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TIME-OF-DAY EFFECTS ON THE NUMBERS AND BEHAVIOR OF NON-BREEDING RAPTORS SEEN ON ROADSIDE SURVEYS IN EASTERN PENNSYLVANIA

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Abstract.—Results are presented of 30 pairs of morning and afternoon roadside surveys of New World vultures and diurnal birds of prey in farmland habitat in eastern Pennsylvania during the non-breeding season. Eight-hundred-twenty-seven raptors, including members of two species of vultures and 10 species of diurnal birds of prey, were counted on 60 surveys between October 1992 and December 1994. Three species of raptors, Turkey Vulture (*Cathartes aura*), Red-tailed Hawk (*Buteo jamaicensis*) and American Kestrel (*Falco sparverius*), comprised 90% of all birds sighted. Although almost equal numbers of birds were seen on morning and afternoon surveys, species composition, the numbers of birds, and the flight behavior of individual species, differed significantly on morning and afternoon surveys. Time of day of survey affected different species differently. Numbers of Turkey Vultures increased significantly, those of Red-tailed Hawks decreased significantly, and those of American Kestrels remained the same between morning and afternoon surveys. In general, sampling variance was higher on morning than on afternoon surveys. These results, which clearly demonstrate the need to take time of day into account when conducting roadside surveys of raptors, suggest that the ability to compare data from different sites is limited by the extent to which those data were collected at the same time of day.

EFECTOS DE LA HORA-DEL-DÍA EN EL NÚMERO Y COMPORTAMIENTO DE RAPTORES NO-APAREADOS VISTOS EN MUESTREOS POR CARRETERAS EN LA PENNSYLVANIA ORIENTAL

Sinopsis.—Se presentan los resultados de 30 pares de muestreos matutinos y vespertinos de aves carroñeras y rapaces diurnos llevados a cabo en las carreteras en habitat de granjas del en el este de Pennsylvania durante la época de no-apareamiento. Ochocientos veintisiete raptores, incluyendo dos especies de buitres y 10 especies de raptores diurnos, se contaron en 60 muestreos entre octubre del 1992 y diciembre del 1994. Tres especies de raptores, *Cathartes aura, Buteo jamaicensis* y *Falco sparverius,* sumaron 90% de todas las aves vistas. Aunque se observaron casi la misma cantidad de aves en los sondeos matutinos y vespertinos, la composición de especies, los números de aves, y el comportamiento de vuelo de especies individuales fueron significativamente diferentes en los sondeos matutinos y vespertinos. La hora del día afectó diferentemente a diferentes especies. Los números de *C. aura* aumentaron significativamente, los de *B. jamaicensis* decrecieron significativamente y los de *F. sparverius* se mantuvieron iguales en sondeos de mañana y de tarde. En general, la varianza del muestreo fue mayor en los sondeos matutinos que en los vespertinos. Estos resultados, que demuestran claramente la necesidad de considerar la hora del día al conducir sondeos de raptores por las carreteras, sugieren que la habilidad para comparar datos de lugares diferentes está limitada en la medida a que esos datos se hallan obtenido en horas similares.

As populations of open-habitat raptors are widespread and occur at relatively low densities, they are often counted and observed with the use

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of roadside surveys (Fuller and Mosher 1981, 1987; Gawlik and Bildstein 1990). The method typically involves driving at low speeds while counting individuals within a certain distance from the road. Data are usually summarized as numbers of birds seen per unit distance or vice versa. As a result of their relative ease of use and seeming effectiveness, roadside surveys have a long history of use in raptor population biology (e.g., Bildstein 1987, Craighead and Craighead 1956). Although many sources of potential bias exist (Fuller and Mosher 1987, Millsap and LeFranc 1988), properly employed, roadside surveys have enabled workers to assess the species composition and the relative abundances of species in raptor communities, to estimate and monitor populations in given areas, to make inter-site comparisons, and to supplement other population survey techniques (Allan and Sime 1943, Andersen et al. 1985, Bildstein 1987, Brown 1971, Cade 1969, Craig 1978, Craighead and Craighead 1956, Enderson 1965, Hiatt 1944, Mathisen and Mathisen 1968, Nankinov 1977, Rowan 1964, Schnell 1967, Sigfried 1966, White 1965, Woffinden and Murphy 1977).

A major concern regarding the use of roadside surveys in documenting population changes over time is the need to conduct surveys in as consistent a fashion as possible (e.g., Fuller and Mosher 1987, Gawlik and Bildstein 1990). For example, as raptor activity, and presumably detectability, can vary considerably over the course of the day (Bildstein 1987, Craighead and Craighead 1956), researchers are frequently cautioned to conduct roadside counts at specific times of the day to avoid confusing shifts in raptor behavior with shifts in local abundance (i.e., Gawlik and Bildstein 1990, Millsap and LeFranc 1988). Although time of day is known to affect the results of many kinds of avian surveys and censuses (e.g., Robbins 1972, 1981; Robbins and Van Velzen 1970; Shields 1977), the extent to which time of day affects roadside surveys of raptors remains little studied (Robbins 1981). Indeed, we are aware of no study specifically designed to test this suggestion.

As part of its long-term monitoring program of raptor populations in eastern Pennsylvania (cf. Bednarz et al. 1990, Broun 1948), Hawk Mountain Sanctuary began surveying wintering open-habitat raptors along a 45-km survey route in farmland near the Sanctuary in 1987. As a result of the long-term nature of the project, as well as the fact that we wanted to conduct our surveys with as much flexibility as possible, in 1992 we decided to study the impact of time of day on survey results. Here we report the results of that study, together with suggestions regarding the need to take time of day into account when designing similar surveys.

STUDY AREA AND METHODS

Our roadside survey route is centered on Wanamakers, Pennsylvania (40°40′N; 75°50′W), approximately 25 km north of Reading and 20 km west of Allentown, Pennsylvania, in northern Berks and northwestern Lehigh counties. The site consists of rolling, partly wooded, open habitat, in the Kempton Valley at the base of the Kittatinny Ridge, directly south-

TABLE 1. Monthly occurrence of 60, 57-km roadside surveys in eastern Pennsylvania, 1992–1994.

Month	1992	1993	1994	All years
January	0	4	0	4
February	0	4	2	6
September	0	2	6	8
October	6	4	10	20
November	4	4	10	18
December	4	0	0	4
All surveys	14	18	28	60

east of the Ridge and Valley province of the central Appalachian Mountains. Small (approximately 80-ha), owner-operated dairy, hog, poultry, Christmas-tree, grain, hay and vegetable farms, with numerous fencerows, woodlots and riparian forests dominate the area.

From October through February 1992–1993, September through February 1993–1994, and September through December 1994, we conducted 30 paired morning and afternoon roadside surveys along a figure-eight-shaped, 57-km route. Most of the route consisted of secondary roads with little morning or afternoon traffic. Paired surveys were conducted at approximately 1–3-wk intervals (Table 1) in a vehicle traveling at 17–40 km/h along the survey route. Eighty-five percent of the surveys were conducted by one observer, 10% by two observers and 5% by three observers. Additional observers, who occurred equally on morning and afternoon surveys, spent much of the time recording observations of the primary observer. Morning surveys began at 0847–1023 hours EST (i.e., within approximately 2–4.5 h of local sunrise). Afternoon surveys began at 1240–1440 hours EST and ended at 1443–1643 hours EST. Surveys took approximately 2–4 h to complete, depending upon the numbers of birds seen. Morning surveys were paired with afternoon surveys conducted on the same day (five pairs), consecutive days (24 pairs), or with a l-d interval (1 pair). To reduce temporal and directional biases, the direction of travel was reversed on alternate pairs of surveys and initiation points along the survey loop were staggered. Surveys were not conducted in periods of constant precipitation, fog, especially high winds (>25 miles/h) or low temperatures (<−10 C). Binoculars and a 20–60× spotting scope were used to identify sighted raptors.

All falconiforms, including New World vultures, sighted from the moving vehicle within 0.4 km from either side of the road were included in the count. Birds were identified to species, and their behavior when first sighted (perched vs. flying) was recorded. (Birds that were first sighted as they left a perch were recorded as perched.) No vulture roosts were recorded along the survey route.

We used chi-squared tests for heterogeneity, and paired *t*-tests (SAS 1988) to analyze the extent of differences in the behavior and numbers of raptors sighted on morning versus afternoon surveys. All tests were

TABLE 2. Numbers of birds seen (and % flying in parentheses) during 30 pairs of morning and afternoon 57-km roadside surveys in eastern Pennsylvania, 1992–1994.

Species	No. birds seen (% flying)			
	Mornings	Afternoons	All surveys	km/bird
Black Vulture (*Coragyps atratus*)	7 (100)	5 (40)	12 (75)	285
Turkey Vulture (*Cathartes aura*)	99 (82)	184 (99)	283 (93)	12.1
Osprey (*Pandion haliaetus*)	3 (100)	0	3 (100)	1140
Northern Harrier (*Circus cyaneus*)	9 (89)	15 (100)	24 (96)	143
Sharp-shinned Hawk (*Accipiter striatus*)	14 (79)	5 (100)	19 (84)	180
Cooper's Hawk (*A. cooperii*)	13 (23)	5 (40)	18 (28)	190
Northern Goshawk (*A. gentilis*)	0	1 (100)	1 (100)	3420
Red-shouldered Hawk (*Buteo lineatus*)	1 (0)	0	1 (0)	3420
Broad-winged Hawk (*B. platypterus*)	1 (100)	0	1 (100)	3420
Red-tailed Hawk (*B. jamaicensis*)	110 (34)	71 (56)	181 (42)	18.9
Rough-legged Hawk (*B. lagopus*)	1 (100)	2 (50)	3 (67)	1140
American Kestrel (*Falco sparverius*)	127 (19)	154 (14)	281 (16)	12.2
All species	385 (46)	442 (61)	827 (54)	4.14

two-tailed. We considered a significant difference to exist if $P < 0.05$. We used Coefficients of Variation (Sokal and Rohlf 1969) to compare variability in counts in morning and afternoon surveys.

RESULTS

Eight-hundred-twenty-seven birds, including two species of New World vultures and 10 species of diurnal raptors, were counted over the course of our study (Table 2). The three most common species, Turkey Vulture (*Cathartes aura*) (34%), Red-tailed Hawk (*Buteo jamaicensis*) (22%) and American Kestrel (*Falco sparverius*) (34%), comprised 90% of all birds sighted. Northern Harriers (*Circus cyaneus*) comprised 3%, and three species of accipiters, Sharp-shinned Hawks (*Accipiter striatus*), Cooper's Hawks (*A. cooperii*) and Northern Goshawks (*A. gentilis*), together, comprised an additional 5% (Table 2). Turkey Vultures were seen on 57%, Red-tailed Hawks on 90% and American Kestrels on 100% of all surveys. No other species was seen on more than 25% of the surveys. As a result of the small sample sizes of most species sighted, we restricted our analyses of individual-species effects to the three most numerous species, and to the three accipiter species considered together.

Forty-seven percent of all birds sighted were seen on morning surveys, whereas 53% were seen on afternoon counts ($t = -0.919$, 29 df, $P = 0.366$). Excluding vultures from the analysis, 53% of diurnal raptors sighted were seen on morning surveys, whereas 47% were seen on afternoon counts ($t = 0.846$, 29 df, $P = 0.404$). Species composition (with the three accipiters and the six least common species grouped into two categories for purposes of analyses) changed significantly between morning and afternoon counts, both with ($\chi^2 = 38.5$, 4 df, $P < 0.0001$) and without vultures ($\chi^2 = 15.3$, 3 df, $P = 0.002$) included in the analysis (Table 2).

TABLE 3. Coefficients of Variation[a] (%) for numbers of Turkey Vultures, Red-tailed Hawks, American Kestrels, accipiters, and all raptors sighted on 30 pairs of morning and afternoon, 57-km roadside surveys in eastern, Pennsylvania, 1992–1994.

Species	Morning	Afternoon	Morning/ Afternoon
Turkey Vultures	148	134	1.10
Red-tailed Hawks	83.9	73.1	1.15
American Kestrels	89.8	62.6	1.43
All birds excluding vultures	69.8	44.3	1.58
All birds including vultures	73.2	66.6	1.10

[a] Coefficients of Variation ([standard deviation of the mean × 100]/mean) are measures of variation, expressed as percentages, that are independent of the magnitude of the mean.

Coefficients of variation in the numbers of individuals sighted were higher for morning than for afternoon counts (Table 3).

Forty-six percent of all birds sighted during morning surveys were flying when first seen, compared with 61% of birds sighted on afternoon counts ($\chi^2 = 18.9$, 1 df, $P < 0.001$). When vultures are excluded, the percentages of birds flying in morning and afternoon surveys were 32 and 34%, respectively ($\chi^2 = 0.001$, 1 df, $P = 0.97$).

Turkey Vultures were less likely, and accipiters and Red-tailed Hawks were more likely to be seen on morning than on afternoon counts ($t = -2.11$, 29 df, $P = 0.043$; $t = 2.10$, 29 df, $P = 0.044$; $t = 2.67$, 29 df, $P = 0.012$) (Fig. 1). There was no significant difference in sighting rates for American Kestrels during morning and afternoon counts ($t = -1.23$, 29 df, $P = 0.226$) (Fig. 1).

Turkey Vultures and Red-tailed Hawks ($\chi^2 = 32.0$, 1 df, $P < 0.0001$; $\chi^2 = 8.03$, 1 df, $P = 0.005$; respectively), but not accipiters or American Kestrels ($\chi^2 = 1.40$, 1 df, $P = 0.237$; $\chi^2 = 1.08$, 1 df, $P = 0.298$; respectively), were less likely to be seen flying in morning than in afternoon counts (Fig. 1).

DISCUSSION

Although total numbers of raptors did not differ significantly between morning and afternoon surveys, species composition, together with both the numbers and behavior of two of the three most common species did change significantly with time of day. Numbers of Turkey Vultures, for example, almost doubled on afternoon surveys, whereas those of Red-tailed Hawks dropped by more than a third (Fig. 1). Numbers of accipiters sighted also decreased significantly on afternoon surveys. Moreover, both Turkey Vultures and Red-tailed Hawks were more likely to be perched when first seen on morning than on afternoon surveys (Fig. 1). On the other hand, American Kestrels, the second most common species encountered on our surveys, exhibited little variation in either numbers seen or activity as a function of time of day.

In general, our results of shifts in flight activity over the course of the

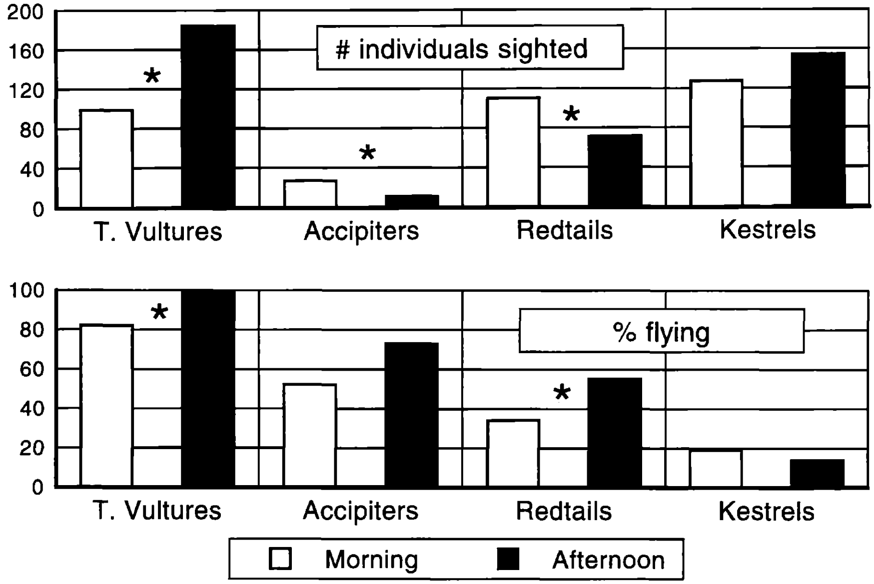

FIGURE 1. Numbers of Turkey Vultures, accipiters (Sharp-shinned Hawks, Cooper's Hawks, and Northern Goshawks), Red-tailed Hawks, and American Kestrels seen on 30 pairs of morning-afternoon roadside surveys in eastern Pennsylvania, 1992–1994 (top). Percentages of Turkey Vultures, accipiters, Red-tailed Hawks, and American Kestrels that were flying when first sighted on morning and afternoon roadside surveys (bottom). Asterisks indicate significant ($P < 0.05$) species differences between morning and afternoon results. (See text for details.)

day confirm those of earlier studies. Turkey Vultures, *Buteos,* and other soaring species frequently remain perched in early morning until thermals and updrafts enable soaring flight (Brown and Amadon 1968, Fuller and Mosher 1981, Rabenold 1983). Although individual Eurasian Kestrels (*F. tinnunculus*) are capable of maintaining daily activity rhythms in synchrony with their prey (Rijnsdorp et al. 1981), both American (Bildstein and Collopy 1987) and Eurasian Kestrels (Village 1983) apparently remain active throughout the day when prey are uniformly available and weather is not severe (Bildstein and Collopy 1987). Furthermore, both Bildstein (1987) and Diesel (1984) reported seeing fewer flying and more perched Red-tailed Hawks on mid-morning versus mid-afternoon surveys, whereas Bildstein (1987) reported no difference in the flight activity of kestrels during the same periods, and Roest (1957) reported kestrels hunting both in morning and late afternoon.

Increases in the numbers of Turkey Vultures sighted on afternoon surveys almost certainly reflect the greater flight activity of that species later in the day (Brown and Amadon 1968), coupled with increases in the observability of flying individuals. Decreases in the numbers of Red-tailed Hawks sighted on afternoon surveys are a bit more difficult to explain, however. Although Red-tailed Hawks, too, were more likely to be seen flying on afternoon than on morning surveys, the difference results largely from a 56% decrease in numbers of perched birds seen later in the day (2.43 vs. 1.07 individuals/route), rather than to a 6% increase in numbers of birds seen flying (1.23 vs. 1.30 individuals/route). Perched raptors frequently perch in less-exposed sites during periods of high winds (Bildstein 1987), and one reasonable explanation for the substantial decrease in numbers of perched Red-tailed Hawks sighted on afternoon counts is that individuals that perched at those times were more likely to be seeking shelter from increased afternoon winds.

Whatever the reasons for the differences observed, our results confirm earlier suggestions (e.g., Fuller and Mosher 1987, Gawlik and Bildstein 1990) that time of day significantly affects the results of roadside surveys of raptors. Indeed even counts of American Kestrels, a species for which neither the mean numbers of birds sighted nor flight activity changed as a function of time of day, exhibited a substantial shift in variance between morning and afternoon surveys. Viewed in their entirety, our findings clearly demonstrate the need (1) to account for time-of-day effects when conducting roadside surveys of raptors and (2) to consider this factor when comparing the results of different surveys.

How best to account for time-of-day effects will probably depend upon the purpose, or purposes, of a given study. For example, our results suggest that investigators interested in quantifying species representation in raptor communities or the behavior of individual species within those communities will need to sample the populations (i.e., conduct roadside surveys) at different times of the day, and then take time of day into account when analyzing their data (e.g., Diesel 1984). When this is not possible, at the very least, temporal biases should be reduced by sampling equitably throughout the course of a study (Shields 1977). On the other hand, our findings suggest that individuals involved in monitoring fluctuations of populations of raptors over long periods should be able to do so by fixing the time of day of their surveys within relatively narrow limits, and then considering their results as indexes, only.

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