Pennsylvania's Importance to American Kestrels: A Regional Context

Nick Bolgiano, Jean-François Therrien, and Greg Grove

Several population indexes provide evidence that American Kestrels (*Falco sparverius*) have been declining across North America, particularly in the northeastern United States. Indeed, according to the Breeding Bird Survey (BBS), American Kestrels declined during 1966-2013 at annual rates of 1.7% continent-wide and 2.1% in the eastern region (Sauer et al. 2014). Over recent decades, migration counts of kestrels have fallen drastically at some hawk watches (Farmer and Smith 2009). Moreover, kestrel nest-box occupancy has shown decreasing trends at several large nest-box deployments, including at Hawk Mountain Sanctuary in eastern Pennsylvania (Smallwood et al. 2009a). In Pennsylvania's second breeding bird atlas, American kestrels were found in 52% of blocks, which was a 13% decline in occupied blocks compared to the first atlas; losses were concentrated in the Piedmont region, especially around Philadelphia (Farmer and Bildstein 2012). Recent breeding bird atlases in other provinces and states such as Ontario, New York, and Maryland corroborate the kestrel declines in those regions that are evident in BBS data (Gahbauer 2007; Nye 2008; Ellison 2010). American Kestrel populations have reached sufficiently low levels that it is now listed as endangered in Delaware and threatened in Connecticut and New Jersey, states where it used to be a common species.

Several causes have been proposed to explain these population declines. West Nile virus (WNV) is one of them, as 95% of wild-caught kestrels in eastern Pennsylvania tested positive for WNV antibodies (Medica et al. 2007). However, declines in kestrel nest-box programs began before the actual arrival of WNV in the North America (Smallwood et al. 2009a). Habitat change is also suggested as important by the finding that breeding kestrels prefer suitable habitat patch sizes of at least 1000 ha (~2500 acres) and are scarce when suitable habitat patches fall below 250 ha (~625 acres) (Smallwood et al. 2009b; Brown et al. 2014). This is consistent with Pennsylvania's second atlas results which showed that kestrels retracted from around Philadelphia and Pittsburgh (Farmer and Bildstein 2012). Because fledgling productivity of occupied nest boxes has remained high, Smallwood et al. (2009a) thought that the root causes of the decline occur primarily outside of the vicinity of occupied nest boxes, possibly during migration or the winter period.

American Kestrels are small falcons of farmlands and other open or semi-open areas, where they feed upon small rodents, birds, and large insects. Kestrels are secondary cavity nesters and readily utilize nest boxes, which have proven to increase kestrel numbers where there is suitable habitat (Brauning 1982; Smallwood and Bird 2002). In eastern North America, the American Kestrel breeding range extends south from James Bay and Newfoundland to the Gulf coast and southern Florida. American Kestrels are partial migrants, completely withdrawing from the northern part of their range. They are also leap-frog migrants; kestrels from the northern part of their range tend to migrate to southern latitudes, mid-latitude (33-44 degrees of latitude) kestrels tend to move comparatively shorter distances, often to avoid harsh winter periods, and southern birds do not migrate (Bird and Palmer 1988; Smallwood and Bird 2002; Wheeler 2003).

In this article, we examine data from various sources and address the following questions about the status of Pennsylvania's kestrels: 1) How do Pennsylvania observations of breeding, migrating, and wintering American Kestrels compare to observations elsewhere in eastern North America? 2) Is the number of American Kestrels that winter in Pennsylvania affected by severe winters? 3) Are there differences among Pennsylvania counties in kestrel wintering trends? 4) To what extent are kestrels found wintering in Pennsylvania likely to be local breeders, thus allowing wintering data to reflect local breeding success?

Methods

Hawk Watch. We compared long-term migration counts from hawk watch sites in Pennsylvania and elsewhere in eastern North America, using maps of kestrel numbers observed at hawk watches and summarizing hawk watch trend analysis.

Daily fall and spring counts for eastern North American hawk watch sites 2005-2014 were obtained from Hawkcount (2014) and Inzunza (2008). The seasonal time period in which 95% of migrant kestrels were tallied was determined and the 10-year mean number of kestrels/hour in the 95% passage period was calculated. Density maps of hawk watch locations were created for fall and spring using this passage period statistic, to compare the kestrel migration across sites.

Hawk Migration Association of North America researchers have analyzed data from several North American hawk watches. For each watch site, a yearly raptor population index is computed and its trend over time assessed (Farmer and Hussell 2008). We summarize their findings for those eastern North American hawk watch sites with higher kestrel numbers and longer spans of operation.

Breeding Bird Survey. BBS data and trend analyses were obtained from Sauer et al. (2014) and density maps of the mean number of American kestrels/route in eastern North American states and provinces were created for each of the four decades from 1970-2009.

Christmas Bird Count. CBC data were obtained from National Audubon Society (2014). Each American Kestrel count was standardized as the count per 10 party-hours, and a record was omitted if the party-hours were missing or less than 20, or if the kestrel count was determined to be missing. The year referred to is the year in which Christmas occurred.

Density maps of the mean number of American kestrels/10 party-hours were created for each of four decades, 1970-2009, using data from sites with four or more reports in a decade.

The 1973-2013 trends were evaluated from sixteen geographic regions. Eastern regions include each of Pennsylvania, New York, New Jersey, Virginia, North Carolina, and Florida; the combined area of Massachusetts, Connecticut, and Rhode Island; and the combined area of Delaware, Maryland, Virginia, and the District of Columbia. Regions to the west include Ontario south of 45 degrees of latitude (i.e. the southern peninsula north of Lakes Erie and Ontario) and each of Ohio, Indiana, Illinois, Kentucky, Tennessee, Arkansas, and Louisiana. Standardized values in each region were averaged for each year, thus equally weighting the sites. Polynomial regression analysis was used to assess trends.

Winter Raptor Survey. Since 2001, vehicle-based Winter Raptor Surveys (WRS) have been conducted in Pennsylvania. Most routes are 20-80 miles long, each contained within a single county, and designed to pass primarily through open country. County and annual WRS summary statistics are graphically displayed, as are three December-February weather variables measured at Williamsport, Pennsylvania, located at the north end of the central Susquehanna Valley: average temperature (°C), total snowfall (cm), and

average snow depth (cm) (NOAA National Climatic Data Center 2015; The Pennsylvania State Climatologist 2015). The statewide trend in American Kestrels/hour was assessed using polynomial regression, with the weather variables included.

Pennsylvania CBC and WRS by County. Pennsylvania counties except Philadelphia were assigned to one of five regions by similar topography and WRS kestrel counts: six southeastern counties around Philadelphia (Bucks, Chester, Delaware, Lehigh, Montgomery, and Northampton); three counties to the west (Berks, Lancaster, Lebanon); 19 counties in the south-central; 14 counties in the southwest; and 24 counties in the north (Figure 6). CBC sites were assigned to a region by the location of their circle center and each region's mean kestrel count/10 party-hours was computed for sites with at least 20 party-hours, thus equally weighting each site's observations. Polynomial regression was used to assess trends for both CBC and WRS.

Band Returns. American Kestrel bird band return data from 1916-2013 were obtained from the USGS Patuxent Wildlife Research Center's Bird Banding Laboratory. Records were identified for kestrels banded in Pennsylvania during the breeding season (May 15-July 31, the second atlas safe dates) and recovered during a subsequent wintering period (October 27-March 20, the period between the fall and spring 95% migration periods). For these records, the distance between banding and recovery sites was calculated. Records were also identified and source region determined for those kestrels banded in the breeding season and recovered in Pennsylvania during a subsequent wintering period.

Results

Hawk Watch. Maps of eastern North America show hawk watch locations (Figure 1), with symbols representing the annual 2005-2014 average of American Kestrels/hour observed during the period when 95 percent of migrants are observed (9/3-10/26 in fall, 3/21-5/12 in spring). In both fall and spring, the highest numbers of migrating kestrels were observed along the Great Lakes and Atlantic Coast, where water edges concentrate flights.

The fall hawk watch sites that report the highest numbers of American Kestrels are Tadoussac, Québec; Hawk Cliff and Holiday Beach, Ontario; Detroit River, Michigan; Cadillac Mountain, Maine; Blueberry Hill, Connecticut; Lighthouse Point and Quaker Ridge, Connecticut; Raccoon Ridge, Montclair, Chimney Rock, and Cape May, New Jersey; Ashland and Cape Henlopen, Delaware; and Kiptopeke, Virginia. A fall site not shown in Figure 1 is the Florida Keys in southern Florida, which averaged 6.1 kestrels per hour during 2005-2014. The spring hawk watch sites that report the highest numbers of American kestrels are Presque Isle, Pennsylvania; Braddock Bay, New York; Sandy Hook, New Jersey; Pilgrim Heights and Plum Island, Massachusetts; and Bradbury Mountain, Maine (Figure 1).

Among fall sites, there is significant statistical evidence for declines at the Great Lakes sites Tadoussac, Québec, and Holiday Beach, Ontario; at the Atlantic Coast sites Lighthouse Point, Connecticut, and Cape May, New Jersey; and farther inland at Montclair, New Jersey and at Hawk Mountain, Pennsylvania. There is no significant statistical evidence for trends at Detroit River, Michigan, and Waggoner's Gap, Pennsylvania. Among spring sites, there is significant evidence of a decline at Fort Smallwood, Maryland, but there is no significant evidence for trends at Braddock Bay or Derby Hill, New York (Raptor Population Index 2014, Table 1).

Breeding Bird Survey. Decadal maps of eastern North America show the mean number of kestrels per route in each state or province (Figure 2). Three general trends are apparent: 1) in eastern North America, American Kestrels are most abundant in Illinois, Indiana, Kentucky, and Ohio, where breeding populations have mostly been stable; 2) kestrel breeding populations have been declining in an arc of states and provinces to the north and east of Pennsylvania, including Michigan, Ontario, New York, most of New England, New Jersey, and Maryland; and 3) kestrel breeding populations in southern states are low, except in Tennessee. In Pennsylvania, kestrel counts have been of intermediate level and are relatively stable. The BBS data indicate that Pennsylvania and New York have the highest concentrations of breeding American Kestrels east of Ohio (Figure 2).

Christmas Bird Count. Decadal maps of eastern North America show effort-adjusted American Kestrel counts during the CBC (Figure 3). During the 1970s and 1980s, there were two core regions for wintering kestrels within the map area. One was primarily east of the Appalachians, concentrated in western New Jersey, southeastern Pennsylvania, the Delmarva Peninsula, and coastal sites south to Florida (not shown south of Virginia). The other was around the western end of Lake Erie and into Ohio. Compared to the 1970s, fewer kestrels were recorded in northern New Jersey during the 1980s. Changes during the next two decades were of larger magnitude, as the numbers of kestrels found in the eastern core area were a small fraction of what had previously been observed, except in a remnant area extending from the central Susquehanna Valley into northwestern Virginia and eastern West Virginia. In Ohio, numbers remained stable during the 1990s, but declined during the 2000s (Figure 3).

There was significant statistical evidence for a declining trend in the mean number of American Kestrels/10 party-hours in all regions east of Ohio. Wintering numbers declined steeply in New York, southern New England, Delaware-Maryland-D.C., and New Jersey, and their estimated 2013 wintering kestrel densities were low. The CBC data indicate that Pennsylvania and Virginia have the highest wintering concentrations east of Ohio, even though Pennsylvania experienced an estimated 62% decline in wintering numbers since 1973. Florida once had one of the highest wintering densities of American Kestrels; densities there remain relatively high, but at about half their previous level. They also declined in Ohio and southern Ontario, although apparently not as steeply as farther east. Wintering numbers in Indiana, Illinois, Kentucky, Tennessee, Louisiana, and Arkansas were comparatively stable (Figure 4, Table 2).

Table 1. Trend statistics for American Kestrels at eastern hawk watch sites

Site	Years	Season	% Annual Change	P-Value
Tadoussac, QC	1993-2012	Fall	-6.22	0.03 *
Holiday Beach, ON	1979-2012	Fall	-2.04	0.003 *
Detroit River, MI	1996-2012	Fall	-2.90	0.308
Lighthouse Point, CT	1980-2012	Fall	-3.51	<0.001 *
Cape May, NJ	1976-2012	Fall	-3.82	<0.001 *
Montclair, NJ	1977-2012	Fall	-3.59	<0.001 *
Hawk Mountain, PA	1967-2012	Fall	-1.39	<0.001 *
Waggoner's Gap, PA	1987-2012	Fall	1.14	0.081
Braddock Bay, NY	1978-2013	Spring	-1.50	0.169
Derby Hill, NY	1979-2013	Spring	-1.17	0.128
Fort Smallwood, MD	1993-2013	Spring	-8.06	<0.001 *

** - significant statistical evidence for a trend*

Table 2. Trend analysis for CBC American Kestrel data by region

CBC Region	1973-2013 % Change*	2013 Kestrels/10 party-hrs*
New York	-84.3	0.38
Mass-Conn-RI	-95.3	0.09
Delaware-MD-DC	-89.5	0.45
New Jersey	-96.6	0.13
Pennsylvania	-62.1	1.31
Virginia	-51.0	1.52
Florida	-51.4	3.63
North Carolina	-69.7	0.94
Ohio	-58.2	1.70
s. Ontario	-82.0	0.29
Indiana	6.8	2.62
Illinois	119.2	3.65
Kentucky	NA	7.02
Tennessee	31.8	3.74
Louisiana	NA	4.29
Arkansas	-22.3	2.44

** - calculated from regression fits, except used the 10-year (2004-13) average as the estimate for Kentucky and Louisiana's recent density*

Winter Raptor Survey. A map of effort-adjusted American Kestrel counts during the WRS shows that the center of wintering American kestrel abundance during 2001-2015 was the Susquehanna Valley, with southwestern counties being a distant second (Figure 5).

The statewide trend in the WRS number of kestrels/hour was downward, but there were periods of consecutive years with little change. Downward changes occurred during winters when there was a combination of low temperature, high snowfall, and high snow depth (indicated by dark-colored bars in Figure 5). There was significant statistical evidence for both the trend and the effect of snow depth in explaining the observed variation (p-value < 0.001, R^2 = 87.7%).

The highest number of observed American Kestrels/hour occurred during the first survey year, 2001. Kestrel numbers declined in both 2003 and 2004 with severe winter conditions, but bounced back in 2005 to about the 2003 level. In 2011, numbers declined slightly with moderately severe conditions, but bounced back the next year. Another decline occurred in 2014 with severe winter conditions. In 2015, another year with a severe winter, there was little change in kestrel numbers (Figure 5).

Pennsylvania CBC and WRS by county region. Trends in CBC and WRS data from the five Pennsylvania county regions are illustrated in Figure 6. There was significant statistical evidence for declines in CBC data from each region. During the 1970s to mid-1980s, the number of kestrels observed per unit time during the CBC was similar in the six southeastern counties, Berks-Lancaster-Lebanon, and the south-central region. Beginning in the mid-1980s, the kestrel density from the six southeastern counties began to fall below the density of those other two regions and to eventually fall to the low level that is currently observed in the north. Beginning in the mid-2000s, the kestrel density in Berks-Lancaster-Lebanon began to fall below the density in the south-central region. The WRS data show similar patterns as the CBC data. There was significant statistical evidence for declines in the WRS data from the six southeastern counties and Berks-Lancaster-Lebanon, though not for the other three regions (Figure 6).

CBC trend statistics for the Pennsylvania regions indicates that the 1973-2013 percent change and the 2013 wintering density for the six southeastern counties were similar to what was observed in New York, southern New England, New Jersey, Maryland, and Delaware. The decline in Berks, Lancaster, and Lebanon counties was also steep, though not as severe. While the wintering density in the 19 south-central counties also appeared to decline, the 2013 kestrel density there remains comparable to densities observed in some of the Midwestern states. The estimated decline in the southwestern counties was the lowest among the five regions and its 2013 density second to the south-central counties. A large decline was also estimated for the 24 northern counties (Table 3).

Table 3. Trend analysis for CBC American Kestrel data by Pennsylvania region

CBC Region	1973-2013 % Change*	2013 Kestrels/10 party-hrs*
6 se. counties	-93.8	0.35
Berks-Lanc-Leb	-82.3	0.86
South-central	-31.9	3.08
Southwest	-25.1	1.45
North	-73.3	0.52

** - calculated from regression fits*

Band Returns. There were 92 records of an American Kestrel being banded in Pennsylvania during the breeding season and recovered during a subsequent wintering period. Of these, 51 (55%) of the recovery locations were within 100 km (62 mi) of the banding location, and 28 (30%) of recovery locations were more than 500 km (310 mi) from the banding location, as far south as Florida. Thus, a minority of Pennsylvania breeding kestrels appears to migrate far; most appear to winter not far from their breeding territory.

There were 50 records of a kestrel banded during the breeding season in northeastern North America and recovered in Pennsylvania during a subsequent wintering period; of these 46 were banded in Pennsylvania, two banded in New Jersey, and one each banded in Ontario and New York. Although this result may overstate the importance of Pennsylvania as a breeding source of its wintering kestrels, it reinforces that a majority of Pennsylvania's breeding kestrels are likely to winter in relative proximity.

Discussion

While a key finding of Pennsylvania's WRS has been the importance of the Susquehanna Valley for wintering raptors (Grove and Bolgiano 2012; Grove 2014), the CBC data indicate that, for American Kestrels, the Susquehanna Valley is a remnant of a much larger core wintering area that once extended from northern New Jersey through southeastern Pennsylvania to southeastern Maryland and Virginia. In this larger Northeast region, the data sources (hawk watch, BBS, CBC, Pennsylvania WRS, nest-box programs) are consistent in indicating declines in kestrel populations. Because kestrels of this latitude are partial migrants, these declines probably reflect a decline in their regional breeding populations; this doesn't rule out that there may also be fewer immigrant kestrels from more northern latitudes. That the northeastern declines began in the 1970s supports the hypothesis that land-use change might be a primary cause, as large-scale farming and land use changes began to negatively affect many farmland bird species at that time (Bolgiano 1999, 2000). It is possible that there are multiple causes of the American kestrel declines, each additive in its effect.

In contrast, the BBS indicates that breeding American Kestrel populations in Midwestern states are of higher densities and are mostly stable, although these populations are not well-monitored by hawk watches. The CBC also shows that the numbers of kestrels wintering in the Midwest to the west of Ohio are also relatively stable. In Ohio, the BBS indicates that the breeding kestrel population appears to be stable, though CBC data indicate that the wintering population is declining. Many of the kestrels that winter in Ohio may have migrated through southern Ontario and around the western end of Lake Erie; thus, the declining Ontario breeding population may partially explain the Ohio wintering pattern. (Migration through Ohio could also be the source of some of the American Kestrels that winter in western Pennsylvania.)

The WRS and weather data indicate that wintering American kestrel numbers are affected by severe winter

conditions, particularly when there are extensive periods with higher snow cover. American Kestrel numbers have shown different responses to severe winters. After declines in 2004 and 2011, kestrel counts bounced back the following year, suggesting that kestrels may have migrated farther south during those severe-weather winters. The declines of 2003 and 2014 were not followed by bounce-back years, suggesting that juvenile recruitment the next summer did not replace the higher winter mortality. At this latitude, it appears that winter mortality can be a major additional stress upon American Kestrels that are already experiencing declines due to other factors.

The CBC data show that the kestrel wintering declines have occurred throughout all Pennsylvania regions since the mid-1970s, but have been steeper in the southeast. That the same data patterns appear in both CBC and WRS data lends credence to these conclusions. Interestingly, nest-box occupancy in Hawk Mountain Sanctuary's kestrel nest-box program was relatively stable until dropping in 2003-2005 and is now showing an overall decreasing trend (J.-F. Therrien et al. unpubl. data), about the same time that there was separation between the wintering kestrel densities in Berks-Lancaster-Lebanon counties vs. the south-central region.

Our examination of banding data corroborates that many of the American Kestrels that breed in Pennsylvania winter relatively close to their breeding territories, which implies that, to some extent, Pennsylvania's wintering kestrel densities also reflect regional breeding densities and thus the overall species status. The two annual winter surveys, CBC and WRS, detect many more American Kestrels in Pennsylvania than does the annual breeding season survey, the BBS. Since 1970, the range in kestrel numbers annually detected in these surveys in Pennsylvania is 553-1766 (CBC), 265-699 (WRS), and 27-95 (BBS). As it is usually becomes easier statistically to detect trends as the sample size increases, this likely applies for assessing American kestrel trends.

Despite the recent declines in American Kestrels, Pennsylvania contains much suitable habitat for the species. The Susquehanna Valley provides good wintering habitat because it is of relatively low elevation and has extensive farmland with a high proportion of pastures and hayfields. These farmland characteristics are common to locations where higher number of American Kestrels were found in Pennsylvania's second breeding bird atlas: the Susquehanna Valley; the area around Hawk Mountain Sanctuary's nest-box program, centered in Berks County, in Somerset, Bedford, and Blair counties, in Westmoreland and Indiana counties, and in the northwestern counties from Lawrence to Erie.

Pennsylvania is an important state for a number of bird species, providing key habitat for those species' continuing well-being. The American Kestrel is one such species. The data indicate that, east of Ohio, Pennsylvania has one of the highest breeding and wintering concentrations of American Kestrels. One action that Pennsylvania could take to enhance the species' prospects is to continue implementing nest-box programs. New Jersey can serve as a model. There, a statewide nest-box program is concentrated in habitat identified as possessing high value for breeding kestrels (Smallwood et al. 2009b). To improve the success of restoration efforts, further research is needed to assess what life history component (reproduction, survival, growth) kestrel population trends are most sensitive to and what we can do to positively change that.

Acknowledgments

We thank the many volunteers who have made the observations summarized here. This is Hawk Mountain Sanctuary contribution to conservation science number 255.

Nick Bolgiano
711 W. Foster Avenue
State College, PA 16801
nickbolgiano@gmail.com

Jean-François Therrien
Senior Research Biologist
Hawk Mountain Sanctuary
410 Summer Valley Road
Orwigsville, PA 17961
therrien@hawkmtn.org

Greg Grove
9524 Stone Creek Ridge Road
Huntingdon, PA16652
gwg2@psu.edu

References

Bird, D.M., and R.S. Palmer. 1988. American Kestrel. Pages 253-290 in *Handbook of North American birds. Vol. 5: diurnal raptors. Part 2.* (Palmer, R.S., Ed.). Yale University Press, New Haven, Connecticut.

Bolgiano, N.C. 1999. The story of the Ring-necked Pheasant in Pennsylvania. *Pennsylvania Birds* 13:2-10.

Bolgiano, N.C. 2000. A history of Northern Bobwhites in Pennsylvania. *Pennsylvania Birds* 14:58-68.

Brauning, D.W. 1982. The role of cavity availability and cavity temperatures in nest site selection of the American Kestrel. M.S. Thesis. The Pennsylvania State University.

Brown, J.L., M.W. Collopy, and J.A. Smallwood. 2014. Habitat fragmentation reduces occupancy of nest-boxes by an open-country raptor. *Bird Conservation International* 24: 364-378 doi:10.1017/S0959270913000415

Inzunza, E.R. 2008. Raptor-migration watchsite descriptions. Pages 279-302 in State of North America's birds of prey (Bildstein, K.L., J.P. Smith, E.R. Inzunza, and R.R. Veit, eds). Nuttall Ornithological Club, Cambridge, Massachusetts, and The American Ornithologist's Union, Washington, D.C.

Ellison, W.G. 2010. American Kestrel (*Falco sparverius*). Pages 118-119 in Second atlas of the breeding birds of Maryland and the District of Columbia (W.G. Ellison, ed). The Johns Hopkins University Press, Baltimore, Maryland.

Farmer, C.J., and D.T. Hussell. 2008. The Raptor Population Index in practice. Pages 165-177 in State of North America's birds of prey (Bildstein, K.L., J.P. Smith, E.R. Inzunza, and R.R. Veit, eds). Nuttall Ornithological Club, Cambridge, Massachusetts, and The American Ornithologist's Union, Washington, D.C.

Farmer, C.J., and J.P. Smith. 2009. Migration monitoring indicates widespread declines of American kestrels (*Falco sparverius*) in North America. *Journal of Raptor Research* 43:263-273.

Farmer, C.J., and K.L. Bildstein 2012. American Kestrel (*Falco sparverius*). Pages 156-157 in Second atlas of breeding birds in Pennsylvania (A.M. Wilson, D.W. Brauning, and R.S. Mulvihill, eds). The Pennsylvania State University Press, University Park, Pennsylvania.

Gahbauer, J.A. 2007. American Kestrel (*Falco sparverius*). Pages 190-191 in Atlas of the breeding birds of Ontario, 2001-2005 (M.D. Cadman, D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Couturier, eds). Bird Studies Canada, Environment

Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto.

Grove, G., and N. Bolgiano. 2012. Winter Raptor Survey in Pennsylvania – 2001-2011 Results. *Hawk Migration Studies* 37(2):4-10.

Grove , G. 2014. The 2014 Winter Raptor Survey in Pennsylvania. *Pennsylvania Birds* 28:23-26.

Hawkcount. 2014. www.hawkcount.org

Medica, D.L., R. Clauser, and K.L. Bildstein. 2007. Prevalence of West Nile virus in a breeding population of American Kestrels (*Falco sparverius*) in Pennsylvania. *Journal of Wildlife Diseases* 43:538-541.

National Audubon Society. 2014. The Christmas Bird Count Historical Results [Online]. Available http://www.christmasbirdcount.org 2014.

NOAA National Climatic Data Center. 2015. http://www.ncdc.noaa.gov/

Nye, P.E. 2008. American Kestrel (*Falco sparverius*). Pages 206-207 in The second atlas of breeding birds in New York state (K.J. McGowan and K. Corwin, eds). Cornell University Press, Ithaca, New York.

Raptor Population Index. 2014. www.rpi-project.org.

Sauer, J. R., J. E. Hines, J.E. Fallon, K.L. Pardieck, D.J. Ziolkowski, Jr, and W.A. Link. 2014. The North American Breeding Bird Survey, Results and Analysis 1966 - 2012. Version 2.19.2014. USGS Patuxent Wildlife Research Center, Laurel, MD.

Smallwood, J.A., and D.M. Bird. 2002. American Kestrel (*Falco sparverius*), The Birds of North American Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North American Online: http://bna.birds.cornell.edu/bna/species/602 doi:10.2173/bna.602

Smallwood, J.A., M.F. Causey, D.H. Mossop, J.R. Klucsarits, B. Robertson, S. Robertson, J. Mason, M.J. Maurer, R.J. Melvin, R.D. Dawson, G.R. Bortolotti, J.W. Parrish, T.F. Breen, and K. Boyd. 2009a. Why are American Kestrel (*Falco sparverius*) populations declining in North America? Evidence from nest-box programs. *Journal of Raptor Research* 43:274-282.

Smallwood, J.A., P. Winkler, G.I. Fowles, and M. Craddock. 2009b. American Kestrel breeding habitat: the importance of patch size. *Journal of Raptor Research* 43:308-314.

The Pennsylvania State Climatologist. 2015. http://climate.psu.edu/data/

Wheeler, B.K. 2003. Raptors of eastern North America. Princeton University Press, Princeton, New Jersey.

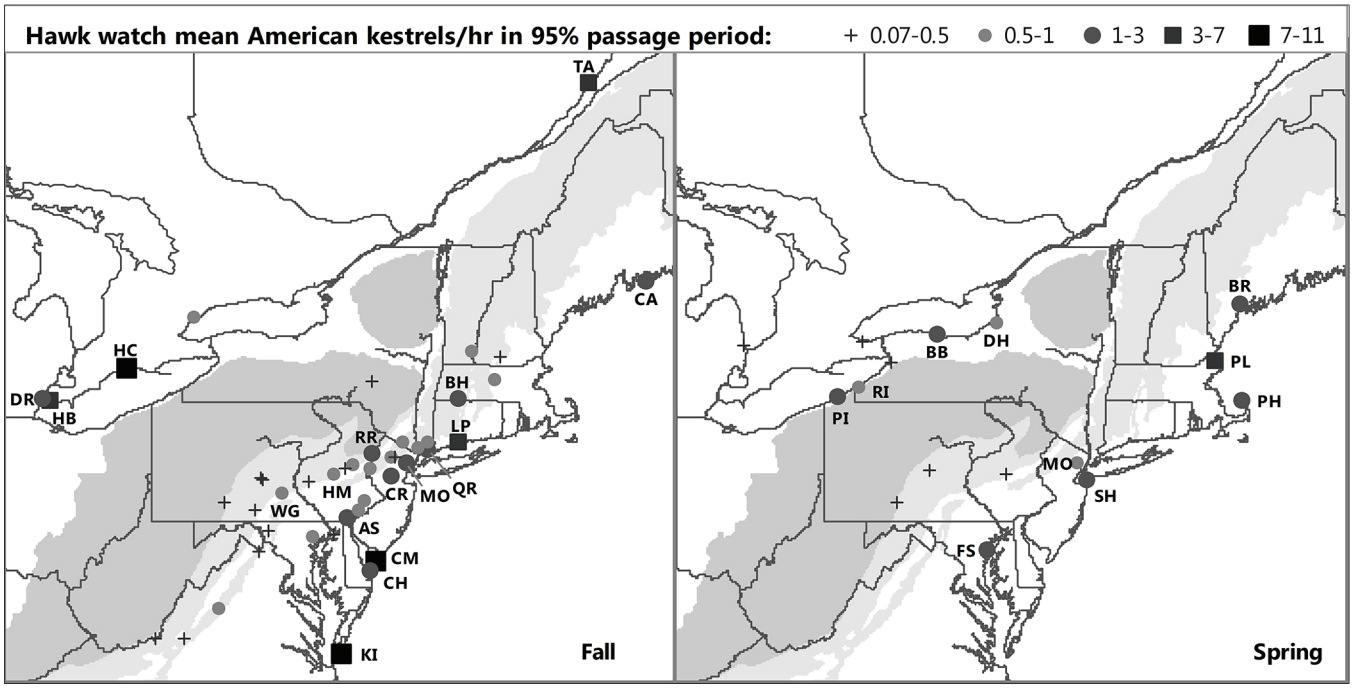

Figure 1. Map of eastern hawk watches, with symbols representing the average number of American Kestrels tallied in fall (left) and spring (right). Shaded areas represent mountainous or upland physiographic provinces. Data are 10-year (2005-2014) mean 95% passage period count/hour, except that Tadoussac data from 1995-2004. Labeled sites are **Connecticut**: QR=Quaker Ridge; **Delaware**: Ashland, CH=Cape Henlopen; **Maine**: BR=Bradbury Mt; **Maryland**: FS=Fort Smallwood; **Massachusetts**: PH=Pilgrim Heights, PL=Plum Island; **Michigan**: DR=Detroit River; **New Jersey**: RR=Raccoon Ridge, CM=Cape May, CR=Chimney Rock, MO=Montclair, SH=Sandy Hook; **New York**: BB=Braddock Bay, DH=Derby Hill, RI=Ripley; **Ontario**: HB=Holiday Beach, HC=Hawk Cliff, **Pennsylvania**: HM=Hawk Mt, PI=Presque Isle, WG=Waggoner's Gap; **Québec**: TA=Tadoussac; Virginia: KI=Kiptopeke.

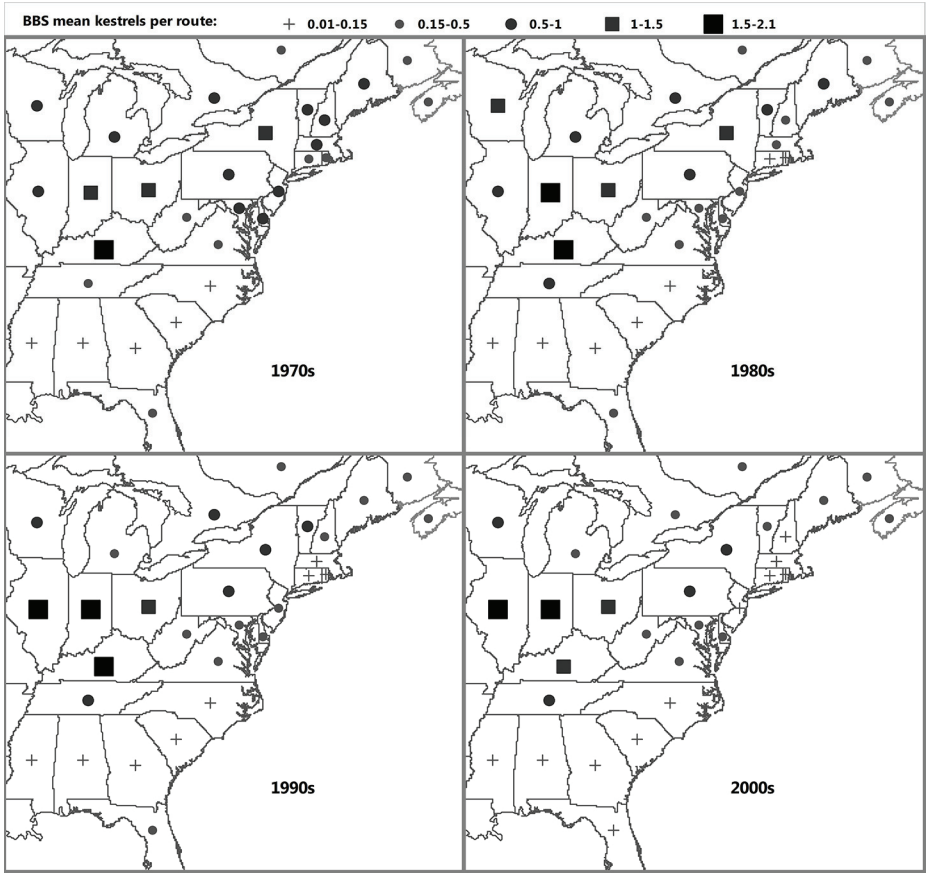

Figure 2. BBS maps of mean American Kestrels per route, during each of four decades, 1970-2009.

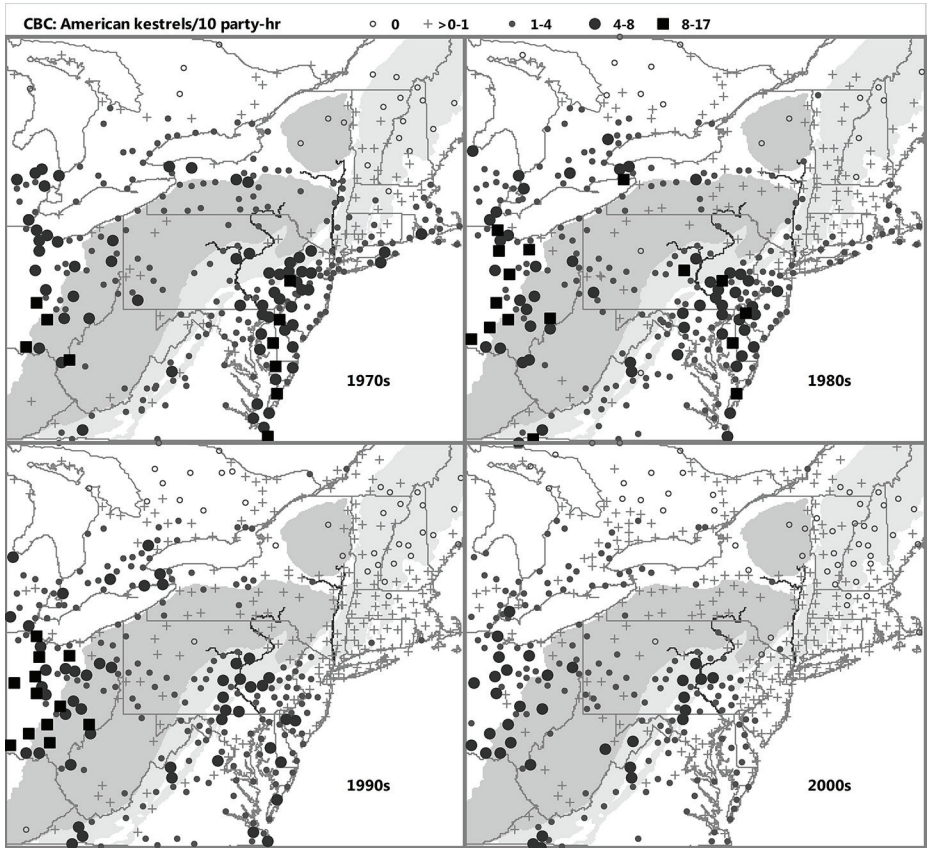

Figure 3. CBC maps of mean American Kestrels per 10 party-hours by site, during each of four decades, 1970-2009. Shaded areas represent mountainous or upland physiographic provinces.

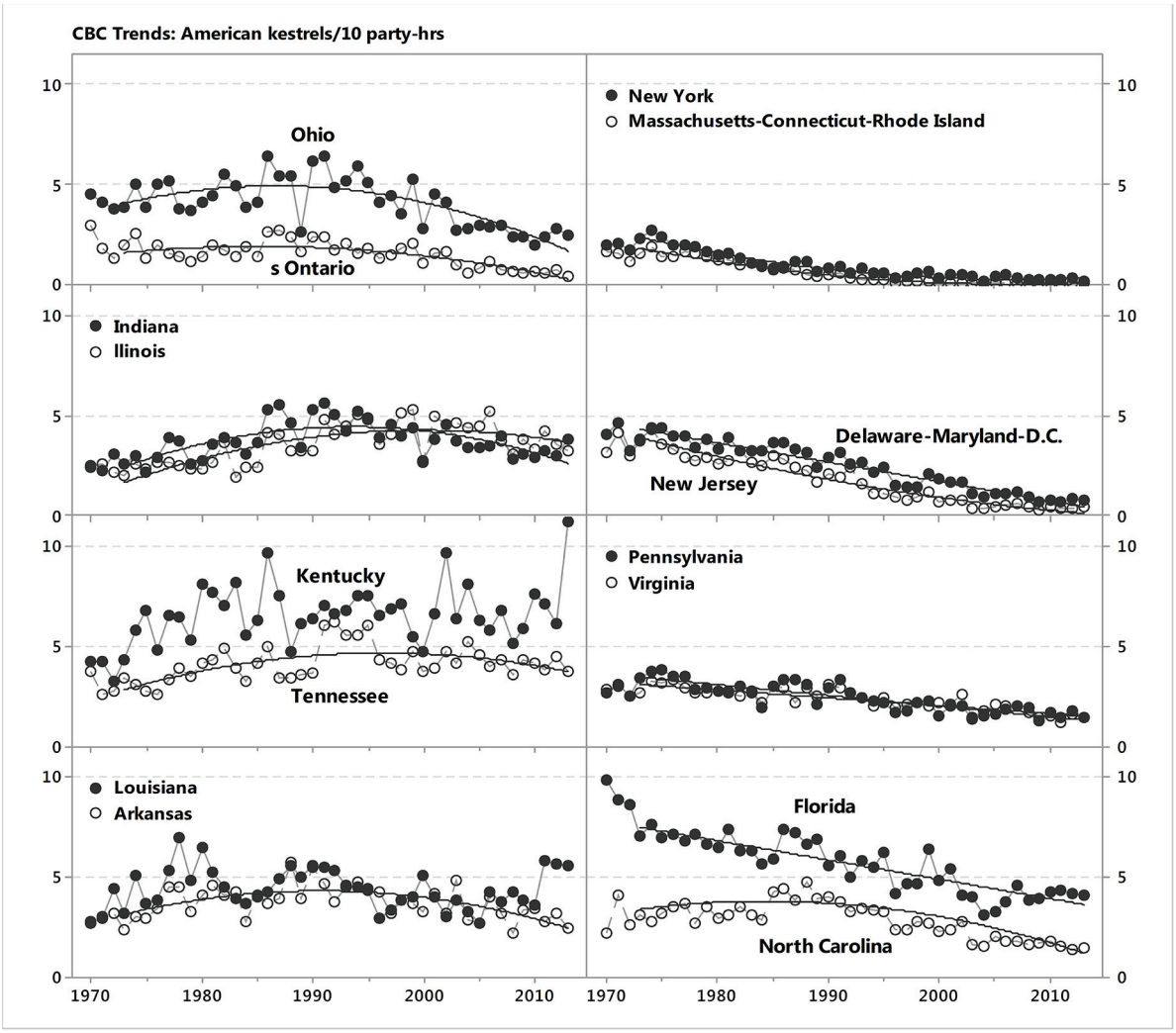

Figure 4. Mean CBC counts of American kestrels per 10 party-hours, from sixteen regions, for sites with 20 or more party-hours. Lines represent statistically significant regression fits for 1973-2013 data; statistically significant fits were not found for Kentucky or Louisiana data.

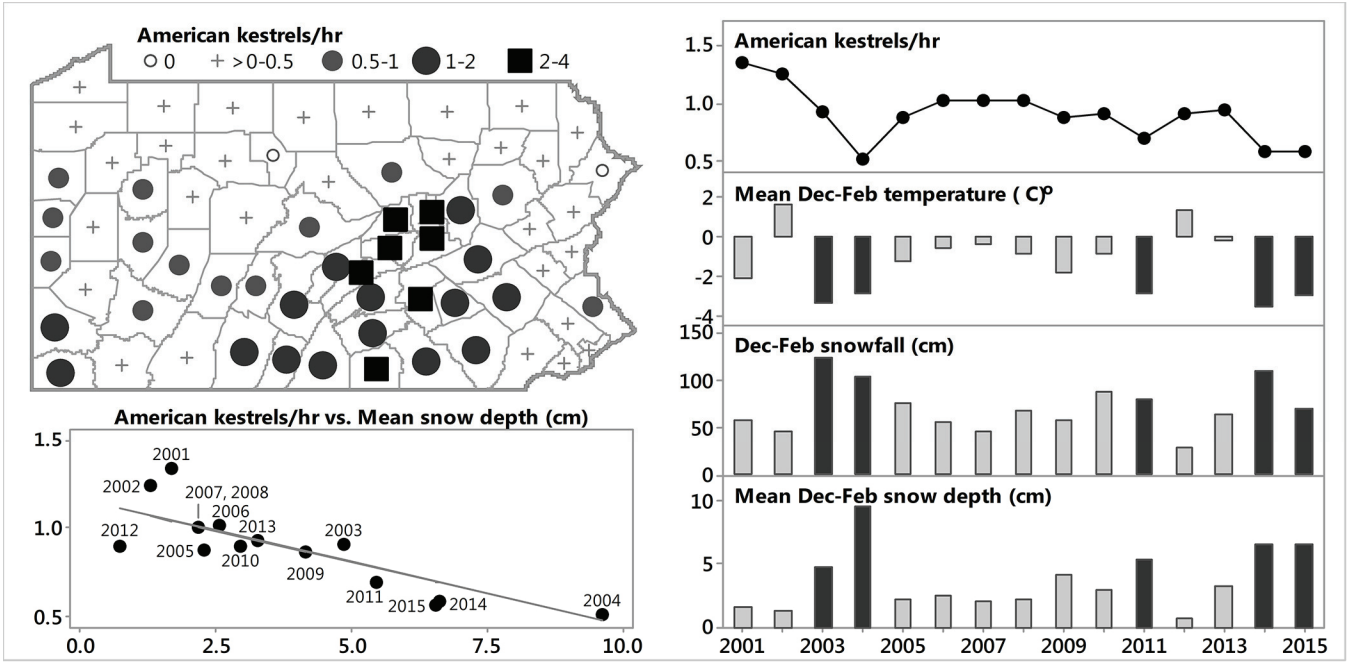

Figure 5. Map of mean WRS American kestrels/hour, 2001-2015 (top left); the statewide trend of American Kestrels/hour (top right); bar charts of three weather variables from Williamsport, PA, with dark bars representing years with the combination of mean temperature < 2C, snowfall > 65 cm, and mean snow depth > 4.5 cm (right); and plot of annual American kestrels/hour versus mean snow depth (cm) (bottom left), with regression fit.

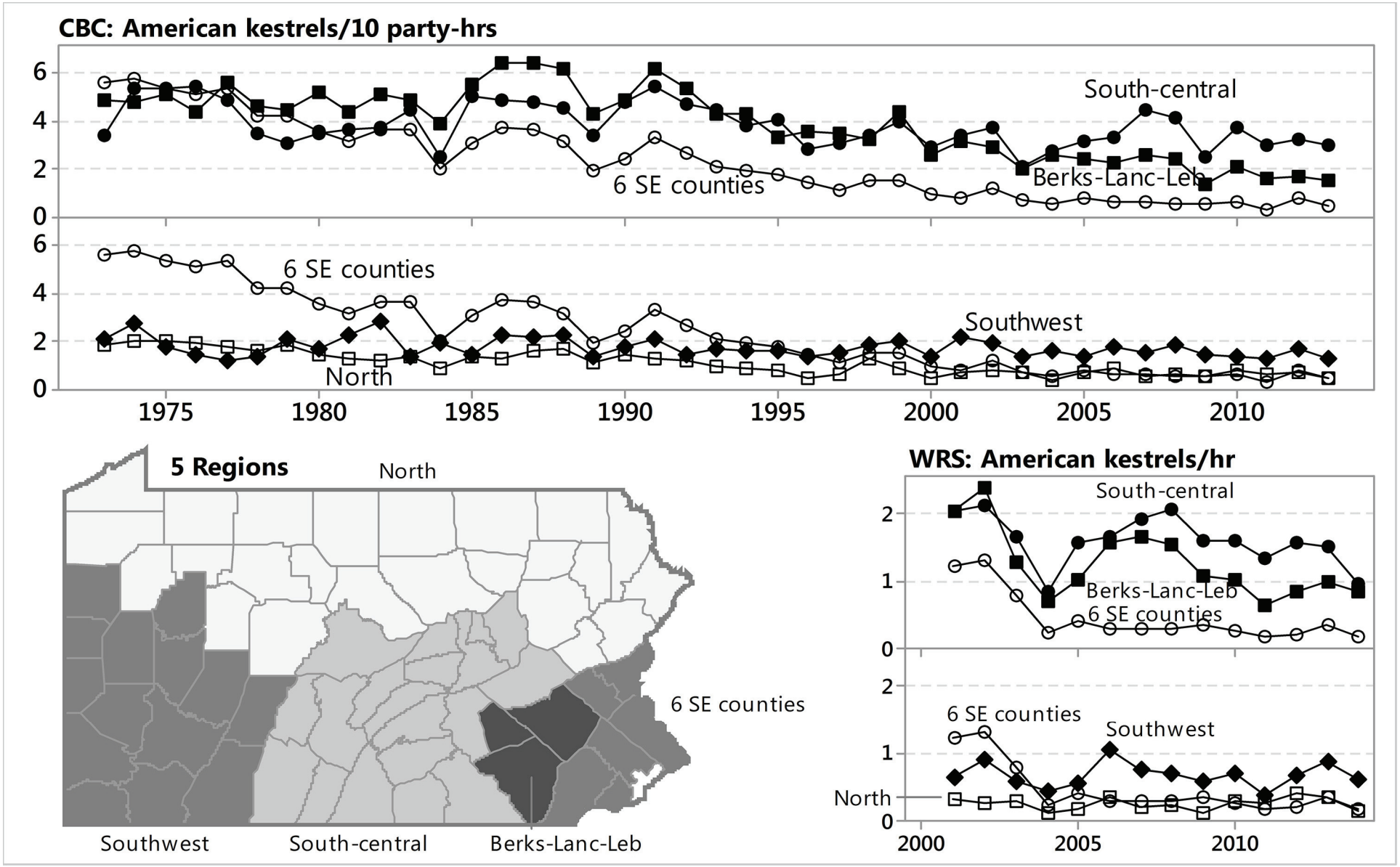

Figure 6. CBC American kestrels per 10 party-hours from each of five regions, 1973-2013, top. Regions are shown bottom left. CBC sites were assigned to a region by the location of their circle center. WRS American kestrels per hour from each of five regions, 2001-2014, bottom right.