Wilson Bull., 107(3), 1995, pp. 452–462

DISTRIBUTION AND ABUNDANCE OF RAPTORS IN PUERTO RICO

FRANK F. RIVERA-MILÁN[1]

ABSTRACT.—From July 1986 to June 1988, I counted all raptors (Falconiformes and Strigiformes) seen or heard along 15 8-km routes in the three major life zones of Puerto Rico (moist, wet, and dry). Red-tailed Hawks (*Buteo jamaicensis*) and American Kestrels (*Falco sparverius*) were the most abundant year-round residents. Red-tailed Hawks were more abundant in the moist zone than in the wet zone. American Kestrels did not differ significantly in the dry and moist zones. Red-tailed Hawks were more abundant than American Kestrels in the moist zone. The most abundant winter residents were Merlins (*F. columbarius*), Peregrine Falcons (*F. peregrinus,*) and Ospreys (*Pandion haliaetus*); all three species were frequently detected in the dry zone but were less abundant than American Kestrels. The abundances of Merlins, Peregrine Falcons, and Ospreys did not differ significantly. The abundances of raptors (pooled) peaked in autumn (September–November) and winter (December–February). Roadside counts were highly variable (coefficients of variation ranged from 85–243%). As a result, the within-year sample-sizes (8-km routes) needed to provide confidence limits of ±10–50% ($t_{0.05} \approx 2.0$) on mean abundance estimates ($\bar{Y}$) of the most abundant species in the life zones were high. *Received 19 Oct. 1994, accepted 15 Feb. 1995.*

Eight diurnal raptors are reported for Puerto Rico: Sharp-shinned Hawk (*Accipiter striatus*), Red-tailed Hawk (*Buteo jamaicensis*), Broad-winged Hawk (*B. platypterus*), Northern Harrier (*Circus cyaneus*), Osprey (*Pandion haliaetus*), Peregrine Falcon (*Falco peregrinus*), Merlin (*F. columbarius*), and American Kestrel (*F. sparverius*); and two species of owls, Puerto Rican Screech-Owl (*Otus nudipes*) and Short-eared Owl (*Asio flammeus*). Northern Harriers, Peregrine Falcons, Merlins, and Ospreys are winter residents. Sharp-shinned Hawks, Red-tailed Hawks, Broad-winged Hawks, American Kestrels, Puerto Rican Screech-Owls, and Short-eared Owls are year-round residents (Biaggi 1983, Raffaele 1989). General information about the diurnal and nocturnal raptors of Puerto Rico can be found in Pérez-Rivera and Cotté-Santana (1977), Biaggi (1983), Wiley (1985), and Raffaele (1989). Detailed studies have been conducted by Santana et al. (1986) and Delannoy and Cruz (1988). Little is known, however, about the distribution and abundance patterns of raptors in Puerto Rico. From July 1986 to June 1988, I counted raptors in the same sampling units used to study the distribution and abundance of pigeons and doves (Columbidae) in Puerto Rico (Rivera-Milán 1990, 1992, 1993). My main objectives were to examine seasonal distribution and abundance patterns of raptors and to determine the number of within-

[1] Dept. of Natural Resources, Scientific Research Area, Terrestrial Ecology Section, Stop 3 Pta. de Tierra, Puerto Rico 00906. (Present address: U.S. Fish and Wildlife Service, Office of International Affairs, 4401 North Fairfax Drive, Suite 860-ARLSQ, Arlington, Virginia 22203.)

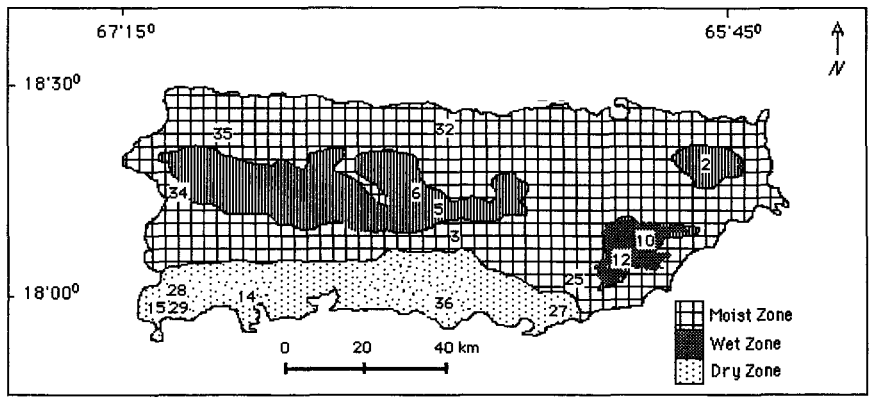


FIG. 1. Map showing the 8-km routes sampled in the three major life zones of Puerto Rico.

year sampling units (8-km routes) needed to have ±10–50% ($t_{0.05} \approx 2.0$) in the relative precision of mean estimates ($\bar{Y}$) of the most abundant resident species in the three major life zones of Puerto Rico.

STUDY AREAS AND METHODS

Puerto Rico is the easternmost and smallest of the Greater Antilles (17°55′–18°35′ north, 65°37′–67°17′ west; land area is about 8903 km^2). The three major life zones of the island are the subtropical moist zone (≈5326 km^2), the subtropical wet zone (2124 km^2), and the subtropical dry zone (1216 km^2; Fig. 1). The forest area of Puerto Rico, which covers approximately 3400 km^2 (38%) of the island, is dominated by second-growth forests in lower and upper montane habitats (Ewel and Whitmore 1973, Little et al. 1977, Birdsey and Weaver 1982, Silander et al. 1986, Ortiz 1989).

From July 1986 to June 1988, 15 8-km routes were sampled once per month in the three major life zones of the Puerto Rican mainland (five routes/life zone; Fig. 1). Each route had six stations spaced at 1.6-km (1-mi) intervals. At each station, I stopped for three minutes and counted all the raptors seen or heard. The driving speed between stations fluctuated between 16 and 32 kph, depending upon the terrain and traffic conditions. The counts started at 05:30 and finished at 10:30 h, but were discontinued if it rained or if wind speed exceeded 19 kph. A separate record was kept of the individuals of each species seen while driving between the 3-min stations. Detailed information about the routes sampled can be found in Rivera-Milán (1990, 1992, 1993).

Call- and sight-counts were used to generate descriptive statistics. The within-year sample-sizes (8-km routes) needed to provide 95% confidence limits for an estimate of mean abundance ($\bar{Y}$) were calculated according to Eberhardt (1978:229–230). Samples sizes were estimated for confidence limits ranging from 10–50% of the true mean for Red-tailed Hawks and American Kestrels in each life zone. Analysis of variance (ANOVA) with repeated measures at one factor (season) was used to examine abundance patterns of Red-tailed Hawks and American Kestrels in the life zones (Winer 1971; Gurevitch and Chester 1986; Beal and Khamis 1990, 1991; Quinn and Keough 1991). Separate ANOVAs were conducted for each species. A one-tailed unpaired *t*-test was used to compare mean abundance estimates

TABLE 1

DESCRIPTIVE STATISTICS OF ROADSIDE COUNTS OF RAPTORS ON THE PUERTO RICAN MAINLAND

Species	Life zone	Mean	SE	CV (%)	Sum	N
Red-tailed Hawk	Moist zone	5.87	1.09	91	141	24
Red-tailed Hawk	Wet zone	2.29	0.40	86	55	24
American Kestrel	Dry zone	2.67	0.55	101	64	24
American Kestrel	Moist zone	1.71	0.30	85	41	24
Puerto Rican Screech Owl	Moist-wet zone	1.45	0.30	172	24	24
Merlin	Dry-moist zone	0.54	0.23	204	13	24
Peregrine Falcon	Dry-moist zone	0.50	0.17	167	12	24
Osprey	Dry zone	0.50	0.18	177	11	24
Broad-winged Hawk	Wet zone	0.46	0.19	203	11	24
Puerto Rican Sharp-shinned Hawk	Wet zone	0.25	0.12	243	6	24

of Red-tailed Hawks in the moist and wet zones and mean abundance estimates of Kestrels in the moist and dry zones (intraspecific comparisons across life zones). A one-tailed unpaired *t*-test was also used to compare mean abundance estimates of Red-tailed Hawks and American Kestrels in the moist zone and mean abundance estimates of American Kestrels, Merlins, Peregrine Falcons, and Ospreys in the dry zone (interspecific comparisons within a life zone). Since means and standard deviations were positively correlated (Pearson's $r = 0.97$, df = 8, $P = 0.00001$), counts were log-transformed before conducting statistical analyses (Sokal and Rohlf 1981). Details of other statistical analyses are given with the corresponding results. Statistics were performed with the programs SuperANOVA and StatView II (Abacus Concepts, Inc., Berkeley, California, 1987, 1989). Significance was accepted at $P \leq 0.05$.

TABLE 2

ANALYSIS OF VARIANCE WITH REPEATED MEASURES AT ONE FACTOR (SEASON) FOR COUNTS OF RED-TAILED HAWKS IN THE MOIST AND WET ZONES OF PUERTO RICO

Source of variation	df	Sum of squares	Mean square	*F*-test	*P*-value
Life zone	1	3.801	3.801	5.279	0.051
Routes (life zone)	8	5.760	0.720		
Season	3	2.442	0.814	1.724	0.188
Life zone × season	3	2.055	0.685	1.451	0.276
Routes (life zone) × season	24	11.327	0.472		

Repeated measures:	Winter	Spring	Summer	Autumn
Life zone				
Moist	1.298	1.621	1.916	2.258
Wet	1.449	0.635	1.196	1.346

RESULTS

Red-tailed Hawks were more abundant in the moist zone than in the wet zone (t-statistic = 3.1, df = 46, P = 0.003; Tables 1 and 2). Their abundances increased from autumn (September–November) to winter (December–February) in the wet zone and from summer (June–August) to autumn in the moist zone (Table 2 and Fig. 2A). Red-tailed Hawks were relatively uncommon in the dry zone.

Abundance of American Kestrels did not differ significantly in the dry and moist zones (t = 1.2, df = 46, P = 0.252; Tables 1 and 3). They increased from autumn to winter in the dry zone and from summer to autumn in the moist zone (Table 3 and Fig. 2B). American Kestrels were relatively uncommon in the wet zone. Red-tailed Hawks were more abundant than American Kestrels in the moist zone (t = 3.7, df = 46, P = 0.001).

The Puerto Rican Screech-Owl was the third most abundant raptor in the moist and wet zones (Table 1 and Fig. 3A). Screech-Owl counts increased from autumn to winter in three 8-km routes sampled from July 1986 to June 1988 (Fig. 3A). They were not recorded in the sampling units of the dry zone.

The Broad-winged Hawk and Puerto Rican Sharp-shinned Hawk were the least abundant year-round residents (Table 1 and Fig. 3B). Eleven Broad-winged Hawks were found in the wet zone; six occurred in the Luquillo National Rainforest (route #2; Fig. 1). Six Sharp-shinned Hawks were in the wet zone; five occurred in the Carite State Forest, Cayey (routes #10 and #12; Fig. 1). Broad-winged Hawks and Sharp-shinned Hawks were not observed in the moist and dry zones.

The most common winter residents were Merlins, Peregrine Falcons, and Ospreys (Table 1 and Fig. 3C). Merlins and Peregrine Falcons were frequently found in agricultural areas and saltflats in the dry zone (routes #15 and #29; Fig. 1) but were less abundant than American Kestrels (t = 5.2, df = 46, $P < 0.001$; t = 5.1, df = 46, $P < 0.001$). Ospreys were also frequently detected in saltflats (routes #15 and #29; Fig. 1), but were less abundant than American Kestrels (t = 4.3, df = 46, $P < 0.001$). The rarest of the winter residents was the Northern Harrier. One Northern Harrier was found on the Cabo Rojo saltflats (route #15).

The Short-eared Owl was not found in the routes sampled, but was frequently flushed from the ground when conducting nest searches in the vicinity of route #15 (Rivera-Milán, unpubl. data). The Turkey Vulture (*Cathartes aura*) was not included in the roadside counts, but it was common in the agricultural areas of the dry zone (e.g., routes #15 and #29).

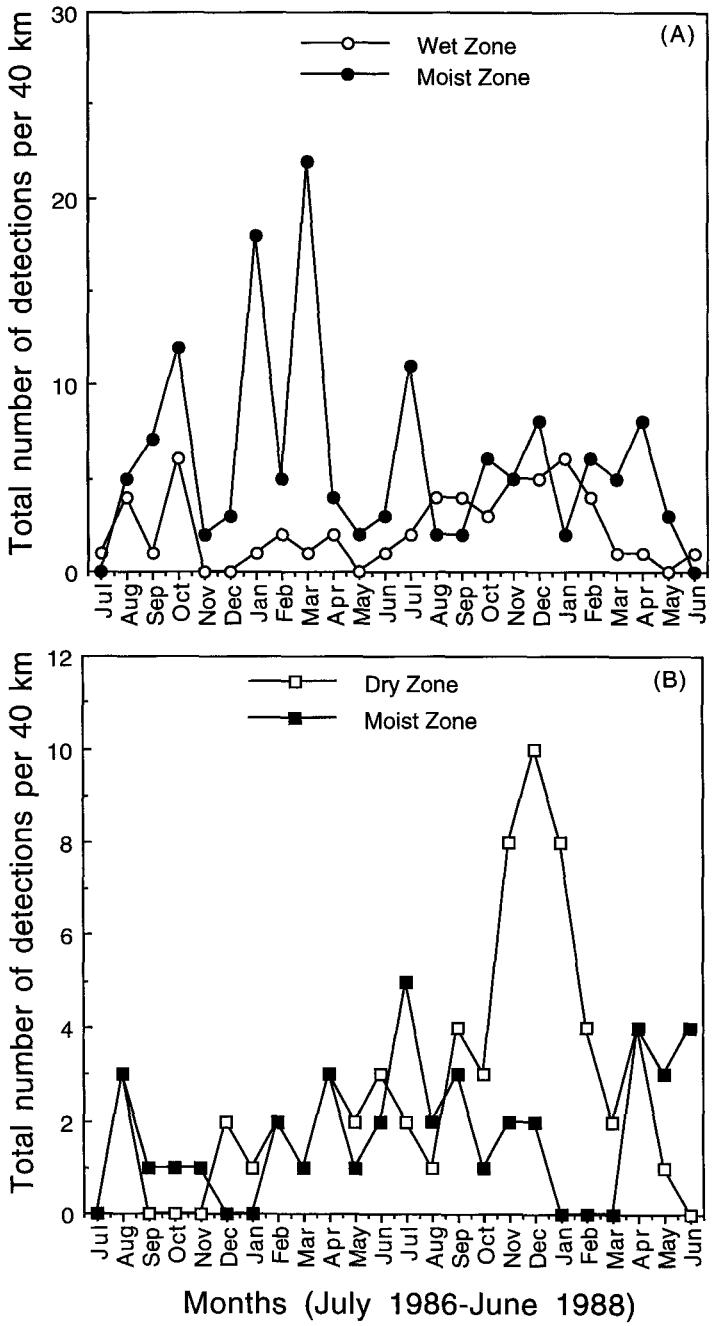

(A)
Wet Zone
Moist Zone
Total number of detections per 40 km
0
10
20
30
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
(B)
Dry Zone
Moist Zone
Total number of detections per 40 km
0
2
4
6
8
10
12
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
Months (July 1986-June 1988)

TABLE 3

ANALYSIS OF VARIANCE WITH REPEATED MEASURES AT ONE FACTOR (SEASON) FOR COUNTS OF AMERICAN KESTRELS IN THE MOIST AND DRY ZONES OF PUERTO RICO

Source of variation	df	Sum of squares	Mean square	*F*-test	*P*-value
Life zone	1	1.757	1.757	1.167	0.312[a]
Routes (life zone)	8	12.040	1.505		
Season	3	0.808	0.269	1.154	0.348
Life zone × season	3	1.618	0.539	2.309	0.102
Routes (life zone) × season	24	5.605	0.234		

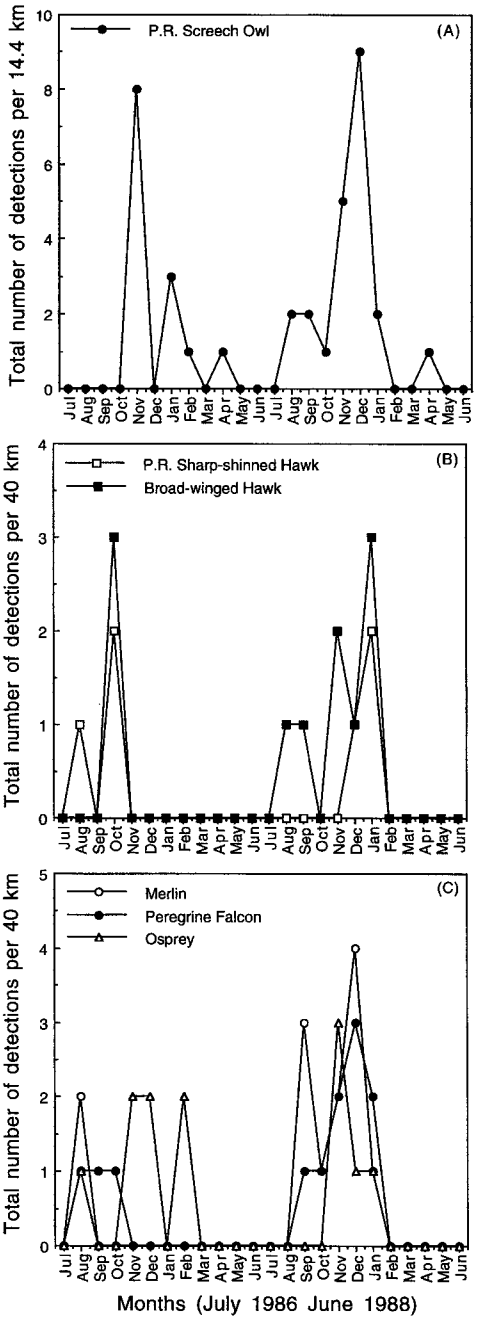
Repeated measures:	Winter	Spring	Summer	Autumn
Life zone				
Dry	1.522	1.230	1.125	1.590
Moist	0.520	0.851	1.259	1.160

The roadside counts of the most common year-round residents were highly variable, even on high-density routes. Annual coefficients of variation (CVs) of the counts of Red-tailed Hawks were in the order of 86-91% (24 counts in ten 8-km routes; Table 1 and Fig. 2A). Similarly, annual CVs of counts of American Kestrels were in the order of 85–101% (Table 1 and Fig. 2B). The counts of both species were positively-skewed and their variances were heterogeneous, but higher counts of Red-tailed Hawks were more extreme (positive) than higher counts of American Kestrels. Red-tailed Hawks were commonly detected soaring in groups of up to 11 birds; whereas American Kestrels usually were detected perching or flying singly or in pairs and had a more regular spatial distribution. The log-transformation normalized and stabilized the variances of the roadside counts.

Sample-size estimates varied by species, spatio-temporal scales, sensitivity (power of a test), and precision (width of a confidence interval). For example, at an α of 0.05 ($t_{0.05} \approx 2.0$) and a CV of 91%, 80 sampling units (8-km routes) were needed to provide confidence limits of $\pm 20\%$ on mean abundance estimates ($\bar{Y}$) of Red-tailed Hawks in the moist zone, and with a CV of 86%, 71 sampling units were needed in the wet zone (Fig. 4). With a CV of 85%, 69 sampling units were needed for American Kestrels in the moist zone; and with a CV of 101%, 98 sampling units

←

FIG. 2. Seasonal abundance patterns of Red-tailed Hawks (A) and American Kestrels (B) in Puerto Rico.


P.R. Screech Owl
(A)
Total number of detections per 14.4 km
P.R. Sharp-shinned Hawk
Broad-winged Hawk
(B)
Total number of detections per 40 km
Merlin
Peregrine Falcon
Osprey
(C)
Total number of detections per 40 km
Months (July 1986 June 1988)

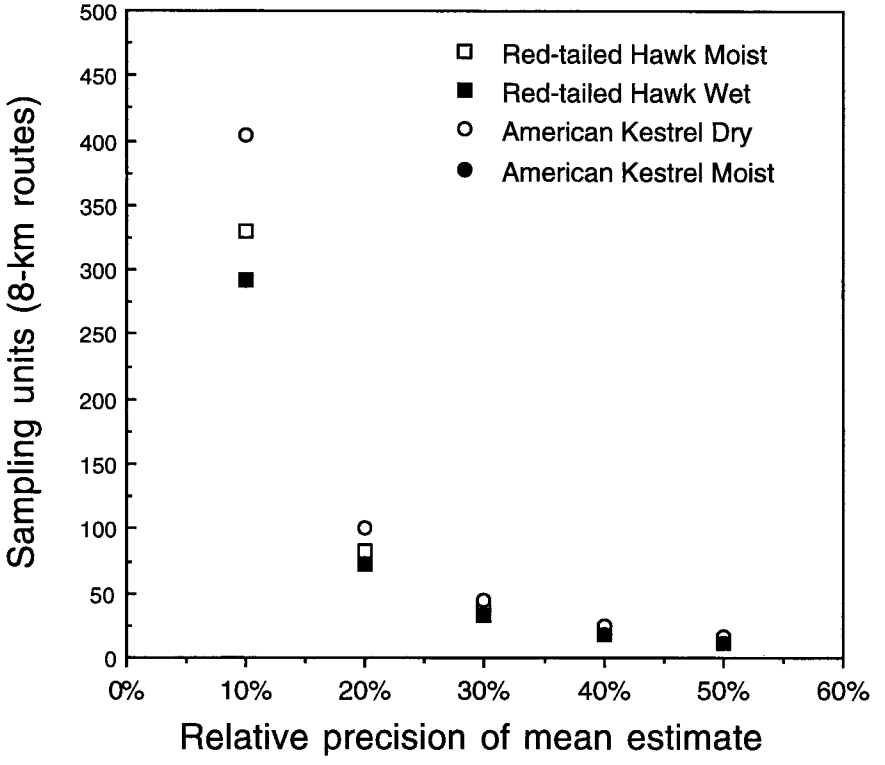


FIG. 4. Number of within-year sample-sizes (8-km routes) needed per life zone to provide confidence limits of ±10–50% ($t_{0.05} \approx 2.0$) on mean abundance estimates ($\bar{Y}$) of Red-tailed Hawks and American Kestrels.

were needed in the dry zone (Fig. 4). Sample-sizes decreased as a function of the desired precision of $\bar{Y}$.

DISCUSSION

The Red-tailed Hawk and American Kestrel were the most abundant year-round residents of Puerto Rico; and the Merlin, Peregrine Falcon, and Osprey were the most abundant winter residents. In general, the abundances of resident and migrant raptors (pooled) peaked from autumn to spring in Puerto Rico.

←

FIG. 3. Seasonal abundance patterns of Puerto Rican Screech-Owls (A), Broad-winged Hawks and Puerto Rican Sharp-shinned Hawks (B), and Merlins, Peregrine Falcons, and Ospreys (C).

The roadside counts of raptors were positively-skewed and their variances heterogeneous. Skewness and heterogeneity are characteristics of populations that are patchily-distributed in space and time because of habitat use and availability (Southwood 1978, Baker and Brooks 1981, Janes 1985, Preston 1990). Forest habitat loss and degradation and illegal hunting have been the major human-induced problems affecting the distribution and abundance of Sharp-shinned Hawks and Broad-winged Hawks in Puerto Rico (Pérez-Rivera and Cotté-Santana 1977, Wiley 1985, Santana et al. 1986, Delannoy and Cruz 1988). Although Sharp-shinned Hawks and Broad-winged Hawks seem to have suffered severe populations declines, mainly as a result of forest fragmentation, the populations of Red-tailed Hawks, American Kestrels, and Screech-Owls seem to have increased in edge habitats in suburban and agricultural landscapes (Wiley 1985). As human disturbance increases in lowland habitats of the moist zone, the abundance of Red-tailed Hawks may increase in montane habitats of the wet zone that are considered of critical importance for species such as Sharp-shinned Hawks, Broad-winged Hawks, and Puerto Rican Parrots (*Amazona vittata*), resulting in an increase of negative interactions (e.g., nestling predation, and competition for limited nest sites and foraging resources; Wiley 1985, Santana et al. 1986, Snyder et al. 1987, Delannoy and Cruz 1988, Lindsey et al. 1994).

The roadside counts were highly variable because of the distribution and abundance of raptors in the life zones. As a result, the within-year sample-sizes (8-km routes) needed to provide confidence limits of $\pm$10-50% on $\bar{Y}$ were high. Presently, 30 8-km routes are sampled annually from the second week of May to the second week of June to monitor the population changes of Zenaida Doves (*Zenaida aurita*) and Scaly-naped Pigeons (*Columba squamosa*) in the three major life zones of Puerto Rico (Ramos et al. 1991), and it has been recommended that the number of routes be increased to 60 (30 in the moist zone, 20 in the wet zone, and 10 in the dry zone; Rivera-Milán 1993). This sampling scheme can be used to monitor annual population changes of widely-distributed and abundant species such as Red-tailed Hawks and American Kestrels inside and outside the forest reserves of Puerto Rico. According to the observed seasonal patterns of abundance, the best time of the year to sample raptor populations would be from August to December.

ACKNOWLEDGMENTS

G. Bonilla, M. Miranda, A. Ortiz, J. Pagán, D. Ramos, and E. Ramos provided field assistance. K. Beal, K. Bildstein, H. Raffaele, and J. Wiley reviewed earlier versions of the manuscript. The late J. Vivaldi provided support as Chief of the Terrestrial Ecology Section, Scientific Research Area, Puerto Rico Dept. of Natural Resources. Support was also provided

by the Marine and Estuarine Environmental Sciences Graduate Program and the Agricultural and Life Sciences Division of the Univ. of Maryland at College Park.

LITERATURE CITED

BAKER, J. A. AND R. J. BROOKS. 1981. Distribution patterns of raptors in relation to density of voles. Condor 83:42–47.

BEAL, K. G. AND H. J. KHAMIS. 1990. Statistical analysis of a problem data set: correlated observations. Condor 92:248–251.

——— and ———. 1991. Reply to Quinn and Keough. Condor 93:202-203.

BIAGGI, V. 1983. Las aves de Puerto Rico. Second ed. Plus Ultra Educational Publishers Inc., New York.

BIRDSEY, R. A. AND P. L. WEAVER. 1982. The forest resources of Puerto Rico. U.S. Dep. Agric. For. Serv. Resour. Bull., SO-85, South For. Exp. Stn., New Orleans, Louisiana.

DELANNOY, C. A. AND A. CRUZ. 1988. Breeding biology of the Puerto Rican Sharp-shinned Hawk (*Accipiter striatus venator*). Auk 105:649–662.

EBERHARDT, L. L. 1978. Appraising variability in population studies. J. Wildl. Manage. 42: 207–238.

EWEL, J. J., AND J. L. WHITMORE. 1973. The ecological life zones of Puerto Rico and U. S. Virgin Islands. For. Serv. Res. Paper ITF-18, Río Piedras, Puerto Rico.

GUREVITCH, J. AND S. T. CHESTER, Jr. 1986. Analysis of repeated measures experiments. Ecology 67:251–255.

JANES, S. W. 1985. Habitat selection in raptorial birds. Pp. 159–188 *in* Habitat selection in birds (M. L. Cody, ed.). Academic Press, New York, New York.

LINDSEY, G. D., W. J. ARENDT, AND J. KALINA. 1994. Survival and causes of mortality in juvenile Puerto Rican Parrots. J. Field Ornithol. 65:76–82.

LITTLE, E. L. F. H. WADSWORTH, AND J. MARRERO. 1977. Arboles comunes de Puerto Rico y las Islas Vírgenes. Editorial Universitaria, Río Piedras, Puerto Rico.

ORTIZ, P. R. 1989. A summary of conservation trends in Puerto Rico. Pp. 851–854 *in* Biogeography of the West Indies: past, present and future (C. A. Woods, ed.). Sandhill Crane Press, Gainesville, Florida.

PÉREZ-RIVERA, R. AND R. COTTÉ-SANTANA. 1977. Algunas notas sobre los falconiformes residentes en Puerto Rico. Science-Ciencia 4:89–95.

PRESTON, C. R. 1990. Distribution of raptor foraging in relation to prey biomass and habitat structure. Condor 92:107–112.

QUINN, G. P. AND M. J. KEOUGH. 1991. Repeated measures analysis of variance: a comment on Beal and Khamis (1990). Condor 93:200–201.

RAFFAELE, H. 1989. A guide to the birds of Puerto Rico and the Virgin Islands. Second edition. Princeton Univ. Press, Princeton, New Jersey.

RAMOS, D., A. BON, F. MAESTRE, AND A. ORTIZ. 1991. Annual performance report. Project W-15-1, Puerto Rico Dept. Nat. Res., Pta. de Tierra, Puerto Rico.

RIVERA-MILÁN, F. F. 1990. Distribution and abundance of columbids in Puerto Rico. Ph.D. diss., Univ. of Maryland, College Park, Maryland.

———. 1992. Distribution and abundance patterns of columbids in Puerto Rico. Condor 94:224–238.

———. 1993. Standardization of roadside counts of columbids in Puerto Rico and on Vieques Island. U.S. Fish Wildl. Serv. Resour. Publ. No. 197.

SANTANA, E. C., E. N. LABOY, J. A. MOSHER, AND S. A. TEMPLE. 1986. Red-tailed Hawk nest sites in Puerto Rico. Wilson Bull. 98:561–570.

SILANDER, S., H. G. DE RUBJO, M. MIRANDA, AND M. VÁZQUEZ. 1986. Compendio enciclo-

pédico de los recursos naturales de Puerto Rico. Estudio IV. Vol. 10. Los bosques de Puerto Rico. Puerto Rico Dept. Nat. Res., Pta. de Tierra, Puerto Rico.

SNYDER, N. F. R., J. W. WILEY, AND C. B. KEPLER. 1987. The parrots of Luquillo: natural history and conservation of the Puerto Rican Parrot. Western Found. Vert. Zool., Los Angeles, California.

SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry: the principles and practices of statistics in biological research. Second ed. W. H. Freeman and Co., New York, New York.

SOUTHWOOD, T. R. E. 1978. Ecological methods. Second edition. Chapman and Hall, New York, New York.

WILEY, J. W. 1985. Bird conservation in the United States Caribbean. Pp. 107–159 *in* Bird conservation, Vol. 2 (S. A. Temple, ed.). The University of Wisconsin Press, Madison, Wisconsin.

WINER, B. J. 1971. Statistical principles in experimental design. Second ed. McGraw-Hill Book Co., New York, New York.