Ridge Adherence in Bald Eagles Migrating along the Kittatinny Ridge between Bake Oven Knob and Hawk Mountain Sanctuary, Pennsylvania, Autumn 1998-2001

Steven Hawk
Wildlife Information Center, P.O. Box 198, Slatington, PA 18080
Nigar Agayeva Chingiz kizi, John Musina, and Kyle McCarty
Acopian Center for Conservation Learning, Hawk Mountain Sanctuary
410 Summer Valley Road, Orwigsburg, PA 17961

Introduction

The broad-frontal migrations of raptors often are affected by geographic features or "leading lines" (*sensu* Geyr von Schweppenburg 1963), including river systems and mountain ridges, that attract and concentrate the migrants and influence their direction of travel (Kerlinger 1989). Many hawkwatches, including those along the Kittatinny Ridge in the Central Appalachian Mountains of eastern Pennsylvania, are along leading lines (Heintzelman 1975). The extent to which individual migrants remain along leading lines, including the Kittatinny, which concentrates southbound migrants because of slope-soaring opportunities there, has attracted the attention of hawkwatchers for some time. Frey (1940) compared autumn hawk counts at Hawk Mountain Sanctuary with those at Sterrett's Gap, two hawkwatches 112 km (70 miles) apart on the Kittatinny using counts from 1938 and 1939. He concluded that "perhaps" 70% of the raptors reported at Hawk Mountain were not reported down-ridge at Sterrett's Gap. More recently, Heintzelman (1982) compared Bald Eagle (*Haliaeetus leucocephalus*) and Golden Eagle (*Aquila chrysaetos*) counts at Bake Oven Knob with those at Hawk Mountain, two sites that are 26 km (16 miles) apart on the ridge. His analyses, which were based on counts between 1968 and 1981, led him to conclude that 35% of Golden Eagles and 32% of Bald Eagles reported at Bake Oven Knob were not reported down-ridge at Hawk Mountain Sanctuary.

Here we report a new analysis of ridge adherence by Bald Eagles along the Kittatinny between Bake Oven Knob and Hawk Mountain Sanctuary, in which we compare adherence in adult and immature Bald Eagles during the 1998, 1999, 2000, and 2001 autumn migration seasons, when populations of Bald Eagles in eastern North America, and the numbers of Bald Eagles using the ridge had increased substantially from those of Heintzelman's (1982) earlier study (Bildstein 1998).

Methods

Bake Oven Knob (40° 44'N, 75° 44'W) is a mountaintop watchsite on the Kittatinny Ridge in northern Lehigh County, 11 km west of Slatington, Pennsylvania. Hawk Mountain Sanctuary (40° 38'N, 75° 59'W) is a mountaintop watchsite 26 km west-southwest of Bake Oven Knob in Berks and Schuylkill Counties, 10 km west of Kempton, Pennsylvania. Autumn counts of migrating raptors have been made at Bake Oven Knob since 1961 and at Hawk Mountain since 1934 (Heintzelman 1975; see Swartzentruber and Beck 2001 for details on recent count efforts at the two sites). Each site records the age (immature versus adult and, in some instances, age-in-years for immatures) of individual eagles, as well as the time of day in hours and minutes each eagle passes the watchsite. In our analysis adults included only those individuals whose head feathers, tail feathers, and tail coverts appeared completely white. All other individuals, which included 1st, 2nd, 3rd and 4th year birds, were considered immatures (see Clark and Wheeler 1987 for details).

Using Bald Eagles reported at the two watchsites on days when both sites were operating between 15 August and late November 1998-2001, we classified individuals as (1) birds seen only at Bake Oven

Knob, (2) birds seen only at Hawk Mountain Sanctuary, and (3) birds seen at both sites. We considered a bird to be seen at both sites when an individual seen at Bake Oven Knob could be paired with one seen at Hawk Mountain Sanctuary based on the relative timing of an observation of a same-age bird at the latter site. Bald Eagles migrating in direct flight at Hawk Mountain Sanctuary have been reported traveling at 36 to 44 mph (Broun and Goodwin 1943). Therefore, in our analysis we assumed that Bald Eagles traveling the 26 km (16 miles) between Bake Oven Knob and Hawk Mountain Sanctuary would require at least 20 minutes to complete their trip. Because many Bald Eagles thermal- as well as slope-soar while migrating along the ridge, and because individuals doing so travel at much lower speeds, we estimated that some eagles would take three to six times the minimum amount of 20 min (i.e., 60 to 120 min) to complete the trip between the two sites. Thus, we conducted three analyses using 20 to 60-min, 20 to 90-min, and 20 to 120-min temporal criteria for pairing observations at the two sites. We restricted our analyses to birds seen after 12 noon because we wanted to reduce the possibility of misidentifying as "Hawk Mountain only" rather than "paired" birds that had interrupted their trip to roost at night between the two sites; and to birds seen no later than 1600 (4 p.m.) local time at Bake Oven Knob, and 60, 90, or 120 min later at Hawk Mountain Sanctuary. On days when observers at Bake Oven Knob stopped counting before 1600, we used only birds seen with 60, 90, and 120 min of that time at Hawk Mountain Sanctuary.

Results

Observers reported a total of 1058 Bald Eagles at the two sites from mid-August through late November 1998-2001. Numbers of eagles reported at Bake Oven Knob ranged from 65 in 1998 to 173 in 2001; whereas at Hawk Mountain, numbers ranged from 121 in 2000 to 155 in 1999 (Table 1). Counts adjusted for hours of observation tended to be higher at Bake Oven Knob, and there is no indication that adjusted counts from the two sites were correlated among years (Figure 1). Numbers of eagles used in our analyses ranged from 36 in 1998 to 111 in 2001 at Bake Oven Knob; and from 74 in 1998 to 97 in 2001 at Hawk Mountain Sanctuary (Table 1).

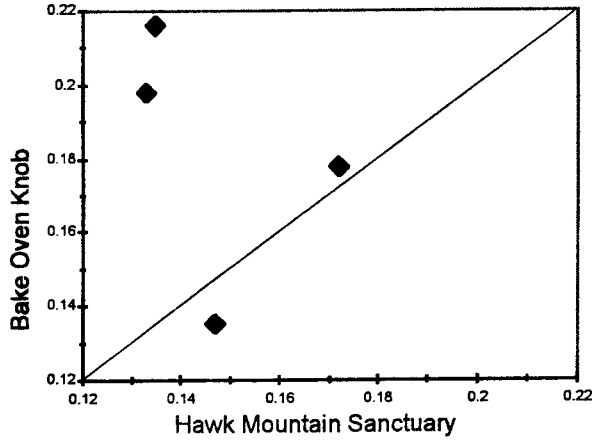


Figure 1. Bald Eagles per hour at BOK and HMS, 1998-2001

Table 1. Numbers of Bald Eagles seen and numbers of Bald Eagles used in analyses of ridge adherence between raptor-migration watchsites at Bake Oven Knob (BOK) and Hawk Mountain Sanctuary (HMS), Pennsylvania, 1998-2001.

Numbers of eagles seen or used	1998		1999		2000		2001	
	BOK	HMS	BOK	HMS	BOK	HMS	BOK	HMS
Total numbers of eagles seen	65	148	123	155	138	121	173	135
Numbers of eagles used in:								
20-60 min analysis	36	74	71	95	79	80	111	96
20-90 min analysis	38	75	69	99	77	81	109	96
20-120 min analysis	39	87	67	100	76	82	109	97

Paired eagles ranged from a low of 26% in 2000 at Hawk Mountain Sanctuary, using the 20 to 60-minute criterion, to a high of 72% in 1998 at Bake Oven Knob, using the 20 to 120-minute criterion (Figure 2). Fewer birds were classified as paired at Hawk Mountain Sanctuary than at Bake Oven Knob regardless of the criterion used (34% vs. 40% [20 to 60 min], 41% vs. 49% [20 to 90 min], and 45% vs. 57% [20 to 120 min]) (Figure 2).

Fig 2(a)

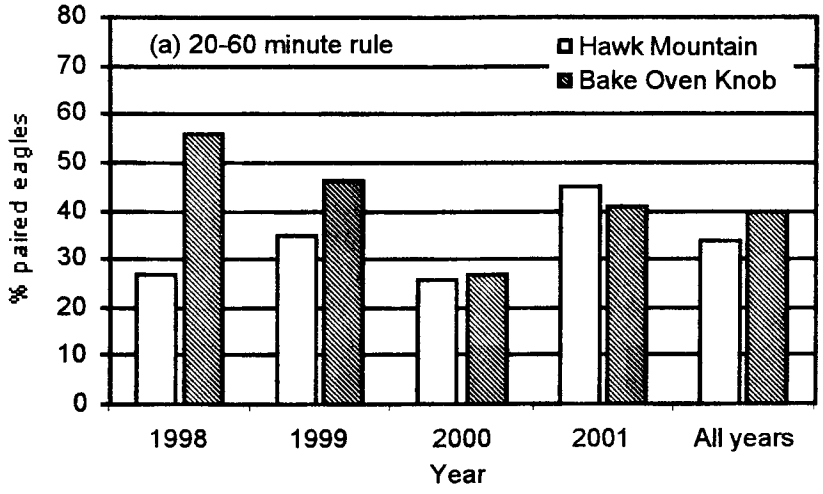


Fig 2(b)

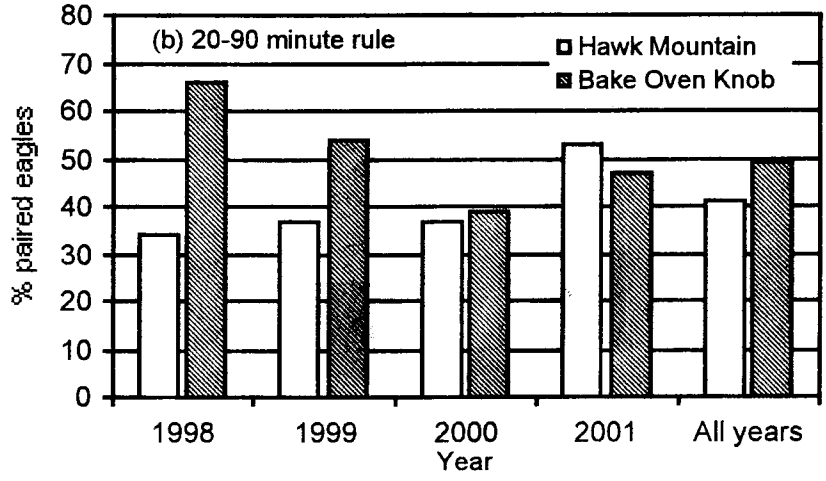


Fig 2(c)

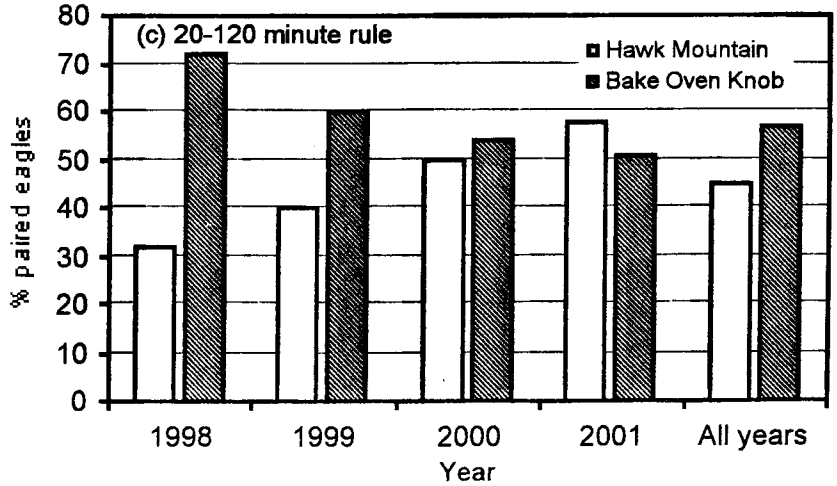


Figure 2. Percentages of paired Bald Eagles at BOK and HMS by year for three different time allowances

Slightly fewer adults than immatures were recorded as paired (35% vs. 39%, 41% vs. 47%, and 47% vs. 53%) regardless of the criterion used (Figure 3).

Fig 3(a)

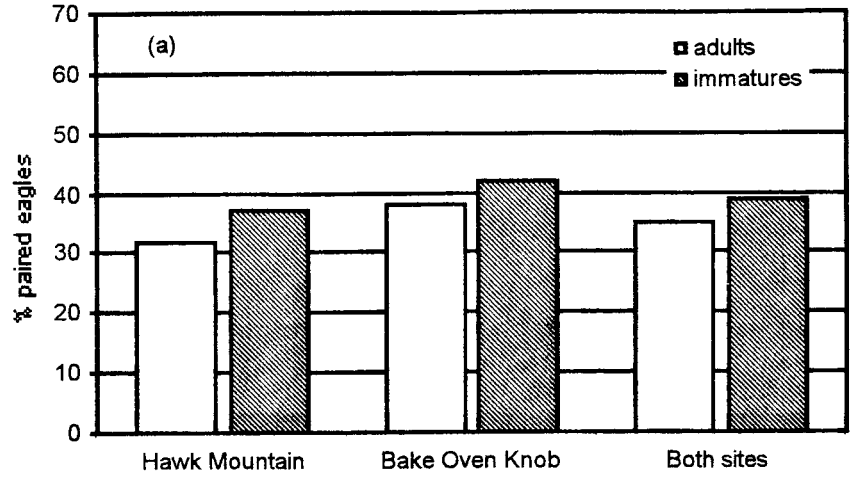
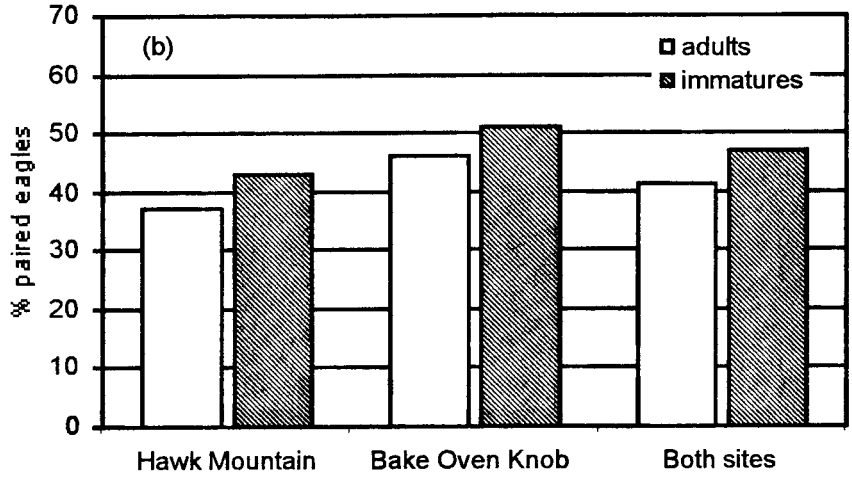


Fig 3(b)



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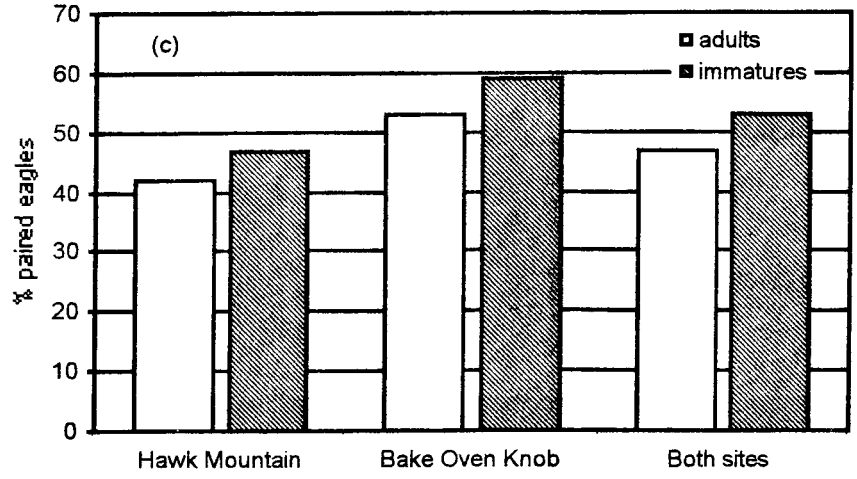
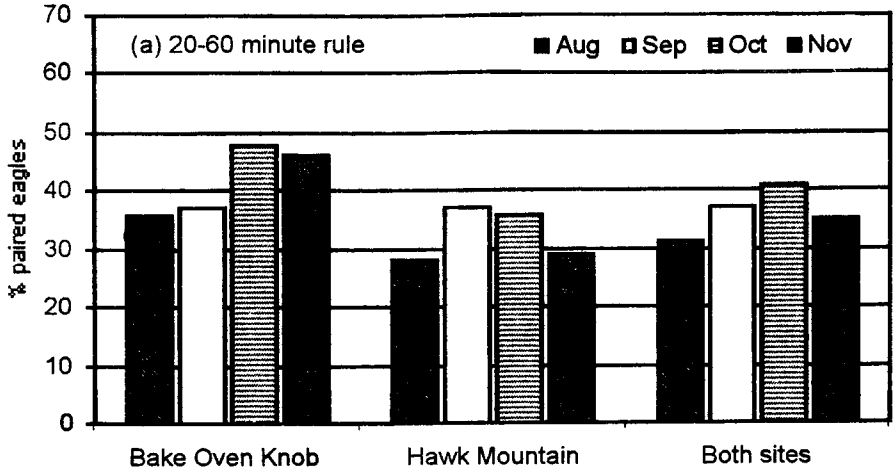


Figure 3. Percentages of adult and immature Bald Eagles at BOK and HMS that were paired.

Eagles were more likely to be classified as paired at Hawk Mountain Sanctuary in September than in other months, particularly when the 20 to 90-minute and 20-to 120-minute criteria were used; but were more likely to be classified as paired at Bake Oven Knob in October and November, particularly when the 20 to 60-minute criterion was used (Figure 4).

Fig 4(a)



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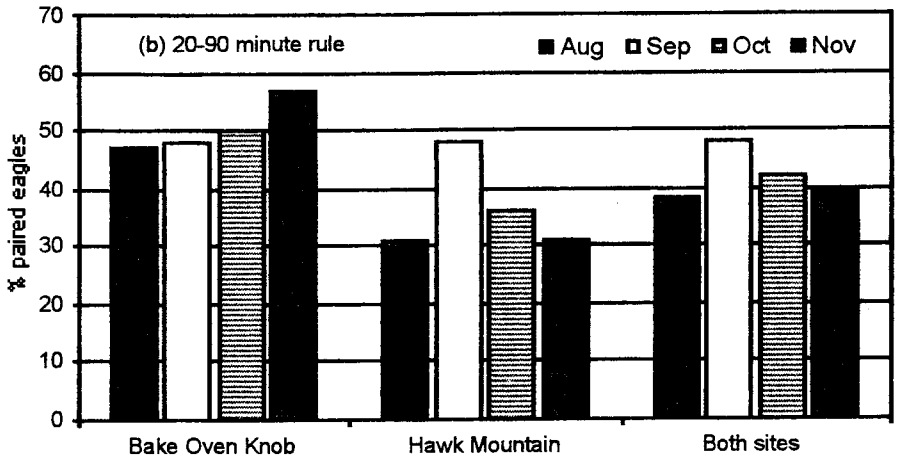

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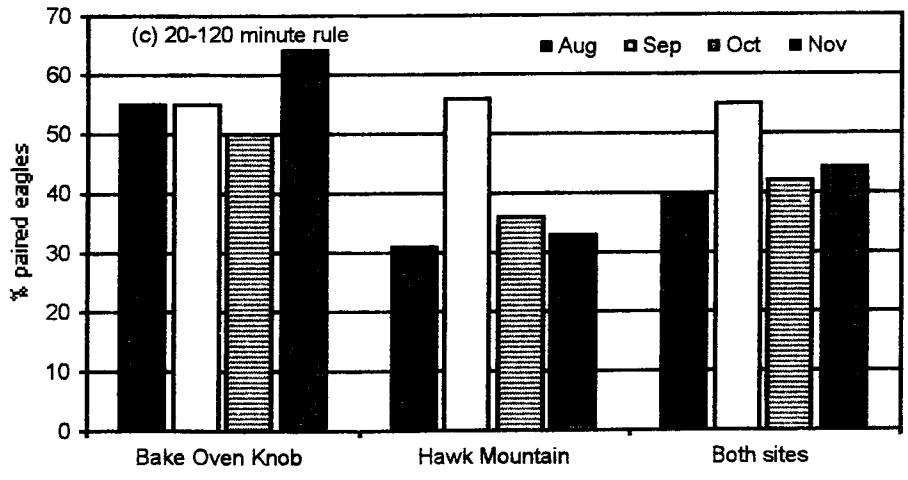

Figure 4. Percentages of paired Bald Eagles at two sites that were paired in each month.

Discussion

Our results suggest that many of the Bald Eagles reported traveling along the Kittatinny at Bake Oven Knob are not the same birds reported 26 km down-ridge at Hawk Mountain Sanctuary, and vice versa. This finding, which confirms and extends earlier studies of the extent of ridge adherence along the Kittatinny (Frey 1940, Heintzelman 1982), has important implications both for raptor-migration science and raptor conservation.

With regard to migration science, our analyses suggest that fewer than half of the birds reported at Bake Oven Knob also are reported at Hawk Mountain Sanctuary. Although the Kittatinny Ridge is oriented mainly northeast to southwest along its entire length, it is oriented east-northeast to west-southwest between these two points of observation. Thus along this portion of its length, the Kittatinny serves principally to "divert" rather than "lead" southbound eagles in autumn, and its attraction for energetically inexpensive slope soaring may be mitigated by the fact that it detours individuals traveling along it. If this is true, we would expect to see greater ridge adherence on days when strong northwesterly winds enhance and increase opportunities for slope soaring the ridge. Additional analyses are needed to test this possibility.

With regard to raptor conservation, our analyses suggest that the many Kittatinny ridge-top watchsites now in operation are counting both overlapping and somewhat independent "populations" of Bald Eagles, and that the numbers of these birds migrating south through eastern Pennsylvania is greater than heretofore estimated. Indeed our results suggest that at least some and perhaps a sizeable portion of the regional population is traveling south undetected by any count site. In addition, ridge adherence appears to vary substantially among years (Figure 2a), perhaps as a result of differences in wind conditions. These observations should be taken into account when counts of Bald Eagles at such watchsites are used to monitor this population.

Our results also suggest that immature Bald Eagles are more likely to remain along the Kittatinny between Bake Oven Knob and Hawk Mountain Sanctuary than are adult Bald Eagles. In other species of raptors, including both Sharp-shinned Hawks (*Accipiter striatus*) (Viverette et al. 1996) and Broad-winged Hawks (*Buteo platypterus*) (Darrow 1983), first-year individuals appear more likely to concentrate along leading- and diversion-lines. Our results suggest that the same is so for Bald Eagles. This may be because younger, less-experienced birds are more likely to be attracted to the movements of conspecifics during their migrations or because younger birds are less efficient at securing ample fat stores prior to migration and, therefore, are more dependent upon atmospheric sources of energy to fuel their movements. Both of these possibilities merit additional study. Whatever the explanation, if immature Bald Eagles are more likely to remain on the ridge than are adults and, therefore, are more likely to be counted at ridge-top watchsites than adults, studies that use the ratio of adult-to-immature birds to assess population increases or decreases (see Bildstein 1998), should take this behavioral difference into account.

Finally, we believe that our methods may have been compromised by differences in count effort, both between the two sites overall, and within Bake Oven Knob itself seasonally. Many site-specific factors including atmospheric conditions, topography, and observer numbers, can affect the likelihood of identifying and reporting theoretically detectable migrants. Both number of observers and numbers of observation hours and observation days tend to be greater at Hawk Mountain Sanctuary than at Bake Oven Knob. The latter two differences may explain, in part, the greater numbers of eagles counted at the latter site when numbers are adjusted for hours of observation, whereas the former probably explains why a greater percentage of birds reported at Bake Oven Knob also were reported at Hawk Mountain Sanctuary, rather than vice versa. Also, the increased percentage of paired birds seen at Hawk Mountain Sanctuary in September compared with other months, particularly when the 20 to 90-min and 20 to

120-min criteria were used, may be due to the fact that September flights represent peak movements of Bald Eagles, when both sites often report 10 or more eagles on single days. At such times, observations characterized as representing "paired" eagles, are more likely to represent those of two individual birds—one seen at Bake Oven that moved off ridge before reaching Hawk Mountain, and a second that approached the ridge west of Bake Oven Knob and continued to fly along it past Hawk Mountain—than are observations made on low-count days.

Acknowledgments

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