

# ABUNDANCE AND TIMING OF RAPTORS DURING SPRING MIGRATION AT HAWK MOUNTAIN, PENNSYLVANIA, 1969 to 2016

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## Introduction

Monitoring of raptors during spring migration can augment our understanding of migration geography and population trends when results are compared to autumn migration patterns and trends (Bildstein et al. 2008, Farmer and Smith 2010). Hawk Mountain Sanctuary, in Berks and Schuylkill counties of eastern Pennsylvania, records autumn and spring passage of sixteen species of raptors that nest in northeastern United States and eastern Canada and winter in southern United States and Central and South America (Bildstein et al. 2008).

Spring migration counts were conducted sporadically during 1969 to 1998 and observers used several different observation points for the counts. Consistent spring migration counts were initiated in 1999 and occur primarily from April 1 to May 15, and only from the North Lookout, the same lookout used for autumn monitoring (McCarty et al. 1999).

Here, we describe the species composition and magnitude of spring migration at Hawk Mountain Sanctuary from 1969 to 2016. We also discuss the timing and trends of three short to medium-distance migrants, the Sharp-shinned Hawk (*Accipiter striatus*), Red-tailed Hawk (*Buteo jamaicensis*), and Bald Eagle (*Haliaeetus leucocephalus*), and two long-distance migrants, the Broad-winged Hawk (*Buteo platypterus*) and Osprey (*Pandion haliaetus*) for 1969 through 2016.

## Methods

Since 1999, Hawk Mountain Sanctuary spring migration counts have occurred at the North Lookout (40.6338° N, 75.9876° W). Daily counts were conducted from April 1 to May 15 primarily between 8:00-15:00 EST, weather permitting. A few days in late March also were covered in many years. From 1969 to 1998 the migration counts were sporadic and conducted from nine lookouts all of which were within one mile of North Lookout and within sight of the North Lookout. Moreover, the majority (89%) of the 1969 to 1998 counts were conducted at either the North Lookout or the Cobble, directly southwest of North Lookout in line with the northeast flight path of migrants (McCarty et al. 1999). Thus, we believe the data collected on the composition and magnitude of flights passing Hawk Mountain from 1969 to

1998 are comparable to the more recent data collected in 1999 to 2016.

Since 1999, spring counts were taken by one to four observers stationed at the northeast section of the North Lookout to allow greatest visibility to south. Observers scan the skies using binoculars to spot and identify migratory raptors that arrive from the south and fly to the north or northeast. For all years, hourly data was collected similarly to how data are collected during autumn usually by one or two observers (Bednarz et al. 1990, Therrien et al. 2012). If rain or dense fog occurred, counts were suspended. In early years, 1969 to 1998, the vultures were not consistently recorded so only vulture data from 1999 to 2016 are shown.

**Analysis.** We describe the magnitude and species composition of spring flights at Hawk Mountain from 1969 to 2016 only for counts conducted between April 1<sup>st</sup> and May 15<sup>th</sup>, the period with most consistent coverage in recent years. For each time period, 1969 to 1998 and 1999 to 2016, we calculated percent of flight represented by each species, the mean annual count, the mean birds per hour recorded by Julian date, and determined the median date of passage per year (e.g., the date when 50% of the annual flight had passed per year). Median dates of passage were averaged for years within each of the two periods, 1969-1998 and 1999-2016 to examine if shifts in the timing of migration have occurred. We evaluated trends in migration counts from, 1969 to 2016, using linear regression (R ver. 3.2.4 core Team 2016) and compared our results on trends to analyses conducted by the Raptor Population Index for Hawk Mountain for the time period 1999 to 2013 ([www.rpi-project.org](http://www.rpi-project.org); Crewe et al. 2013, Brandes et al. 2013).

## Results and Discussion

### Migration patterns at Hawk Mountain Sanctuary

**Flight magnitude and composition.** A total of 23,251 raptors were observed at Hawk Mountain Sanctuary during 5,348 observation hours during April and May, from 1969 through 2016, with an average of 4.35 birds per hour for all years (Table 1). From 1969 to 1998, 14 raptor species were recorded with an average of 388 migrants per year and 7.6 birds per hour (Table 1). For 1999 to 2016, an average of 925 raptors per year, or 3.7 birds per hour, were counted including Black Vultures (*Coragyps atratus*) and Turkey Vultures

(*Cathartes aura*), which were not counted during earlier years. Mean hourly counts were higher in earlier years because observers tended to cover lookout only on better days for migration. Daily coverage was instituted in 1999.

Rarities observed in spring included seven Mississippi Kites (*Ictinia mississippiensis*), recorded on following dates: May 11, 1999, April 17 and 23, 2004, April 21, 2005, March 26, 2008, April 29, 2011, April 15, 2012 (Table 1). A Swallow-tailed Kite (*Elanoides forficatus*) was spotted gliding north along the ridge on April 28, 2013 by several trainees and visitors. No kites were recorded in earlier years of study (Table 1).

In all years, spring flights were primarily composed of four species, Osprey, Sharp-shinned Hawk, Broad-winged Hawk, and Red-tailed Hawk. These four species represented 86.1% of the flights, from 1969 to 1998 and 76.5% of the spring flights in 1999 to 2016 (Table 1) (McCarty et al. 1999). The decrease in the proportion is partly a result of (1) addition of vultures to the count in recent years, along with (2) increased abundance of less abundant species such as Bald Eagles and Cooper's Hawks, and (3) an increase in sightings of unidentified raptors in recent years (Table 1).

### Migration patterns

**Broad-winged Hawks.** Broad-winged Hawks are the most numerous migrant during both spring and autumn at Hawk Mountain (Bildstein 2006). They are long-distance, complete migrants that overwinter in forest from southern Mexico south through Brazil, Peru, and Bolivia. Small numbers of this species also winter in south Florida (Goodrich et al. 2014). Broad-winged Hawk represents 52.8 % of spring migrants during 1969 to 1998 and 40.5% of migrants in recent years (Table 1).

From 1969 to 1998, Broad-winged Hawks showed an average median passage date of April 23 ( $\pm 4.2$  days) and for recent years, 1999 to 2016, they also had a median passage date of April 23 ( $\pm 3.0$  days). When counts for all years are combined, the highest passage rate of Broad-winged Hawks (birds/hour) occurred on April 22 (Figure 1a). The record one-day spring count of Broad-winged Hawks was 501 counted on April 27, 1984 (Table 3). Although no shift to earlier timing for migrating Broad-winged Hawks was observed at Hawk Mountain,

Table 1. Comparison of spring migration flight composition at Hawk Mountain, Pennsylvania (Berks and Schuylkill counties), for April 1 to May 15, 1969-1998 and 1999-2016<sup>1</sup>

Species	1969-1998			1999-2016		
	Total # <sup>1</sup>	% Flight	Average Annual Count <sup>1</sup>	Total #	Total Flight %	Average Annual Count <sup>1</sup>
Black Vulture ( <i>Coragyps atratus</i> ) <sup>2</sup>	-	-	-	422	2.7	26
Turkey Vulture( <i>Cathartes aura</i> ) <sup>2</sup>	-	-	-	469	2.8	26
Osprey ( <i>Pandion haliaetus</i> )	694	10.5	41	1808	11.2	101
Bald Eagle( <i>Haliaeetus leucocephalus</i> )	17	0.3	1	367	2.4	22
Northern Harrier ( <i>Circus cyaneus</i> )	195	3.0	12	438	2.8	25
Sharp-shinned Hawk ( <i>Accipiter striatus</i> )	971	14.7	57	1966	12.6	113
Cooper's Hawk ( <i>Accipiter cooperii</i> )	82	1.2	5	653	4.3	38
Northern Goshawk ( <i>Accipiter gentilis</i> )	15	0.2	1	12	0.1	1
Red-shouldered Hawk ( <i>Buteo lineatus</i> )	48	0.7	3	136	1.0	9
Broad-winged Hawk ( <i>Buteo platypterus</i> )	3476	52.8	204	6489	40.5	363
Rough-legged Hawk ( <i>Buteo lagopus</i> )	4	0.1	0.2	1	0.0	<1
Red-tailed Hawk ( <i>Buteo jamaicensis</i> )	533	8.1	31	1851	12.2	109
Golden Eagle ( <i>Aquila chrysaetos</i> )	11	0.2	0.2	15	0.1	1
American Kestrel ( <i>Falco sparverius</i> )	260	4.0	15	474	3.1	28
Merlin ( <i>Falco columbarius</i> )	7	0.1	<1	79	0.5	5
Peregrine Falcon ( <i>Falco peregrinus</i> )	5	0.1	<1	27	0.2	2
Mississippi Kite( <i>Ictinia mississippiensis</i> )	0	-	-	6	0.04	<1
Swallow-tailed Kite ( <i>Elanoides forficatus</i> )	0	-	-	1	0.01	<1
Unidentified Raptors <sup>3</sup>	247	3.8	8.7	1446	8.7	35
<b>TOTAL</b>	<b>6,589</b>		<b>387.6</b>	<b>16,662</b>		<b>925.4</b>

<sup>1</sup>Data shown here excludes March or February counts.

<sup>2</sup>Turkey Vultures and Black Vultures not counted in 1969-1998.

<sup>3</sup>Unidentified Raptor includes, Unidentified accipiter, buteo, falcon, and raptor

Sullivan et al. (2016) has documented earlier timing at spring watchsites in the Great Lakes. Kim et al. (2015) linked earlier spring passage dates for Broad-winged Hawks at Hawk Mountain (for 1998 to 2013) to years with higher North Atlantic Oscillation Index (NAO) during April, although no annual trend in spring passage date was found. A higher NAO index has been correlated with higher temperatures in southern states which may enhance or accelerate northbound migration movement (Kim et al 2015).

Numbers of migrating Broad-winged Hawk in spring declined at Hawk Mountain across the period of this study, 1969 to 2016 ( $F_{1,34}=10.19$ ,  $R^2= 0.21$ ,  $P= 0.003$ , slope=  $-1.82$ ; Figure 1b). The declining trend is consistent with a non-significant decline derived by the Raptor Population Index for 1999 to 2013 (a  $-2\%$  per year non-significant change) ([www.rpi-project.org](http://www.rpi-project.org); Crewe et al. 2013, Brandes et al. 2013). The decline may represent regional population declines or changes in migration routes.

**Sharp-shinned Hawks.** Sharp-shinned Hawks are short-distance migrants that winter in mid-Atlantic and south-eastern United States and return to nesting areas in New England and Canada (Bildstein and Meyer 2000). Sharp-shinned Hawks are the second most numerous migrant at Hawk Mountain, comprising 12.6% of the total flight in recent years, 1999 to 2016 (Table 1). The historical peak flight of 58 Sharpshins in a day occurred on April 18 and again on April 27, 1984 (Table 3). Sharp-shinned Hawks migrate past Hawk Mountain during most of the spring with peak daily flights greater than 0.5 birds per hour from April 11 to 30 (Figure 2a) (McCarty et al.1999). For 1969 to 1998, the Sharp-shinned Hawk median spring passage date (i.e. the date that 50% of birds had passed per year) occurred on April 21 ( $\pm 4.8$  days) (Table 2a). For 1999 to 2016, the average annual median date of passage was 19 April ( $\pm 4.5$  days), two days earlier than observed in early period of the study although the difference was not significant ( $t=0.9$ ,  $p=0.41$ ; Table 2, Figure 2a). Based

on analysis of migration patterns at Great Lakes watchsites (Sullivan et. al. 2016), Sharp-shinned Hawks in eastern regions appear to be shifting their spring passage timing earlier at some sites.

The mean annual spring count for Sharp-shinned Hawks at Hawk Mountain during the period April 1 to May 15 declined between 1969 and 2016 ( $F_{1,34}=6.31$ ,  $R^2= 0.13$ ,  $P= 0.02$ ; slope  $-2.46$ ; Figure 2b). This trend was confirmed by analysis of data from 1999 to 2013 by the Raptor Population Index project which showed a significant  $-3.82\%$  per year decline at Hawk Mountain (Crewe et al. 2013, Brandes et al. 2013). Lower Sharp-shinned Hawk numbers could be due to a change in migration behavior, e.g. short-stopping, (Viverette et al. 1996), or be due to their shift in migration timing allowing more migrants to be missed at Hawk Mountain (Sullivan et al 2016), or both, or a decline in populations.

Table 2a. Average median date of spring passage for common raptor migrants at Hawk Mountain, Pennsylvania (Berks and Schuylkill counties) from 1969-1998

Species	Average Median Date (Julian ±SD) <sup>2</sup>	Average Median Date (Calendar)
Osprey	113 ± 4.6 days	April 23
Bald Eagle	114 ± 4.5 days	April 24
Sharp-shinned Hawk	111 ± 4.8 days	April 21
Broad-winged Hawk	113 ± 4.2 days	April 23
Red-tailed Hawk	107 ± 7.6 days	April 17

<sup>2</sup>standard deviation

Table 2b. Average median date of spring passage for common raptor migrants at Hawk Mountain, Pennsylvania (Berks and Schuylkill counties) from 1999-2016.

Species	Average Median Dates (Julian +SD) <sup>2</sup>	Average Median Date (Calendar)
Osprey	115 ± 4.2 days	April 25
Bald Eagle	115 ± 6.9 days	April 25
Sharp-shinned Hawk	109 ± 4.5 days	April 19
Broad-winged Hawk	113 ± 3.0 days	April 23
Red-tailed Hawk	105 ± 5.1 days	April 15

<sup>2</sup>standard deviation.

Table 3. Single day peak records for spring migration at Hawk Mountain, PA (Berks and Schuylkill counties) from 1969-2016<sup>1</sup>

Species Name	Single-day High Count	Date
Black Vulture	14	April 15, 2015
Turkey Vulture	40	May 9, 2001
Osprey	43	April 27, 1984
Bald Eagle	12	May 4, 2008
Northern Harrier	20	April 9, 2001
Sharp-shinned Hawk	58	April 18 and 27, 1984
Cooper's Hawk	13	May 17, 2010
Red-shouldered Hawk	18	March 20, 1984
Broad-winged Hawk	501	April 27, 1984
Red-tailed Hawk	44	March 20, 1984
Rough-legged Hawk	2	April 25, 2011
Golden Eagle	3	March 9, 2007
American Kestrel	70	April 14, 1983
Merlin	3	April 11, 2008
Peregrine Falcon	2	April 10, 2013; April 12, 1992
<b>All raptors</b>	<b>633</b>	<b>April 27, 1984</b>

<sup>1</sup> For calculating record flights, all data from March, April and May were used.

**Red-tailed Hawks.** Red-tailed Hawks are medium-distance migrants that exhibit a leap-frog migration pattern of migration (Morrison and Baird 2016). Southern New England and mid-Atlantic migrants winter in or near their breeding range while northern nesting birds "leap frog" over other populations to migrate farther south, into the southern United States (Morrison and Baird 2016, Preston and Beane 1993). Red-tailed Hawks are the third most numerous spring migrant recorded at Hawk Mountain, representing 12.2% of total migrants recorded in recent years (Table 1). The highest one-day spring count ever recorded at Hawk Mountain was 44 Red-tailed Hawks on March 20, 1984 (Table 3) while the peak passage rate for this species during the study period occurred on April 12 (Figure 3a).

For 1969 through 1998, the average median date of passage for Red-tailed Hawks at Hawk Mountain occurred on April 17 ( $\pm 7.6$  days) (Figure 3a, Table 2a). The Red-tailed Hawk average median passage date for 1999-2016 was April 15 ( $\pm 5.1$  days), two days earlier, although the difference was not significant ( $t=0.899$ ,  $p=0.28$ ; Table 2b). McCarty et al. (1999) reported that Red-tailed Hawks show a peak passage during late March for 1969 to 1998. In this study we did not include March data in our analysis as March was not consistently covered in more recent years.

Counts of migrating Red-tailed Hawks at Hawk Mountain declined significantly from 1969-2016 ( $F_{1,16}=6.22$ ,  $R^2=0.24$ ,  $P=0.02$ , slope= $-15.76$ ; Figure 3b) possibly due to earlier migration timing and short-stopping (Bolgiano 2013, Morrison and Baird 2016, Paprocki et al. *In press*). Red-tailed Hawks have been shown to be wintering farther north in recent years leading to widespread declines in migration counts at mid-latitude watchsites and increases in Christmas Bird Counts at northern latitudes (Bolgiano 2013, Paprocki et al. *in press*).

**Ospreys.** Ospreys are the fourth most numerous raptor observed at Hawk Mountain during spring migration, representing 11.2% of the migrants observed in recent years (Table 1). Osprey are long-distance migrants that pass through Pennsylvania during April and early May and winter primarily in Central and South America (Martell et al. 2001) (Figure 4a).

The Osprey median date of passage for 1969 to 1998, was April 23 ( $\pm 4.6$  days) compared to April 25 ( $\pm 4.2$  days) in recent years (Table 2a and 2b). The difference was not significantly different ( $t=-0.773$ ,  $p=0.44$ ). The peak daily passage rate occurred from April 23 to 28 across all years (Figure 4a) (McCarty et al. 1999). The one-day, spring record count for Osprey, 43, occurred on April 27, 1984 (Table 4).

We detected a decline of Ospreys from 1969 to 2016 ( $F_{1,34}=5.08$ ,  $R^2=0.10$ ,  $P=0.031$ ; Figure 4b). The trend is consistent with the trend reported by Raptor Population Index for 1999 to 2013, a significant 2.2% per year decline ([www.rpi-project.org](http://www.rpi-project.org), Crewe et al. 2013). Similar declines have been noted during autumn (Crewe et al. 2015).

**Bald Eagle.** Bald Eagles are short-distance to medium-distance migrants that have shown widespread increases in recent years (Buehler 2000, Brandes et al. 2013). Bald Eagles represent 2.4% of the total spring flight at Hawk Mountain with mean counts of 22 birds per season in recent years (Table 1). The record one-day count for this species, 12, was recorded on May 4, 2008.

Bald Eagles occur consistently throughout April and May, with average daily counts greater than 0.6 birds per hour recorded from April 11 through April 30 (Figure 5a). The average median date of spring passage for the Bald Eagle was April 24 ( $\pm 4.5$  days), for 1969 to 1998 and April 25 ( $\pm 6.9$  days) for 1999 to 2016 (Table 2a, 2b). The difference was not significant ( $t=0.54$ ,  $p=0.6$ ).

Bald Eagle counts showed a marginally significant increase for the period between 1969 and 2016 ( $F_{1,34}=3.48$ ,  $R^2=0.07$ ,  $P=0.07$ , slope= $46.92$ ; Figure 5b). In the more recent period, 1999-2016, a significant increase in their population was observed ( $F_{1,16}=46.86$ ,  $R^2=0.73$ ,  $P=3.934e-06$ , slope= $69.59$ ; Figure 5c). The Raptor Population Index also found a significant increase of 14.8% per year from 1999 to 2013 ([www.rpi-project.org](http://www.rpi-project.org); Brandes et al. 2013). These trends coincide with a known population increase throughout north-eastern states and Canada (Brandes et al. 2013).

## Conclusions

The magnitude of spring flights of the most common raptors observed at Hawk Mountain (Broad-winged Hawk, Sharp-shinned Hawk, Red-tailed Hawk, and Osprey) has decreased whereas rarer species, such as the Bald Eagle, have increased. Short-stopping or changes in migration timing or behavior may explain declines in observations of migrating Sharp-shinned and Red-tailed Hawks while changes in counts of Broad-winged Hawks and Osprey bear further investigation. Despite the observed change, the four raptor species comprised the bulk of spring flights at Hawk Mountain in all years, 1969 through present. Because the spring counts at Hawk Mountain do not include March, some early-migrating species, e.g., Golden Eagle, Red-shouldered Hawk, are underrepresented in our counts.

Shifts in spring and autumn migration phenology for migratory birds, including raptors, have been described by several

authors in recent years (e.g., Gordo 2007, van Buskirk 2012, Sullivan et al 2016, Paprocki et al. *In press*). At Hawk Mountain, no significant changes were observed in spring migration dates in contrast to what has been reported by other researchers (Butler 2003, Sullivan et al. 2016). Median passage dates at Hawk Mountain showed high variability among years which suggests local weather likely affects annual timing as well (see Table 2a, 2b).

Long-term monitoring of raptors during spring season, particularly when paired with autumn counts from the same site, can greatly enhance our understanding of raptor population dynamics, migration behavior, and trends (Farmer and Smith 2010). We encourage other Pennsylvania autumn watchsites to consider launching a spring count to augment understanding of migration patterns in their region.

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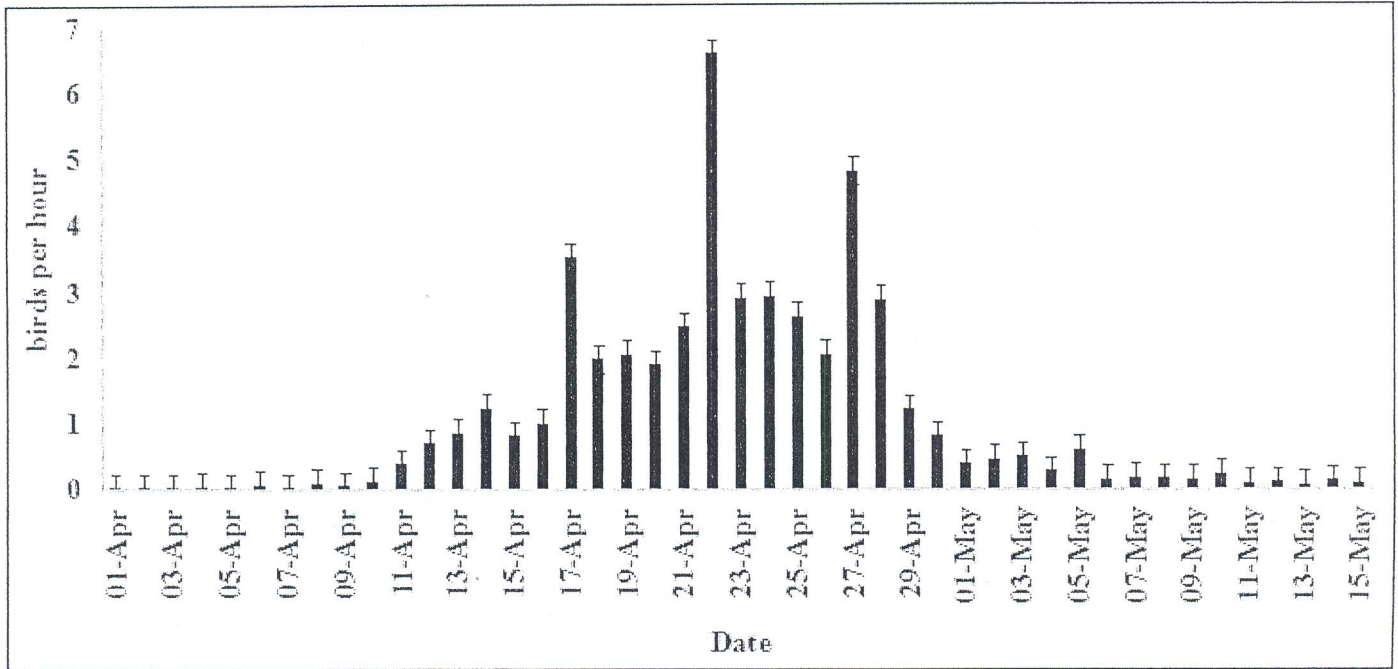


Fig1a. Seasonal timing (birds per hour) of migrating Broad-winged Hawks at Hawk Mountain, April 1 to May 15, 1969-2016.

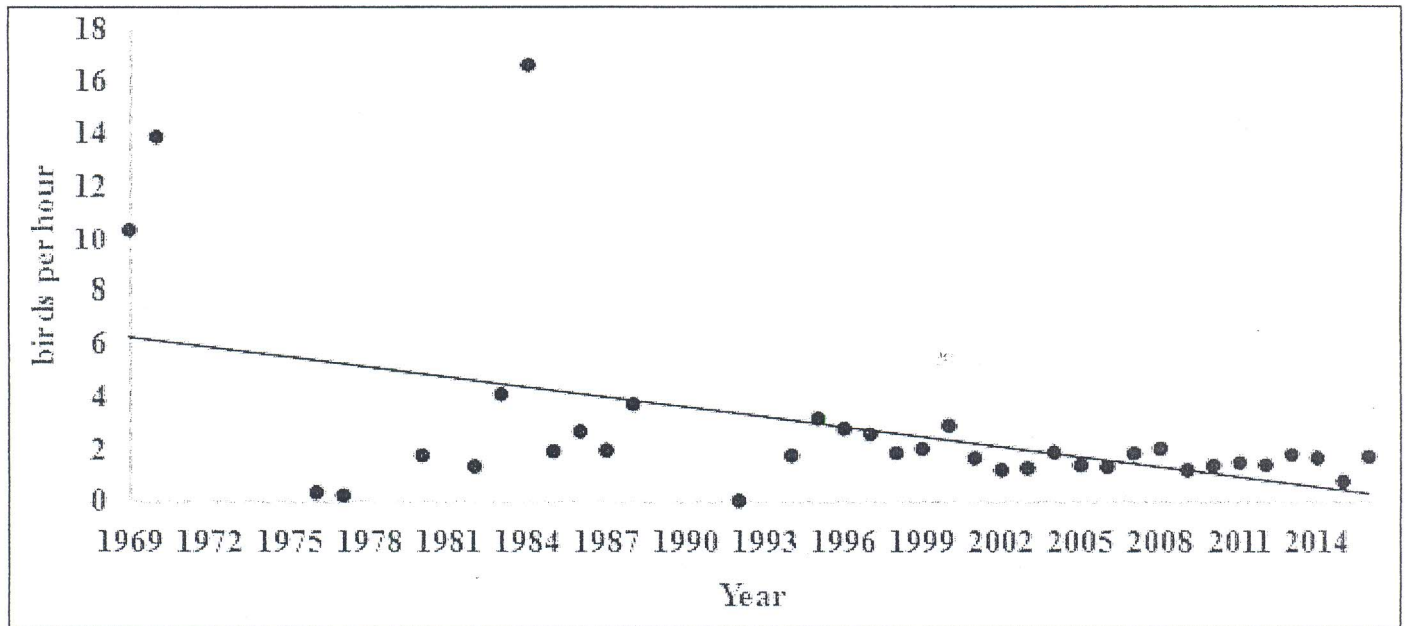


Fig.1b. Mean annual passage rate (birds per hour) of migrating of Broad-winged Hawks at Hawk Mountain from 1969-2016.

