

# Ridge Adherence in Golden Eagles Migrating along the Kittatinny Ridge between Bake Oven Knob and Hawk Mountain Sanctuary, Pennsylvania, Autumn 2000-2002

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## Introduction

The Golden Eagle (*Aquila chrysaetos*) in North America is a partially migratory raptor that concentrates on outbound migration along the Rocky Mountains in the West and the Appalachian Mountains in the East (Kochert et al. 2002). Geographic features such as mountain ranges are known as "leading lines" for migrating birds (Geyr von Schweppenburg 1963). Leading lines influence raptor migrations by concentrating numbers of migrants along them and by influencing flight direction (Kerlinger 1989).

The Kittatinny Ridge in the Central Appalachian Mountains of eastern Pennsylvania is one such leading line, which has contributed to the establishment of many hawkwatches along the ridge (Heintzelman 1975, 1979, 1986). For many years hawkwatchers, including those along the Kittatinny, have questioned the extent to which migrants adhere to leading lines. Based on a two-year comparison study of autumn migration counts at Sterrett's Gap and Hawk Mountain Sanctuary, two Pennsylvania hawkwatches that are 112km (70mi) apart along the Kittatinny Ridge, Frey (1940) concluded that approximately 70% of raptors reported at Hawk Mountain (the up-ridge site) were not observed down ridge at Sterrett's Gap. Bake Oven Knob, another hawkwatch on the Kittatinny, is 26km (16mi) up-ridge from Hawk Mountain. Heintzelman (1982) used data from 1968 through 1980 to compare counts of Bald Eagles (*Haliaeetus leucocephalus*) and Golden Eagles at these two latter sites and concluded that 32% of Bald Eagles and 35% of Golden Eagles reported at Bake Oven Knob were not seen at Hawk Mountain Sanctuary. A similar study, based on migration count data of Bald Eagles from 1998 through 2001, found that more than half of the eagles seen at Bake Oven Knob were not the same birds recorded down-ridge at Hawk Mountain Sanctuary. The results from this study also suggested that immature Bald Eagles were more likely to remain along the Kittatinny Ridge between the two watch sites than were adult Bald Eagles (Hawk et al. 2002).

We present the results of a study that investigated ridge adherence of migrating Golden Eagles along the Kittatinny between Bake Oven Knob and Hawk Mountain Sanctuary. Using migration count data from 2000, 2001, and 2002, we report on adherence in both immature and adult Golden Eagles.

## Methods

Autumn counts of migrating raptors have occurred at Bake Oven Knob (BOK) since 1961 and at Hawk Mountain Sanctuary (HMS) since 1934 (Bildstein, 1998). Both of these sites are on the Kittatinny Ridge (Heintzelman 1975; see Swartzentruber and Beck 2001 for details on recent count efforts). Bake Oven Knob (40° 44' N, 75° 44' W) is in northern Lehigh County, 11 km (6.5 mi) west of Slatington, Pennsylvania. Hawk Mountain Sanctuary (40° 38' N, 75° 59' W) is 26 km (16 mi) west-southwest of Bake Oven Knob in Berks and Schuylkill Counties, 10 km (6 mi) west of Kempton, Pennsylvania. Counters at both watch sites record the age (immature versus adult) of individual Golden Eagles, as well as the time of day (EST) each eagle passes the site. Golden Eagles were considered adults or immatures according to Clark and Wheeler 1987.

In our study, we used Golden Eagles that were reported at the two watch sites on days when both sites were counting migrants in September-November 2000-2002. Our analyses follow the protocols developed by Hawk et al. (2002). Specifically, each bird was classified as (1) a bird seen only at Hawk Mountain Sanctuary, (2) a bird seen only at Bake Oven Knob, or (3) a bird seen at both sites. A bird was considered seen at both sites when an individual eagle seen at Bake Oven Knob could be paired with an eagle seen at Hawk Mountain Sanctuary based on the relative timing of the observation of a same-age bird at the latter site. There were two instances when an eagle of an unknown age at one site was paired with an aged eagle at the other site.

In straight-line flight, Golden Eagles have been recorded flying past HMS at 28-32 mph (Broun and Goodwin 1943). Therefore, we assumed that it would require at least 20 minutes for a Golden Eagle to travel the 26 km (16 mile) route from Bake Oven Knob to Hawk Mountain Sanctuary. Because some Golden Eagles thermal- as well as slope-soar when migrating along the ridge, and because doing so causes a bird to spend more time traveling between the two sites, we estimated that some eagles would take three to six times the minimum time of 20 minutes (i.e., 60 to 120 minutes) to complete the trip between Bake Oven Knob and Hawk Mountain Sanctuary. We conducted three separate analyses using 20 to 60 minutes, 20 to 90 minutes, and 20 to 120 minutes as criteria for pairing observations of eagles at the two sites. We restricted our analyses to birds seen after 12:00 noon at Hawk Mountain Sanctuary because we wanted to reduce the possibility of misidentifying a "paired" bird as "Hawk Mountain Sanctuary only" since Golden Eagles sometimes roost between the two sites. We also restricted our analyses to birds seen no later than 16:00 (4 p.m.) at Bake Oven Knob, and 60, 90, or 120 minutes later at Hawk Mountain Sanctuary. On days when observations stopped at Hawk Mountain Sanctuary before 18:00 we used only birds that had passed Bake Oven Knob at least two hours earlier than the time the HMS count had ceased. Also, on days when observation stopped at Bake Oven Knob before 16:00, we used only birds seen at Hawk Mountain Sanctuary within 60, 90, or 120 minutes of the time that the Bake Oven Knob count had ceased.

### Results

From September to November 2000, 2001, and 2002, 476 Golden Eagles were recorded at Bake Oven Knob and Hawk Mountain Sanctuary. Annual counts ranged from 57 (2001) to 81 (2002) at Bake Oven Knob, and from 81 (2001) to 104 (2002) at Hawk Mountain Sanctuary (Table 1). Once they had been adjusted for hours of observation, annual counts appeared to be correlated between the two sites (Fig. 1). The number of records eligible for analysis under at least one time rule ranged from 38 (2001) to 64 (2002) at BOK and from 47 (2000) to 55 (2002) at HMS (Table1).

The percentages of eagles paired ranged from 31% (in 2001 at Hawk Mountain Sanctuary, using the 20 – 60 minute rule) to 50% (in 2001 at Bake Oven Knob, using the 20 – 120 minute rule). When data from all years were combined, regardless of time criteria, the percentage of birds paired at Hawk Mountain Sanctuary was equal to or slightly lower than (3%) those paired at Bake Oven Knob (Fig. 2).

There was no indication that either age class was more likely to be paired overall. However, the relative likelihood of pairing depended on which criterion was used, with

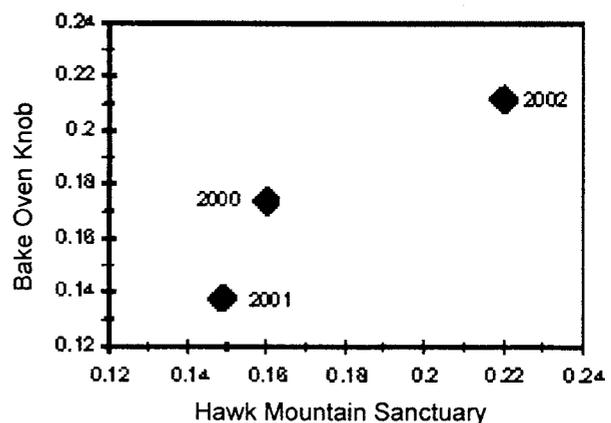


Fig. 1 Golden Eagle per hour at Bake Oven Knob and Hawk Mountain Sanctuary, 2000-2002

more adults being paired under the shortest time rule (43%) and more immatures being paired under the longest time rule (44%) (Fig. 3).

Only two Golden Eagles were counted in September. Overall, birds were more likely to be paired under the shortest time rule in November (44%), and were more likely to be paired under the longest time rule in October (42%) (Fig. 4).

**Table 1.** Numbers of Golden Eagles seen and used in analyses of ridge adherence between Bake Oven Knob (BOK) and Hawk Mountain Sanctuary (HMS), Pennsylvania, Sept-Nov 2000-2002.

Number of eagles seen or used	2000		2001		2002	
	BOK	HMS	BOK	HMS	BOK	HMS
Total numbers of eagles seen:	68	85	57	81	81	104
Number of eagles used in:						
20-60 min analysis	49	47	38	52	64	55
20-90 min analysis	48	48	39	52	57	55
20-120 min analysis	51	48	40	52	50	53

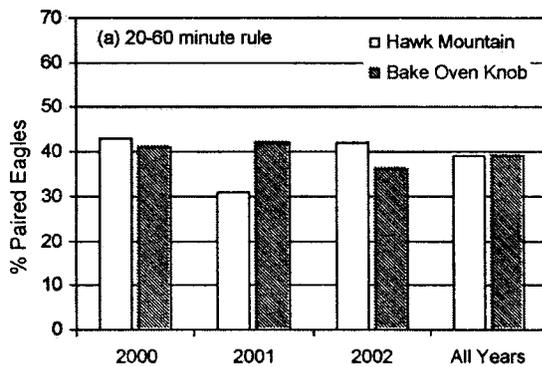


Fig 2(a)

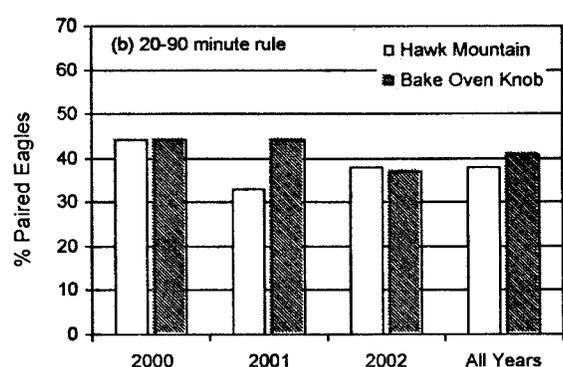


Fig 2(b)

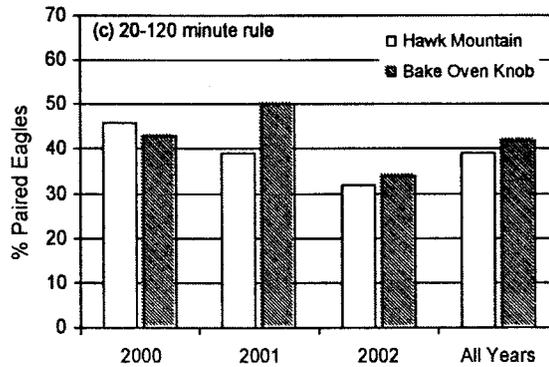
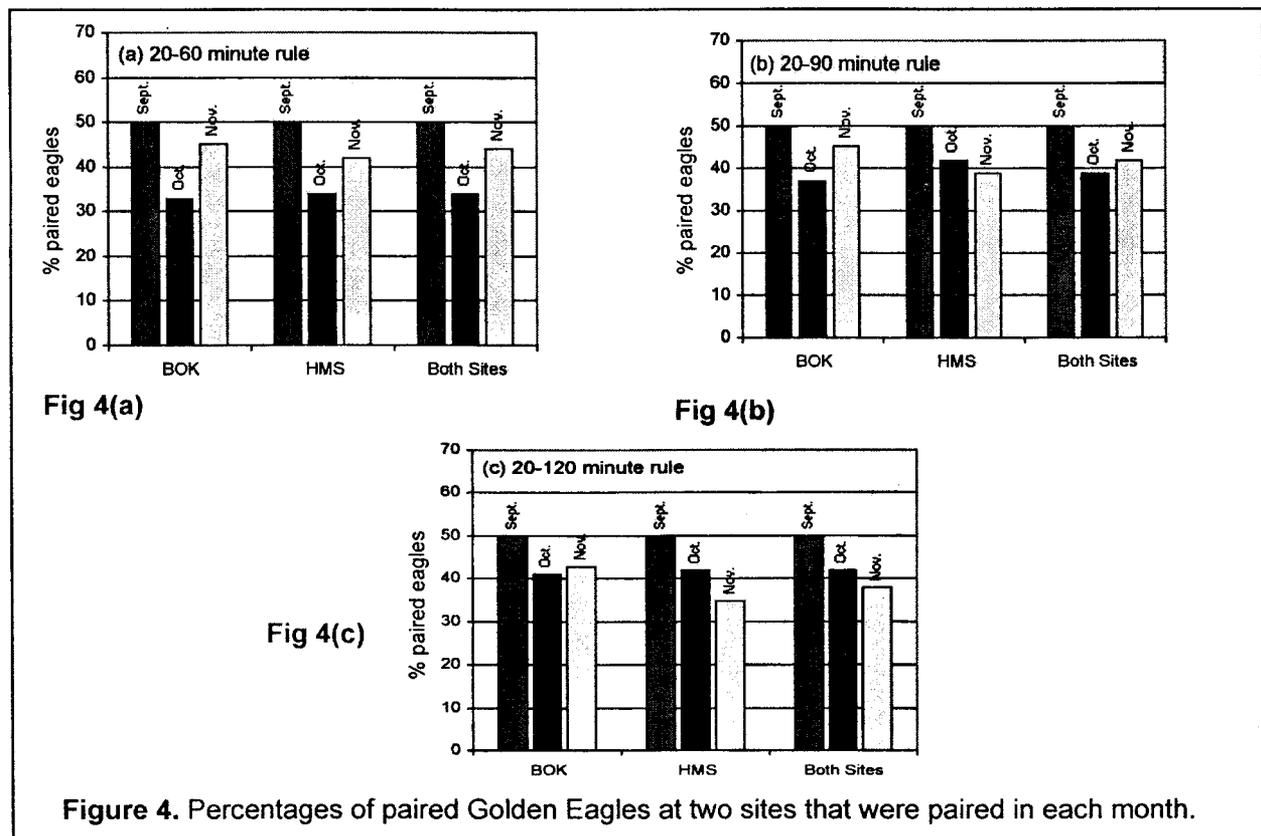
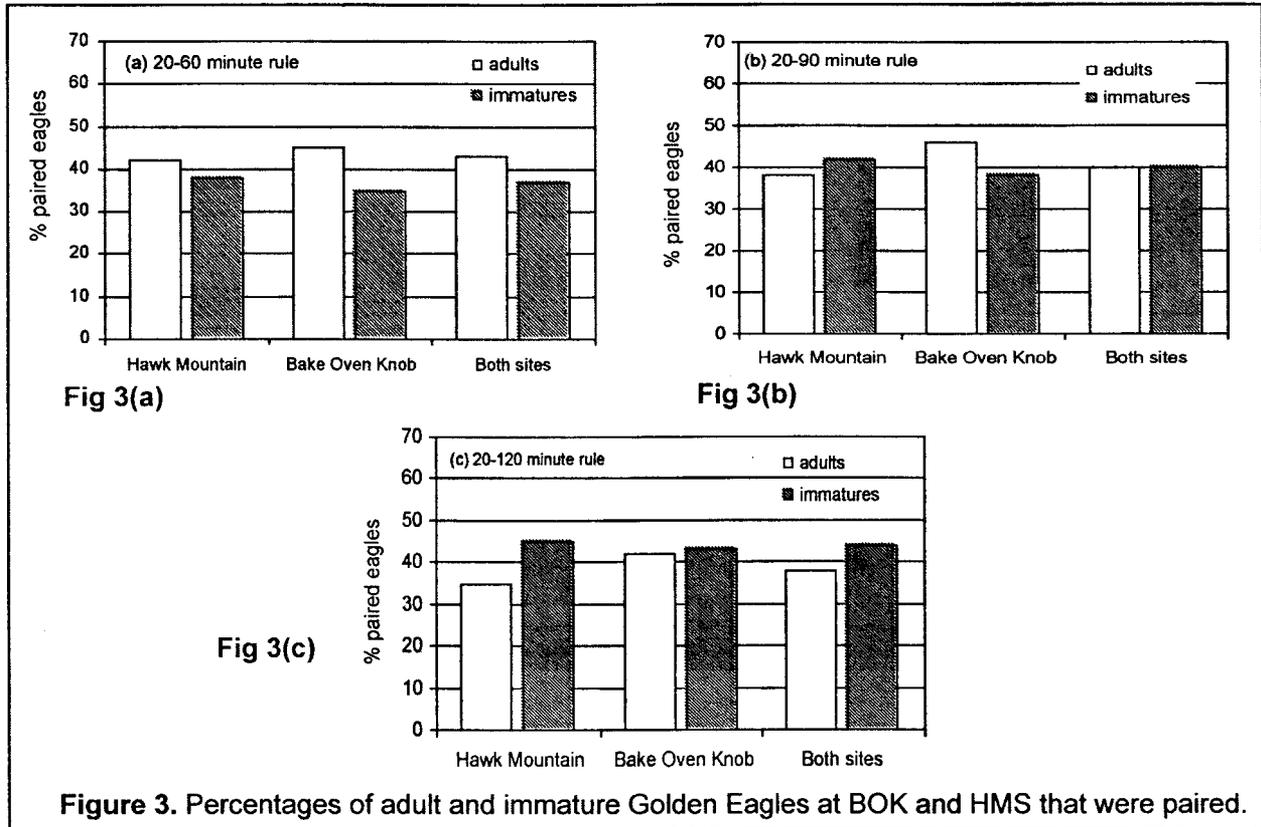


Fig 2(b)

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



### Discussion

Our findings suggest that about 40% of the Golden Eagles counted along the Kittatinny at Bake Oven Knob and Hawk Mountain Sanctuary represent the same individuals. This finding agrees generally with previous studies measuring raptor ridge adherence along the Kittatinny (Frey 1940, Heintzelman 1982, Elwell 1989, Hawk et al. 2002), in suggesting that many raptors seen at Bake Oven Knob are not seen at Hawk Mountain Sanctuary.

The Kittatinny Ridge is oriented east-northeast to west-southwest between BOK and HMS. As such, the ridge tends to divert north-to-south migrants on days when beneficial winds make using the ridge less energetically expensive than flying off-ridge. The higher likelihood of birds being paired in November when using the shorter time rule (Fig. 4) may indicate an increased dependence on slope-soaring at this time, given the decline in solar thermal activity over the course of autumn. An analysis of daily weather data and the extent of ridge adherence could test this possibility.

Our data also suggest that there is little difference in ridge adherence in Golden Eagle individuals based on age (Fig. 3). This finding differs from a recent study of Bald Eagle ridge adherence (Hawk et al. 2002), as well as from studies of Sharp-shinned Hawks (*Accipiter striatus*) (Viverette et al. 1996) and Broad-winged Hawks (*Buteo platypterus*) (Darrow 1983), all of which indicated a tendency for immature birds to be diverted by leading lines more than adults. It is unclear as to why Golden Eagles do not show an age-related difference in ridge adherence. Satellite tracking data of four adult Golden Eagle migrants suggests that adults, at least, show little ridge adherence along the Central Appalachian Mountains (Brodeur et al. 1996).

Compared with Bake Oven Knob, Hawk Mountain Sanctuary tends to have greater numbers of counters. Given that more counters may lead to more birds detected overall, Hawk Mountain Sanctuary may be detecting more of the flight and this, in turn, may be responsible for Hawk Mountain Sanctuary counting more "unpaired" birds than Bake Oven Knob.

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