individual parrot in a particular habitat under the null hypothesis of proportional use of habitat types (no preference). The randomization test is a distribution-free procedure, adequate and consistent with small sample sizes (Alldredge & Ratti 1986, Manly 1991, Legendre & Legendre 1998) and where goodness-of-fit or standard normal procedures, like Bonferroni simultaneous confidence intervals, will lack power (Wright 1992). Pre- and post-hurricane habitat availabilities were calculated separately because of changes in areas used by parrots after the hurricane. We assessed preference using broad vegetation categories (Abreu & Guerrero 1997) to minimize misclassification errors, and because detailed habitat use data (e.g., micro-habitat use), except for foraging observations reported in this work, could not be recorded on every sampling occasion. Although our approach is statistically conservative, we believe that it is adequate to make basic inferences about use of habitat in light of the scale of damage caused by Hurricane Georges (Category 4).

We also documented plant species that

TABLE 2. Results of habitat preference assessment for the periods before and after Hurricane Georges based on habitat use patterns of 49 captive-reared Hispaniolan Parrots (*Amazona ventralis*) released in Parque Nacional del Este, Dominican Republic, 1997-1999. *P*-values generated from algorithm (10,000 iterations) using MATLAB software.

Habitats	Availability[a]		Use[b]		*P*-upper[c]		*P*-lower[d]	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Active conucos[e]	0.055	0.018	0.001	0.008	1	0.988	< 0.001	0.041
Abandoned conucos	0.021	0.007	0.035	0.096	< 0.001	< 0.001	1	1
Tall forest	0.353	0.187	0.552	0.455	< 0.001	< 0.001	1	1
Medium forest	0.570	0.737	0.407	0.436	1	1	< 0.001	< 0.001
Coastal scrub	0.001	0.052	0.003	0.006	< 0.001	1	1	< 0.001

[a]Proportion of total area used by parrots.
[b]Proportion of parrot locations within habitat type.
[c]*P*-values < 0.1 indicate use greater than expected (preference).
[d]*P*-values < 0.1 indicate use less than expected (avoidance).
[e]Subsistence agriculture.

released parrots fed upon. This was done to identify specific components that might explain use of particular habitats by the released parrots. These observations were recorded while actively monitoring radio-marked parrots and observing wild parrots.

RESULTS

Home ranges. We collected a total of 3236 locations of radio-tagged parrots, of which 2724 were pre-hurricane and 512 were post-hurricane. Mean number of locations for pre-hurricane home ranges was 86 (CI = 56–115) and for post-hurricane home ranges was 24 (CI = 19–29). Although post-hurricane home ranges were determined using fewer locations than pre-hurricane, we believe post-hurricane sampling duration (6 months) was sufficient to allow stabilization of home ranges (Swihart & Slade 1985). Mean MCP home ranges of 18 individual birds monitored before and after the hurricane increased ($t = -1.85$, $df = 17$, $P = 0.08$) from 864 ha (CI = 689–1039) pre-hurricane to 1690 ha (CI = 1003–2377) post-hurricane. For all parrots combined, pre-hurricane core-use areas were 139 ha and 1104 ha for 50% and 95% kernels, respectively (Fig. 1). Following the hurricane, core-use areas shifted northwesterly and expanded to 158 ha and 1559 ha for 50% and 95% kernels, respectively (Fig. 2). Overall, the total area (MCP) traversed by released parrots before the hurricane (4884 ha) increased by > 300% following the hurricane, to 15,490 ha. (Figs 1 and 2).

Habitat use and preference. Parrots preferred coastal scrub, tall broadleaf forest, and abandoned conucos prior to the hurricane (Table 2). Conversely, medium broadleaf forest and active conucos were avoided. After the hurricane, habitat selection patterns shifted. Parrots exhibited preference for abandoned conucos and tall broadleaf forest, and avoided medium broadleaf forest and coastal scrub (Table 2).

Foraging observations. We observed both wild and released Hispaniolan Parrots feeding on leaves, fruits, and flowers of 13 tree species within PNE boundaries as well as on sur-

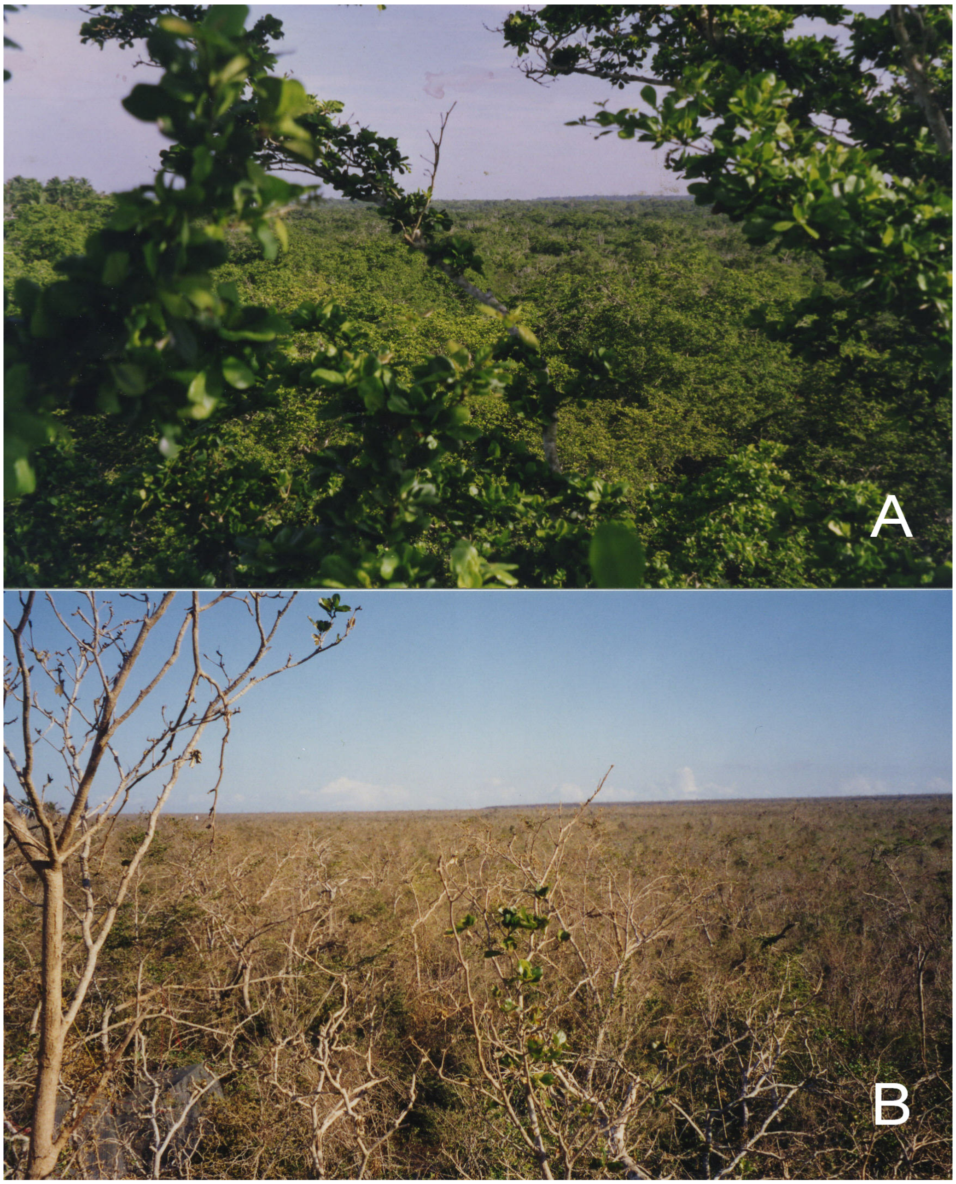

FIG. 3. Canopy-level view across Parque Nacional del Este one day before (A) and one day after (B) passage of Hurricane Georges on 22 September 1998. Both photographs depict the same area and were taken from the same vantage point.

rounding private lands (Table 1). Although captive parrots accepted all wild foods offered during pre-release acclimation, after release they were observed feeding most frequently on fruits from *Guaiacum* and *Coccoloba* species, *Bursera simaruba* and *Acacia macracan-*

tha. Released parrots also fed readily on *Clusia rosea*, consuming leaves and fruits. Approximately 1 month after the hurricane, we observed a released parrot also feeding on the1 pseudobulbs of an endemic epiphytic orchid *Broughtonia domingensis*, a common species throughout PNE but not documented as a parrot food source prior to the hurricane. The parrot was possibly near starvation; it was found dead 3 days later <100 m of where seen feeding on orchids.

DISCUSSION

Captive-reared Hispaniolan Parrots released in Parque Nacional del Este showed a marked response to the passage of Hurricane Georges. After the hurricane, ranges of most individuals changed dramatically. Moreover, the total area traversed by all released parrots increased more than threefold following the hurricane. Collazo *et al*. (2003) reported that post-hurricane survival of Hispaniolan Parrots was linked to increased movements, presumably providing surviving parrots with increased encounters with dispersed resources. Expansion of foraging areas following hurricanes also has been reported for both resident and migratory birds (Wiley & Wunderle 1992). For example, for several weeks following Hurricane Hugo, Puerto Rican Parrots were observed making daily flights from montane forests to lowland areas that they had not used prior to the storm (Vilella & García 1995). The relatively flat topography of PNE may have contributed to the amplification of post-hurricane ranges of Hispaniolan Parrots. Low relief likely contributed to the near total defoliation over vast areas (. 3). In contrast, in mountainous areas, presence of deep valleys can result in some areas receiving little damage, with food being available for parrots following a hurricane (Brokaw & Grear 1991, Walker *et al*. 1991, Wunderle 1999). Notwithstanding the value of the topographic relief afforded by mountains, an increase in movements by both wild and captive-reared parrots could be expected in the aftermath of a hurricane, especially if the release area or area of established home ranges is severely impacted (Waide 1991).

Hispaniolan Parrots exhibited preference for three habitat types (i.e., coastal scrub, tall broadleaf forest, and abandoned conucos) before the hurricane. In these habitats, commonly used food plants were abundant (e.g., *Coccoloba diversifolia*, *Guaiacum sanctum*). The use of abandoned conucos was probably due to the presence of 10 of 13 tree species used by parrots in our study. Early successional tree species (e.g., *Acacia macracantha*, *Pithecellobium arboreum*), typical of disturbed PNE habitats such as abandoned conucos, also were frequently used for foraging by Hispaniolan Parrots.

Following the hurricane, there was a detectable shift in habitat use. Heavily impacted coastal scrub forest was virtually abandoned as surviving parrots increased their activities in areas of tall broadleaf forest and abandoned conucos. In Puerto Rico, Waide (1991) also reported habitat shifts of forest birds following Hurricane Hugo. The most likely factors responsible for observed shifts were the near total defoliation and severe structural damage resulting from the hurricane (. 3). These factors generate marked short-term responses by avian species in the aftermath of such storms (Wiley & Wunderle 1993). Hurricanes disrupt available food resources both in terms of standing crop (Sanford *et al*. 1991, Collazo *et al*. 2003) and spatial distribution (Brokaw & Grear 1991). At the microhabitat level, hurricanes also disrupt the vertical stratification of foraging sites (Waide 1991, Wunderle *et al*. 1992). In Dominica after Hurricane David (1979), Imperial Parrots (*A. imperialis*), normally canopy-level foragers, were observed feeding on shoots of small trees only 3–4 m above

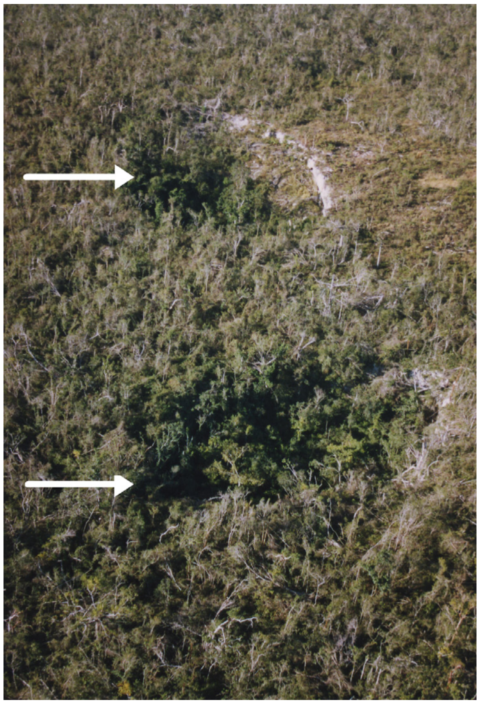

FIG. 4. Typical examples of the large sinkholes (marked by arrows) within the tall broadleaf forest that provided resource refugia for Hispaniolan Parrots and other avian species after Hurricane Georges. Upper sinkhole is approximately 50 m in diameter; lower sinkhole is approximately 80 m in diameter. Vegetation in these sinkholes was undamaged by Hurricane Georges.

ground (Christian *et al.* 1996). Similarly, Waide (1991) documented changes in foraging height and diet of Bananaquits (*Coereba flaveola*) and Black-whiskered Vireos (*Vireo altiloquus*) following passage of Hurricane Hugo in Puerto Rico. Fortunately for parrots in PNE, disturbed habitats (e.g., abandoned conucos) are dominated by leguminous trees that can quickly recover from hurricanes with rapid growth and uptake of nutrients (Lugo *et al.* 1978, Yi *et al.* 1991). Large sinkholes (Fig. 4), common throughout the tall broadleaf forest type (Abreu & Guerrero 1997), provided scattered pockets of available resources for parrots (i.e., "resource refugia") following the hurricane. Core-use areas of released parrots shifted after the hurricane (Fig. 2) and encompassed additional areas where sinkholes were abundant. Further, of nine documented post-hurricane mortalities of released Hispaniolan Parrots (Collazo *et al.* 2003), seven (78%) occurred in areas of PNE where resource refugia (i.e., sinkholes) were absent (White pers. observ.). Telemetry and visual observations indicated use of sinkholes by both captive-reared and wild Hispaniolan Parrots, as well as other frugivorous birds such the Black-crowned Palm-Tanager (*Phaenicophilus palmarum*), White-crowned Pigeon (*Columba leucocephala*) and Greater Antillean Bullfinch (*Loxigilla violacea*) in the aftermath of the hurricane. Although we have no comparable data on the responses of wild Hispaniolan Parrots to Hurricane Georges, our observations and results of other studies (e.g., Askins & Ewert 1991, Lynch 1991, Waide 1991, Will 1991, Wunderle *et al.* 1992) strongly suggest that the wild parrots in PNE were similarly affected.

The population restoration of endangered parrot species through translocations and reintroductions of captive-reared individuals is being increasingly used (see Snyder *et al.* 1994, Sanz & Grajal 1998, Collazo *et al.* 2003, Brightsmith *et al.* 2005, White *et al.* 2005). Unlike restoration programs for continental psittacines, however, restorations of Caribbean psittacines face the additional challenge of stochastic perturbations by hurricanes and attendant reductions in parrot survival. In hurricane-prone areas, translocating and releasing either wild or captive-reared parrots during or immediately prior to the height of local hurricane season should be carefully evaluated. For example, Collazo *et al.* (2003) reported that captive-reared Hispaniolan Parrots released shortly (i.e., < 1 month) before Hurricane Georges had lower post-release survival than parrots released earlier, presumably because of less time for adjustment to the release environment. Hurricane-induced habitat damage can effectively cause a temporary decline in habitat quality, resulting in short-term reduction in carrying capacity, increased stress on survivors, and displays of atypical foraging behaviors (Wunderle *et al.* 1992, Wiley & Wunderle 1993). These lessons are particularly valuable to parrot restoration programs as food resources in tropical forests can vary both seasonally and along elevational gradients (Terborgh 1986, Levy 1988, Chaves-Campos 2004). In Parque Nacional del Este, the total area traversed by released parrots increased by > 300% due to hurricane-induced defoliation over large areas. In this instance, the presence of resource refugia likely contributed to post-release survival of several individuals. The area selected for restoration of a second wild population of Puerto Rican Parrots (USFWS 1999, Wiley *et al.* 2004) is in the Karst region, an area of topographic diversity (Chinea 1980) that may provide numerous resource refugia in the event of a hurricane. Throughout the Caribbean, increasing urbanization and fragmentation of parrot habitat (Wiley *et al.* 2004) can only exacerbate potential impacts of these storms on native psittacines. In particular, the size of areas deemed adequate for parrot releases and restorations can potentially be underestimated in areas subject to frequent hurricanes.

ACKNOWLEDGMENTS

We thank the United States Fish and Wildlife Service, United States Geological Survey-Biological Resources Division, Parque Nacional del Este, Ecoparque, Parque Zoológico Nacional de la República Dominicana, and Puerto Rico Department of Natural and Environmental Resources for their support throughout all phases of this project. The residents of the village of Padre Nuestro, República Dominicana were particularly helpful and supportive of our work. We thank R. Sayre of The Nature Conservancy for the digital land cover of Parque Nacional del Este. R. Minnis and M. López-Flores provided GIS support and guidance during analyses of spatial data. We also thank H. Abreu, W. Abreu, J. Almonte, K. García, S. Goldade, J. Hernández, O. Johnson, D. Mercedes, B. Muiznieks, G. Ortiz, M. Toledo, P. Torres, and M. Weinstein for fieldwork. We are especially grateful to E. Manzana for his skills as a helicopter pilot. Thanks are due F. Núñez and A. Valido for support and insightful discussions about the merits of the project. The staff of the José L. Vivaldi (Rio Abajo) Aviary and the Luquillo Aviary provided training facilities and a steady supply of captive-reared parrots. We thank L. Baeten, J. Dein, J. Inoa, K. Joyner, R. María, F. Nutter, A. Rivera, and M. Stoskopf for veterinary assistance during pre-release phases of the project, and some aspects of fieldwork. Animal care and handling procedures were conducted under permits from the United States Fish and Wildlife Service (SA9601, PRT823656, PRT808118), the Convention on International Trade in Endangered Species (US826126, US833800, US832779), the Puerto Rico Department of Natural and Environmental Resources (98-E-7), and the Agriculture Ministry of the Dominican Republic (P-296). Comments by D. Brightsmith, S. Latta, J. Meyers, and an anonymous reviewer improved an earlier version of this manuscript. This manuscript is dedicated to the memory of Juan Guerrero, Parque Nacional del Este park guard, whose sound advice and generous assistance helped make this project a success.

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