J. Raptor Res. 43(4):263–273

MIGRATION MONITORING INDICATES WIDESPREAD DECLINES OF AMERICAN KESTRELS (*FALCO SPARVERIUS*) IN NORTH AMERICA

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ABSTRACT.—We analyzed migration counts of American Kestrels (*Falco sparverius*) at 20 autumn migration hawkwatch sites throughout North America to estimate population trends. Prior to trend analysis, we converted counts to indexes adjusted for effort and patterns of passage. In eastern North America, autumn counts showed a pattern of significant declines along the Atlantic Coast and eastern Appalachian Mountains, stable numbers in the eastern Great Lakes region, and a significant increase in the western Great Lakes region from 1974 to 2004. From 1994 to 2004, significant declines occurred at most hawkwatch sites in eastern North America, with nonsignificant declines recorded in the western Great Lakes, northeastern Quebec, and Florida. In western North America, three counts from the Intermountain and Rocky Mountain regions that spanned the mid-1980s to 2005 showed mixed long-term trends. From 1995 to 2005, counts decreased significantly at three and nonsignificantly at two of six western hawkwatch sites active throughout the period. These results suggest population declines across much of interior western North America and the Pacific Northwest; however, kestrel counts remained comparatively stable since the mid-1980s in the southern Rocky Mountains. Migration counts along the Gulf of Mexico were variable from 1995 to 2005, with no strong indication of population changes in this region. The overall pattern of migration counts suggests that kestrel populations have undergone a long-term decline in northeastern North America and more recent declines in the midwestern and western regions of the continent.

KEY WORDS: *American Kestrel;* Falco sparverius; *migration monitoring; North America; population trends.*

MONITOREO DE LAS MIGRACIONES INDICA UNA DISMINUCIÓN POBLACIONAL EXTENSA PARA *FALCO SPARVERIUS* EN NORTEAMÉRICA

RESUMEN.—Analizamos datos de conteos de *Falco sparverius* tomados en 20 puntos de observación de la migración de otoño de halcones en Norteamérica con el fin de estimar las tendencias poblacionales. En el este de Norteamérica, los conteos de otoño mostraron un patrón de disminución significativa a lo largo de la costa atlántica y el este de las montañas Apalaches, números estables en el este de la región de los grandes lagos y un aumento significativo en la región oeste de los grandes lagos desde 1974 a 2004. En la mayoría de los puntos de conteo del este de Norteamérica se registraron disminuciones poblacionales significativas entre 1994 y 2004, con disminuciones no significativas en el oeste de los grandes lagos, en el noreste de Québec y en Florida. En el oeste de Norteamérica, tres conteos de las regiones intermontanas y de las montañas Rocallosas que fueron realizados desde mediados de 1980 a 2005, mostraron tendencias de largo plazo mixtas. Entre 1995 y 2005, los conteos disminuyeron significativamente en tres sitios, y de forma no significativa en dos sitios, de los seis sitios de conteo del oeste que estuvieron activos durante ese periodo. Estos resultados sugieren disminuciones poblacionales por casi toda la región interior del oeste de Norteamérica y del Pacífico del noroeste. Sin embargo, los conteos de *F. sparverius* permanecieron relativamente constantes desde mediados de 1980 en la parte sur de las montañas Rocallosas. Los conteos migratorios a lo largo del Golfo de México fueron variables desde 1995 a 2005, sin indicaciones de cambios poblacionales fuertes en esta región. El patrón general de los conteos durante el periodo de migración sugiere que las poblaciones de *F. sparverius* del noreste de Norteamérica han venido disminuyendo desde hace tiempo y que las poblaciones de las regiones del oeste medio y oeste del continente han disminuido sólo recientemente.

[Traducción del equipo editorial]

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The American Kestrel (*Falco sparverius*) is one of the most widespread raptors in the Americas, breeding in eastern and western North America, north to the tree line and south into most of Central and South America (Smallwood and Bird 2002). Although it is a partial migrant (*sensu* Bildstein 2006), large proportions of Canadian and U.S. populations migrate south in autumn, with northern breeders more migratory than those breeding farther south. A small proportion migrates as far south as northern South America. Larger numbers are recorded at coastal hawkwatch sites in eastern North America than at inland eastern sites, but this pattern does not hold in western North America, where migrating kestrels typically are at least as common at Intermountain (i.e., the area between the Rocky Mountains to the east and the Sierra and Cascade mountains to the west) and Rocky Mountain hawkwatch sites as they are in coastal California (Goodrich and Smith 2008).

Previous analyses of migration counts reported generally stable to increasing trends for kestrels in northeastern North America from the 1970s to 1990s (Bednarz et al. 1990, Titus and Fuller 1990, Hussell and Brown 1992, Mueller et al. 2001). Bednarz et al. (1990), however, noted a decline in counts of kestrels at Hawk Mountain Sanctuary, Pennsylvania, from 1973 to 1986, and Mueller et al. (2001) reported a significant decline from 1989 to 1999 at Cedar Grove, Wisconsin. In western North America, mixed trends were reported in the Rocky Mountains, with generally stable populations elsewhere until 2001 (Hoffman and Smith 2003). No continent-wide assessment of kestrel population trends has been attempted until now, nor has any previous study of migration counts attempted to estimate population rates of change across a large area of the continent.

The research reported here was conducted as part of a long-term population monitoring program, the Raptor Population Index. Analyses were initially conducted for population surveillance, with further investigation of the American Kestrel populations prompted by the large number of negative population trends observed. We calculated annual population indexes based on autumn kestrel counts at 20 hawkwatch sites throughout North America (see also Farmer et al. 2008a and Smith et al. 2008a, 2008b). We then estimated trends in these indexes for periods-of-record (variable lengths, 6–39 yr) to test whether kestrel populations declined in North America over the last several decades.

METHODS

We analyzed autumn counts of visible migrating kestrels at 20 hawk migration hawkwatch sites in three regions: eastern North America from Minnesota eastward (hereafter "East"), western North America from New Mexico westward ("West"), and along the shores of the Gulf of Mexico ("Gulf of Mexico"; Table 1). Standard methods described in Farmer et al. (2007, 2008a) and Smith et al. (2008a, 2008b) were used to conduct the migration counts.

We used the counts to calculate effort-weighted, annual indexes of abundance for American Kestrels at each hawkwatch site using methods described by Farmer et al. (2007) and Farmer and Hussell (2008). This analytical approach was similar to that used previously in analyses for both diurnal and nocturnal migrants (Hussell 1981, 1985, Hussell and Brown 1992, Francis and Hussell 1998). Analyses for the Grand Canyon, Arizona (1997–2005 only) and Veracruz, Mexico involved combining counts from two sites following methods outlined in Hussell (1981) and Francis and Hussell (1998). As noted by Farmer et al. (2007), these methods are more appropriate than those previously used to analyze raptor migration counts because they account for variations in effort and seasonal passage, as well as the skewed frequency distributions of such counts.

To estimate population trajectories (patterns of change over time), we fitted a polynomial regression model to the indexes (Francis and Hussell 1998, Farmer et al. 2007). We then estimated trends (geometric mean rate of change; *sensu* Link and Sauer 1997) in annual indexes for each hawkwatch site for full periods-of-record, and calculated average annual indexes for successive 5-yr periods for use in within-site comparisons as recommended by Farmer and Hussell (2008). This method allowed for the fitting of complex curves, which more accurately reflect changes in the population index values than a more traditional linear regression (Farmer et al. 2007).

Farmer and Hussell (2008) suggested three criteria to determine whether population trends are of conservation significance: (1) the rate of change in the most recent 10 yr and its statistical significance, (2) the comparison of recent (last decade) population indexes to the long-term average, and (3) the comparison of current (5-yr average) population indexes to those for successive 5-yr periods in the historical record. As noted by Farmer and Hussell

Table 1. Locations of migration hawkwatch sites in North America.

REGION AND HAWKWATCH SITE	LATITUDE	LONGITUDE	SUBREGION[a]	LOCATION
East				
Cape May Point, New Jersey	39°56′N	74°57′W	Atlantic Coast	coastal peninsula
Hawk Mountain Sanctuary, Pennsylvania	40°38′N	75°59′W	Appalachian	ridge
Hawk Ridge Bird Observatory, Minnesota	46°45′N	92°02′W	Western Great Lakes	lake shoreline
Holiday Beach Migration Observatory, Ontario	42°02′N	83°03′W	Eastern Great Lakes	lake shoreline
Lighthouse Point, Connecticut	41°15′N	72°54′W	Atlantic Coast	coastal
l'Observatoire d'oiseaux de Tadoussac, Quebec	48°09′N	69°40′W	Appalachian	lake shoreline
Montclair Hawkwatch, New Jersey	40°50′N	74°13′W	Coastal Plain	ridge
Waggoner's Gap, Pennsylvania	40°17′N	77°17′W	Appalachian	ridge
West				
Boise Ridge, Idaho	43°36′N	116°04′W	Intermountain	ridge
Bonney Butte, Oregon	45°16′N	121°36′W	Pacific Northwest	ridge
Bridger Mountains, Montana	45°49′N	110°56′W	Northern Rockies	ridge
Chelan Ridge, Washington	48°01′N	120°06′W	Pacific Northwest	ridge
Goshute Mountains, Nevada	40°25′N	114°16′W	Intermountain	ridge
Grand Canyon, Arizona[b]	36°02′N	111°51′W	Intermountain	canyon rim
Manzano Mountains, New Mexico	34°42′N	106°25′W	Southern Rockies	ridge
Wellsville Mountains, Utah	41°41′N	112°03′W	Western Rockies	ridge
Gulf of Mexico				
Curry Hammock State Park, Florida	24°44′N	80°59′W	Eastern Gulf	coastal peninsula
Corpus Christi, Texas	27°52′N	97°38′W	Northern Gulf	coastal plain
Smith Point, Texas	29°31′N	94°45′W	Northern Gulf	coastal peninsula
Veracruz River of Raptors, Mexico[b]	19°22′N	96°22′W	Western Gulf	coastal plain

[a] Subregions were defined by the authors (see text).
[b] The Grand Canyon and Veracruz hawkwatch sites consisted of pairs of observation points on transects. These paired locations were analyzed together following Farmer and Hussell (2008) to produce a single overall trend estimate for the hawkwatch site.

(2008), "significant recent declines to population levels below the long-term average and especially 5-yr averages lower than ever recorded previously would be cause for concern and action." Accordingly, in addition to calculating trends, we constructed paired *t*-tests (with Bonferroni adjustment, where appropriate) to make the comparisons (2) and (3) above.

We estimated and tested the significance (α = 0.05) of a trend between two preselected years on the polynomial curves using a two-tailed *t*-test as described by Francis and Hussell (1998) and Farmer et al. (2007). The null hypothesis tested in each case was that the actual trend was zero. Our trend analysis transformed year terms in the regression equation so that the first-order term estimated the geometric rate of change between the two sets of years (Francis and Hussell 1998, Farmer et al. 2007). We constructed 95% confidence intervals (CIs) around the estimated trend for the longest available time series for each hawkwatch site as described in Farmer et al. (2008a).

For comparison to independent population indexes, we obtained Breeding Bird survey (BBS; Sauer et al. 2007 and J. Sauer pers. comm.) and Christmas Bird Count (CBC; National Audubon Society 2002) data for areas likely to be either the origin or destination of migrants passing hawkwatch sites within each region (Table 2). We used BBS trends calculated by the estimating-equations algorithm (Sauer et al. 2007) and calculated trends in CBC indexes using log-linear regression.

RESULTS

East. Migration counts decreased significantly from 1974 to 2004 at rates of 1.6–4.5% per yr from the Atlantic Coast to the Appalachian Mountains (Table 3). Migration counts decreased nonsignificantly over this period between the Appalachian Mountains (Hawk Mountain, Waggoner's Gap)

Table 2. Regions used in the analysis of Breeding Bird Survey (BBS) and Christmas Bird Count (CBC) annual indexes.

REGION	STATES	PROVINCES
East		
BBS northeastern North America	CT, MA, MN, NH, NJ, NY, PA, RI, VT	NB, NS, ON, QC
CBC northeastern North America	CT, MA, MN, NH, NJ, NY, PA, RI, VT	NB, NS, ON, QC
CBC southeastern North America	DE, FL, GA, KY, MD, NC, SC, TN, VA, WV	
West		
BBS western North America	AZ, CA, ID, NM, NV, OR, UT, WA, western CO, western MT, western WY	BC
CBC western North America	AZ, CA, ID, MT, NM, NV, OR, UT, WA, WY	AB, BC, NWT, YT
BBS U.S. Fish and Wildlife Service Region 2	AZ, NM, OK, TX	
Gulf of Mexico		
BBS U.S. Fish and Wildlife Service Region 4	AL, AR, FL, GA, KT, LA, MS, NC, PR/VI, SC, TN	

and the eastern Great Lakes (Holiday Beach), and increased significantly in the western Great Lakes (Hawk Ridge). From 1994 to 2004, statistically significant decreases of 3.3–8.5% per yr occurred at hawkwatch sites from the Atlantic Coast to the eastern Great Lakes, with a nonsignificant decrease in the western Great Lakes (Table 3, Fig. 1).

At Atlantic Coast and coastal plain hawkwatch sites, mean count indexes from 2000 to 2004 were significantly lower than means from all previous 5-yr periods and the long-term (1974–2004) means. Total declines over 30 yr at these hawkwatch sites ranged from 82.7% to 110.3%. The differences weakened in the Appalachian Mountains and eastern Great Lakes, and total 30-yr changes at hawkwatch sites in this region ranged from −35.3% to +23.3%. At Hawk Ridge, Minnesota, the mean index from 2000 to 2004 was significantly greater than those from all preceding 5-yr periods except 1995–99, with a total increase of 108.7% over 30 yr (Table 4, Appendix).

BBS abundance indexes for kestrels decreased significantly (1.4% per yr) in northeastern North America from 1976 to 2003 (J. Sauer pers. comm.), as did CBCs in northeastern (4.6% per yr) and southeastern (1.4% per yr) North America.

West. Among three sites with counts that began in the early to mid-1980s, we found a mixture of long-term trends (Table 3). Although substantially tempered by a recent decline, a significant long-term increase occurred in the Intermountain region of Nevada since 1983, whereas a significant decline occurred in the western Rockies of Utah since 1987, and no trend occurred in the southern Rockies of New Mexico. From 1995 to 2005, however, most western counts decreased, with significant decreases of 5.9–8.6% per yr recorded in the Pacific Northwest, Intermountain region, and western Rocky Mountains (Table 3, Fig. 1).

Comparisons of mean indexes for successive 5-yr periods further corroborated these patterns (Table 4, Appendix). Mean indexes from 2001 to 2005 were more than 50% lower than those from the mid-1980s to late-1990s in the western Rockies, but were 30.4% higher than those from the mid-1980s in the Intermountain region, and there were no significant differences in the southern Rocky Mountains.

Breeding Bird Survey indexes decreased significantly in western North America from 1983 to 2005 (1.7% per yr) and from 1995 to 2005 (2.7% per yr). Western CBCs decreased at similar rates over the same periods (1.5% and 2.3% per yr, respectively).

Gulf of Mexico. In the last decade, a nonsignificant increase occurred in counts of American Kestrels at Corpus Christi, Texas (1997–2005); high interannual variability but no significant trend was recorded at Veracruz, Mexico (1995–2005); a nonsignificant decrease occurred at Smith Point, Texas (1997–2005); and a nonsignificant (P = 0.07) decrease occurred in the Florida Keys (1999–2005; Table 3, Fig. 1).

Breeding Bird Surveys in U.S. Fish and Wildlife Service Region 4 (southeastern United States) indi-

Table 3. Estimated population trends (% change per yr ± 95% confidence interval) and test statistics (2-tailed t-test) for periods-of-record and the most recent decade at 20 hawk migration watch sites in North America.

REGION AND HAWKWATCH SITE	PERIOD-OF-RECORD	PERIOD-OF-RECORD TREND[a,b]	LAST 10-YR TREND[b,c]
East			
Tadoussac, Quebec	1994–2004	−1.8 ± 8.0 $t_{10} = -0.49$, $P = 0.633$	−1.8 ± 8.0 $t_{10} = -0.49$, $P = 0.633$
Lighthouse Point, Connecticut	1974–2004	−3.1 ± 1.5 $t_{29} = -4.23$, $P = 0.003$	−8.5 ± 4.4 $t_{29} = -4.03$, $P = 0.005$
Cape May Point, New Jersey	1976–2004	−4.5 ± 1.5 $t_{27} = -6.12$, $P = 0.000$	−4.5 ± 1.5 $t_{27} = -6.12$, $P = 0.000$
Montclair, New Jersey	1974–2004	−3.3 ± 1.3 $t_{29} = -6.12$, $P = 0.000$	−3.3 ± 1.3 $t_{29} = -6.12$, $P = 0.000$
Hawk Mountain, Pennsylvania	1966–2004	−1.7 ± 0.9 $t_{29} = -4.39$, $P = 0.000$	−4.4 ± 3.1 $t_{29} = -3.08$, $P = 0.004$
Waggoner's Gap, Pennsylvania	1974–2004	0.2 ± 2.9 $t_{29} = 0.16$, $P = 0.875$	2.9 ± 5.0 $t_{29} = 0.77$, $P = 0.449$
Holiday Beach, Ontario	1974–2004	−0.4 ± 1.6 $t_{29} = -0.58$, $P = 0.568$	−4.1 ± 4.0 $t_{29} = -2.12$, $P = 0.044$
Hawk Ridge, Minnesota	1974–2004	3.2 ± 1.3 $t_{29} = 4.98$, $P = 0.000$	−0.4 ± 3.7 $t_{29} = -0.23$, $P = 0.190$
West			
Bridger Mountains, Montana	1992–2005	−4.2 ± 7.3 $t_{13} = -1.25$, $P = 0.236$	−9.0 ± 9.3 $t_{13} = -2.13$, $P = 0.056$
Wellsville Mountains, Utah	1987–2004	−3.6 ± 2.8 $t_{16} = -2.77$, $P = 0.015$	−8.6 ± 5.5 $t_{16} = -3.40$, $P = 0.004$
Manzano Mountains, New Mexico	1985–2005	0.1 ± 1.6 $t_{20} = 0.09$, $P = 0.928$	0.1 ± 1.6 $t_{20} = 0.09$, $P = 0.928$
Boise Ridge, Idaho	1995–2005	−1.9 ± 4.3 $t_{10} = -1.01$, $P = 0.336$	−1.9 ± 4.3 $t_{10} = -1.01$, $P = 0.336$
Goshute Mountains, Nevada	1983–2005	3.4 ± 1.5 $t_{22} = 4.72$, $P = 0.000$	−5.9 ± 3.5 $t_{22} = -3.55$, $P = 0.002$
Grand Canyon, Arizona	1997–2005	−4.0 ± 7.6 $t_7 = -1.25$, $P = 0.252$	na[d]
Chelan Ridge, Washington	1998–2005	−11.7 ± 13.5 $t_6 = -2.13$, $P = 0.077$	na
Bonney Butte, Oregon	1994–2005	−7.9 ± 3.7 $t_{10} = -4.79$, $P = 0.001$	−7.9 ± 3.7 $t_{10} = -4.79$, $P = 0.001$
Gulf of Mexico			
Curry Hammock State Park, Florida	1999–2005	−8.8 ± 9.6 $t_6 = -2.35$, $P = 0.066$	na
Smith Point, Texas	1997–2005	−2.9 ± 6.8 $t_7 = -1.01$, $P = 0.346$	na
Corpus Christi, Texas	1997–2005	6.7 ± 13.4 $t_7 = 1.17$, $P = 0.279$	na
Veracruz River of Raptors, Mexico	1995–2005	0.0 ± 7.3 $t_9 = -0.14$, $P = 0.894$	0.0 ± 7.3 $t_9 = -0.14$, $P = 0.894$

[a] Sources: Farmer et al. (2008a), Smith et al. (2008a, 2008b).
[b] Source: Farmer et al. (2008b).
[c] Tests of significance are based on the mean squared deviation from the trend regression of all data points in the time series, not only those within the 10-yr period.
[d] Period-of-record is shorter than 10 yr.

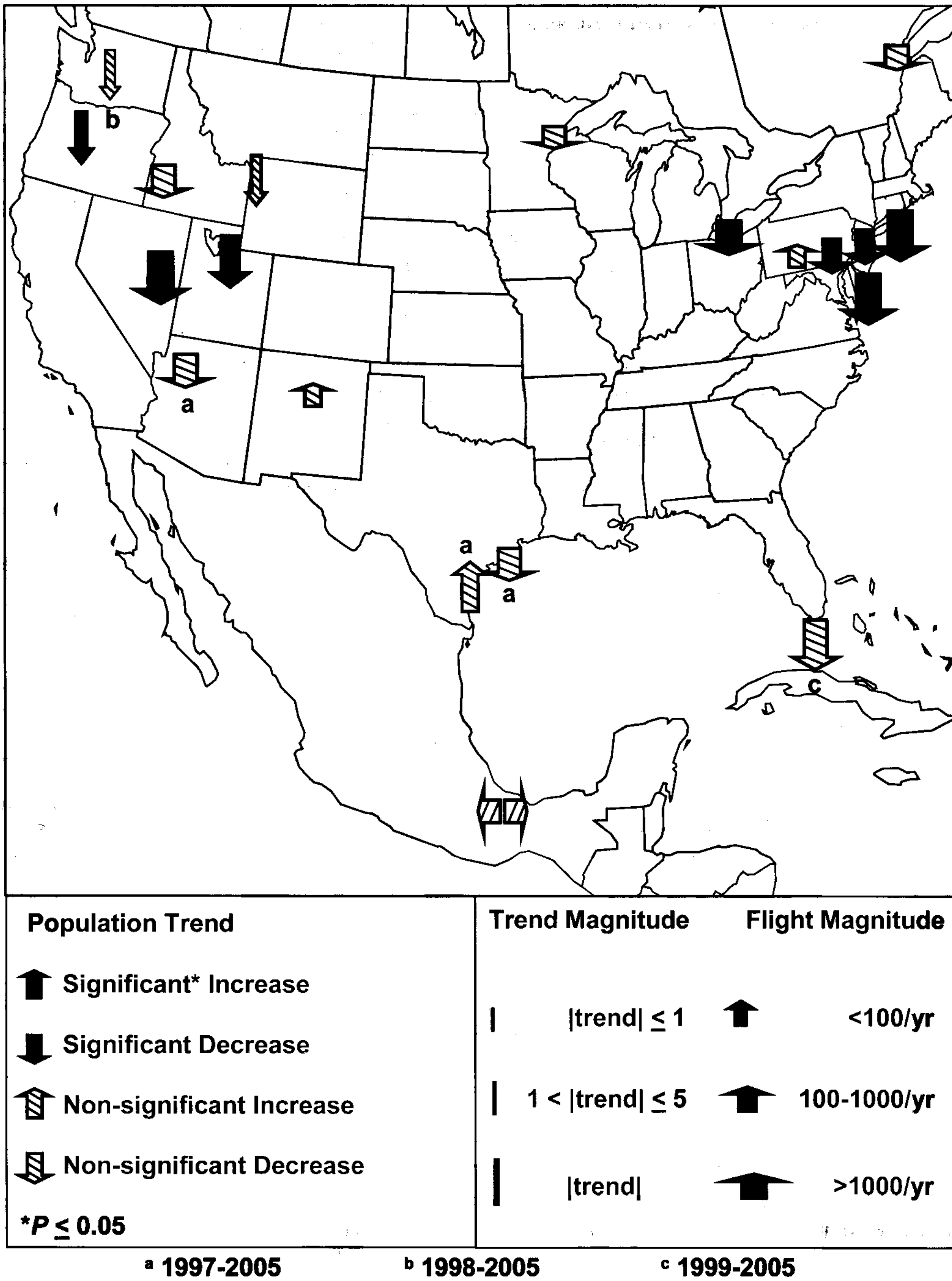

Figure 1. Recent population trends for American Kestrels at eight eastern and midwestern (1994–2004), and 12 western and Gulf Coast (1995–2005) autumn migration hawkwatch sites in North America. Trend magnitudes (arrow height) are expressed in percent change per yr. Flight magnitudes (arrow width) are depicted in three ranges (<100, 100–1000, and >1000) of birds per yr. A bidirectional arrow indicates that the estimated trend is 0.0% per yr.

Table 4. Percentage differences between mean annual count indexes for the most recent 5 yr (2000–04) and mean indexes for previous 5-yr periods and long-term (period-of- record) mean index at 10 autumn migration hawkwatch sites having ≥15 yr of American Kestrel counts.

HAWKWATCH SITE	PERIOD OF COMPARISON					
	1995–99	1990–94	1985–89	1980–84	1975–79	LONG-TERM[a]
Lighthouse Point, Connecticut	−39.4*[b]	−81.4**	−66.5**	−58.6*	−110.3**	−59.5*
Cape May Point, New Jersey	−22.4**	−44.9**	−67.3**	−89.7**	−107.7**	−53.8**
Montclair, New Jersey	−16.6**	−33.1**	−19.6**	−66.2**	−82.7**	−43.0**
Hawk Mountain, Pennsylvania	−2.5*	−22.5	−15.5	−19.2	−35.3**	−20.5*
Waggoner's Gap, Pennsylvania	17.2	32.6	18.7	19.3	23.2	17.6
Holiday Beach, Ontario	−21.5	−33.8	−36.9	−30.8	−15.5	−23.2
Hawk Ridge, Minnesota	−5.7	25.6	70.5**	106.0*	108.7*	52.1*
Goshute Mountains, Nevada	−25.6*	−12.5	39.3*	na	na	6.9
Manzano Mountains, New Mexico	0.3	0.7	1.0	na	na	0.5
Wellsville Mountains, Utah	−43.2*	−55.0*	−35.3	na	na	−35.7*

[a] 1974–2004 for all hawkwatch sites except Cape May Point (1976 to 2004), Goshute Mountains (1983 to 2005), Manzano Mountains (1985 to 2005), and Wellsville Mountains (1987 to 2004).

[b] Two-sample t-test, Bonferroni-adjusted experiment-wide P-value: ** $P \leq 0.01$, * $P \leq 0.05$.

cated a relatively stable kestrel population from 1995 to 2005 in the Gulf region (−0.2% per yr, $P = 0.92$; Sauer et al. 2007).

DISCUSSION

Migration counts, BBS data, and CBCs indicate that populations of the American Kestrel have (1) declined in much of northeastern North America since 1974, but increased or remained stable around the western Great Lakes; (2) declined in portions of western North America since the mid-1980s, with increasingly widespread declines coinciding with the onset of regional drought in the late 1990s (Hoffman and Smith 2003, Smith et al. 2008a); and (3) declined in the eastern Gulf of Mexico, but increased or remained stable elsewhere in the Gulf of Mexico over the last decade (Fig. 1). Declines in migration counts can be indicative of changes in migration geography (e.g., migratory short-stopping). Migratory short-stopping, however, should produce a pattern of declining migration counts, stable to increasing BBSs, and increasing CBCs in the north but stable or decreasing CBCs in the south. Instead, we see declining BBSs and CBCs that coincide with the changes in migration counts.

In the East, migration counts, BBS data, and CBCs indicate that kestrel populations are declining, but that these declining trends weaken west of the Appalachian Mountains. Results from Hawk Ridge Bird Observatory and Holiday Beach Migration Observatory suggest that breeding populations of American Kestrels north of the Great Lakes were increasing or stable until recently, when they began to decline. Comparison of recent indexes to previous 5-yr periods also reflects these patterns and shows that population indexes at most hawkwatch sites were much higher in the 1970s than at present.

In the East, the three easternmost hawkwatch sites recorded declines of >50% over 30 yr, a decline that places kestrels in the most vulnerable category defined by Partners in Flight (Rich et al. 2004). The IUCN rates any population undergoing a decline of 30% over 10 yr as vulnerable (IUCN 2001), and five eastern hawkwatch sites recorded declines of this magnitude (Table 4). With respect to the conservation status criteria of Farmer and Hussell (2008), trends in this region clearly indicate cause for conservation concern, with five hawkwatch sites showing recent indexes below long-term averages and currently lower than in any previous 5-yr period on record.

In the West, kestrel counts showed moderate to strong declining patterns during the past decade at all migration sites except the Manzano Mountains, suggesting that populations in the central and southern Rocky Mountains may be more secure at present than in other regions of the West extending from the northern Rocky Mountains to the Pacific Northwest. Whether the recent declines are entirely due to recent widespread drought or a combination of other factors is unknown, but further investigation of potential factors appears warranted. Average rates of change currently range from roughly −4% to −12% per yr where declines are occurring. Prudent management should take these declines into account regardless of cause before undertaking any actions that may further depress kestrel populations. Only the trends in the western Rocky Mountains, however, indicate cause for concern according to the criteria of the IUCN, Partners in Flight, or Farmer and Hussell (2008).

Declines in kestrel populations migrating past raptor migration watch sites may be due to several factors. Kestrels continued to be exposed to high levels of DDT well into the late 1970s, even after the pesticide was banned in the United States in 1972 (Smallwood and Bird 2002), and DDT interferes with successful reproduction in the species (Porter and Wiemeyer 1969, Lincer 1975). Unknown numbers of kestrels die due to poisoning by other pesticides in agricultural areas, and we have recently recovered two kestrels that were killed by organophosphates or carbamates (one bird), and rodenticides (one bird; C. Farmer unpubl. data).

Populations of Cooper's Hawks (*Accipiter cooperii*) increased throughout northeastern North America from 1974 to 2004 (Farmer et al. 2008a). Research at Hawk Mountain Sanctuary suggests that this species sometimes preys upon American Kestrels in settings where open fields are interspersed with woodlots (Farmer et al. 2006). Other recent research suggests that intraguild predation can be a significant factor determining the population density and dispersion of raptors (e.g., Petty et al. 2003, Sergio et al. 2007).

At the same time, much of this region has been reforested or developed, replacing foraging habitat for kestrels with forests or suburban land cover that provide fewer feeding, nesting, and migratory stopover opportunities.

Since 1999, West Nile virus apparently has affected numerous bird species throughout the continent (CDC 2009). Although the effect of the virus on kestrel populations is unknown, approximately 95% of the adults using nest boxes in 2004 in southeastern Pennsylvania near Hawk Mountain Sanctuary had been exposed to the virus, although this exposure rate has since declined (Medica et al. 2007, Medica and Bildstein 2009). Productivity in this nest-box program declined 57% between 2000 and 2004, stemming primarily from a 44% decline in nesting attempts. West Nile virus seems unlikely as a causal agent for the long-term declines reported here, as they predate the arrival of West Nile virus by more than 20 yr in some cases (e.g., at Cape May, New Jersey).

Overall, migration count data suggest substantial recent declines in populations of American Kestrels across much of North America, and consequently strong cause for conservation concern. Whether these declines represent a crisis for the species or simply a return to numbers present prior to agricultural development is unknown due to the lack of information regarding historical population levels. Patterns of decline over the last decade suggest that the declines are not merely a return to historical levels, however, because the declines have occurred consistently across large regions with very different ecologies and recent histories of development.

A gradient from east to west is apparent in trend estimates for northeastern North America, with stronger declines occurring at coastal hawkwatch sites (Fig. 1). This pattern may indicate that negative influences on populations are strongest in areas from which kestrels migrate near dense human populations along the Atlantic Coast. More recent declines in western North America, however, appear to have occurred in concert with a prolonged drought.

The species' North American population is estimated to exceed one million birds (Ferguson-Lees and Christie 2001), with some previous trend estimates suggesting stable or increasing populations in many areas (e.g., Titus and Fuller 1990, Kirk and Hyslop 1998, Hoffman and Smith 2003). The widespread, significant declines we found using new, more powerful methods of analysis (Farmer et al. 2007) clearly warrant further investigation to identify causal factors and determine appropriate conservation measures. The duration and magnitude of the declines we have documented suggest that this common raptor may not remain common in the future.

ACKNOWLEDGMENTS

This manuscript would not have been possible without the efforts of hundreds of seasonal migration counters. Each migration season, these dedicated individuals spent long hours and often endured harsh conditions to advance our understanding of raptor ecology, and we heartily thank them for their service and dedication. Similarly, over the years, all the migration projects covered here were supported by numerous government, foundation, corporate, nonprofit, and private-donor financial sponsors. These entities are far too numerous to list individually here, but most have been specifically acknowledged in previous manuscripts, such as Hoffman and Smith (2003), Farmer et al. (2008a), and Smith et al. (2008a, 2008b). We thank the compilers at the following migration hawkwatch sites for providing data: Audubon's Hawk Watch at Waggoner's Gap, Pennsylvania; Boise Ridge, Idaho (Idaho Bird Observatory); Cape May Point, New Jersey (New Jersey Audubon); Florida Keys Raptor Migration Project, Florida; Hawk Mountain Sanctuary, Pennsylvania; Hawk Ridge Bird Observatory, Minnesota; Holiday Beach Migration Observatory, Ontario; Lighthouse Point Hawkwatch, Connecticut; l'Observatoire d'Oiseaux de Tadoussac, Quebec; Montclair Hawk Lookout (New Jersey Audubon); Veracruz River of Raptors (Pronatura Veracruz). We thank J. Sauer for analyzing BBS data in a special "northeastern North America" region for the RPI project, and D. Bird for organizing the kestrel symposium at the 2007 conference of the Raptor Research Foundation and the Hawk Migration Association of North America. This manuscript benefited from constructive reviews by David Brandes, Keith Bildstein, George Wallace, and two anonymous reviewers. This is Hawk Mountain Sanctuary Contribution to Conservation Science No. 183.

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Received 6 March 2008; accepted 4 August 2009
Associate Editor: Bryan D. Watts

Appendix. Test statistics and observed *P*-values for comparisons of average indexes among 5-yr periods and the long-term mean index at 10 autumn migration hawkwatch sites having ≥15 yr of American Kestrel counts.

	PERIOD OF COMPARISON					
HAWKWATCH SITE (df)	1995–99 t *P*	1990–94 t *P*	1985–89 t *P*	1980–84 t *P*	1975–79 t *P*	LONG-TERM[a] t *P*
Lighthouse Point, Connecticut (29)	−2.88 0.008	−5.72 0.000	−5.17 0.000	−3.89 0.007	−6.41 0.000	−6.05 0.000
Cape May Point, New Jersey (27)	−6.12 0.000	−6.12 0.000	−6.12 0.000	−6.12 0.000	−6.12 0.000	−6.12 0.000
Montclair, New Jersey (29)	−5.23 0.000	−5.23 0.000	−5.23 0.000	−5.23 0.000	−5.23 0.000	−5.23 0.000
Hawk Mountain, Pennsylvania (29)	−3.11 0.004	−2.40 0.022	−1.64 0.111	−2.09 0.044	−3.64 0.001	−3.04 0.004
Waggoner's Gap, Pennsylvania (29)	1.34 0.193	2.06 0.051	1.15 0.263	0.95 0.351	1.08 0.291	1.60 0.124
Holiday Beach, Ontario (29)	−2.12 0.044	−2.10 0.045	−2.02 0.053	−1.71 0.098	−0.82 0.417	−1.84 0.077
Hawk Ridge, Minnesota (29)	−0.59 0.559	2.21 0.0361	5.94 0.000	8.89 0.000	8.59 0.000	6.11 0.000
Goshute Mountains, Nevada (22)	−3.29 0.004	−1.18 0.252	3.53 0.002	na	na	0.95 0.394
Manzano Mountains, New Mexico (20)	0.09 0.928	0.09 0.928	0.09 0.928	na	na	0.09 0.928
Wellsville Mountains, Utah (16)	−3.40 0.004	−3.59 0.003	−1.65 0.121	na	na	−3.59 0.003