TIMING OF SPRING WILD TURKEY HUNTING IN RELATION TO NEST INCUBATION

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Abstract: State wildlife agencies are often requested to open spring wild turkey (*Meleagris gallopavo*; hereafter, turkey) hunting seasons earlier to increase hunter satisfaction by hunters hearing more gobbling male turkeys. Timing of spring turkey hunting season in several states, including Pennsylvania, has been established to open, on average, near median date of incubation initiation of turkey nests. This is believed to reduce illegal and undesired hen harvest and possibly nest abandonment, while maintaining hunter satisfaction of hearing male turkeys when most hens are incubating eggs. However, Pennsylvania's spring season structure was established in 1968. Given earlier spring phenology, and potentially more variation in spring weather due to climate change, there is concern that timing of nest incubation for turkeys in Pennsylvania could be changing. Therefore, our objective was to determine if nest incubation and opening of spring turkey hunting in Pennsylvania have continued to coincide. We attached satellite transmitters to 254 female turkeys during 2010–2014 and estimated median incubation initiation date to be 2 May, which was 2 days earlier than median date during a statewide study during 1953–1963 and 9 days earlier than during a smaller scale study in south–central Pennsylvania during 2000–2001. However, incubation initiation varied greatly among years and individual hens during all 3 studies. During 4 of 5 years of our study, Pennsylvania's spring season opened 3 to 8 days prior to median date of incubation initiation. Over the 5 years, estimated initiation of incubation for first nesting attempts, measured from earliest date of incubation initiation to latest, was $>$2 months and maximum proportion of hens beginning incubation at any one time differed by several days to $>$1 week. Consequently, in years of late incubation, a constant season opening date set near the long-term median date of incubation initiation exposes few additional hens to risk and hunter satisfaction is likely maintained at greater levels than would be seen with a more conservative approach of opening the season later. Long-term and large scale studies using GPS transmitters that provide precise determination of incubation initiation will be useful to study environmental influences on initiation of incubation.

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During 2006–2009, 230,000 spring turkey (*Meleagris gallopavo silvestris*) hunters in Pennsylvania harvested 35–39% of adult males each spring (Diefenbach et al. 2012, Casalena 2015*b*) and during 2010–2014, 158,000 fall hunters harvested 2–10% of female turkeys (D. R. Diefenbach, U.S. Geological Survey, unpublished data). During 2006–2013, hunter densities averaged 2.0 and 1.4 hunters per km^2 during spring and fall seasons, respectively (Casalena 2015*b*). Great harvest rates and hunter density, combined with evidence of declining turkey populations in the mid-Atlantic (Casalena et al. 2015), midwestern (Parent et al. 2015), and southeastern states (Byrne et al. 2014), provide strong impetus for reevaluating harvest management strategies, particularly timing of opening dates for spring season. Declining turkey populations are more vulnerable to negative effects resulting from harvest management, especially when harvest rates and hunter densities remain great (Healy and Powell 1999, Norman et al. 2001). Timing of spring hunting season is one area where biologically informed management can potentially reduce negative effects on the population (Healy and Powell 1999, Norman et al. 2001).

State wildlife agencies typically seek to structure spring hunting seasons early enough to maximize hunter satisfaction, but late enough to reduce hen kill and nest abandonment. The most important determinants of hunter satisfaction are hearing and seeing male turkeys (Cartwright and Smith 1990, Vangilder et al. 1990, Siemer et al. 1996, Little et al. 2000, Swanson et al. 2007, Casalena et al. 2011). Therefore, hunter satisfaction is maximized by seasons that coincide with peak of gobbling activity (Norman et al. 2001, South Carolina Department of Natural Resources 2009). Gobbling activity in unhunted populations has a short peak during winter break-up of flocks and a longer, more consistent, peak near peak of nest incubation initiation (South Carolina Department of Natural Resources 2009). The longer peak in gobbling is due to increased efforts of male turkeys to locate receptive hens, as more hens become unreceptive to gobbling once they begin incubation (Bevill 1974, Miller et al. 1997, Norman et al. 2001, South Carolina Department of Natural Resources 2009). However, spring turkey hunters have generally been interested in hunting males during the entire gobbling period, which covers mating, egg-laying, and incubation periods (Vangilder et al. 1990, Norman et al. 2001, Swanson et al. 2007, Casalena et al. 2011). Hunting during mating and egg-laying have potential negative biological effects, such as removing dominant males before they have bred hens, illegal harvest of females, and nest abandonment (Gloutney et al. 1993, Palmer et al. 1993, Norman et al. 2001, Whitaker et al. 2007, South Carolina Department of Natural Resources 2009).

Pennsylvania and several other states have attempted to balance hunter satisfaction and hen protection by setting spring hunting season in accordance with median date of initiation of nest incubation (Healy and Powell 1999, Casalena 2006, Whitaker et al. 2007, South Carolina Department of Natural Resources 2009, New York State Department of Environmental Conservation 2015). This hunting season timing should also maximize hunter satisfaction because of the second gobbling peak and increased response of male turkeys to hunters' calls during peak of initiation of nest incubation (Bevill 1974, South Carolina Department of Natural Resources 2009). Pennsylvania has established a season structure of opening spring turkey season the Saturday closest to 1 May since its first spring season in 1968, with a few exceptions, based on data collected 1953–1963, which showed that 53% of hens had initiated incubation by 4 May (Rinell et al. 1965, Casalena 2006). This date coincides with incubation initiation dates of 5–9 May in the mid-Atlantic states (Whitaker et al. 2007). However, >50 years have passed since Rinell et al. (1965) and those findings may no longer be relevant, given possible changes in timing of incubation initiation resulting from a warming climate in the northern hemisphere and weather becoming more variable (Easterling et al. 2000, Magnuson et al. 2000, Coumou and Rahmstorf 2012). Dunn and Winkler (2010) calculated that, based on estimates from long-term studies of observed laying dates from 52 bird species (European and North American), egg-laying date is advancing an average 0.13 days per year (SE = 0.03, range –0.8 to 0.51), and egg-laying is occurring 2.4 days (SE = 0.27, range −10.3 to –0.01) earlier for every degree centigrade warmer.

Although many bird species lay earlier when spring temperatures are warmer in any given year (Dunn 2004), a variety of other proximate factors are hypothesized to influence start of breeding for turkeys and other bird species, including precipitation, food abundance, breeding density, photoperiod, and hormones (Porter et al. 1983, Vander Hagen et al. 1988, Thogmartin and Johnson 1999, Pekins 2007, Porter 2007, Dawson 2008, Dunn and Winkler 2010). For most temperate-breeding birds, these factors are thought to act in a hierarchy, with increasing photoperiod as the primary cue for gonadal maturation and release of hormones during spring (Dunn and Winkler 2010). Photoperiod is fixed at the same latitude but likely interacts simultaneously with these other environmental cues to set the physiological window during which egg-laying will occur (Dawson 2008, Schoech and Hahn 2008, Dunn and Winkler 2010). Whether egg-laying is occurring consistently earlier in turkeys has not been studied but, if earlier spring phenology has resulted in earlier egg-laying, then changes to spring hunting season dates may be warranted. Therefore, to evaluate if median date of incubation initiation has changed in Pennsylvania and evaluate if it continues to coincide with opening of the Pennsylvania spring hunting season, our objective was to examine incubation data from 2010–2014 and from 2 previous Pennsylvania studies (Rinell et al. 1965, Lowles 2002).

STUDY AREA

We investigated turkey nesting phenology across a 43,914-km^2 area of central Pennsylvania within 2 physiographic regions, the Allegheny Plateau and the Valley-and-Ridge regions (Berg et al. 1989). Our study was part of a larger study to investigate annual survival and fall harvest rates of female turkey under different fall season structures (Casalena 2015*a*), using 8 of Pennsylvania Game Commission's 23 Wildlife Management Units (WMUs) and comprising 37% of Pennsylvania (Fig. 1). We grouped the 8 WMUs into a southern study area (SA 1) and a northern

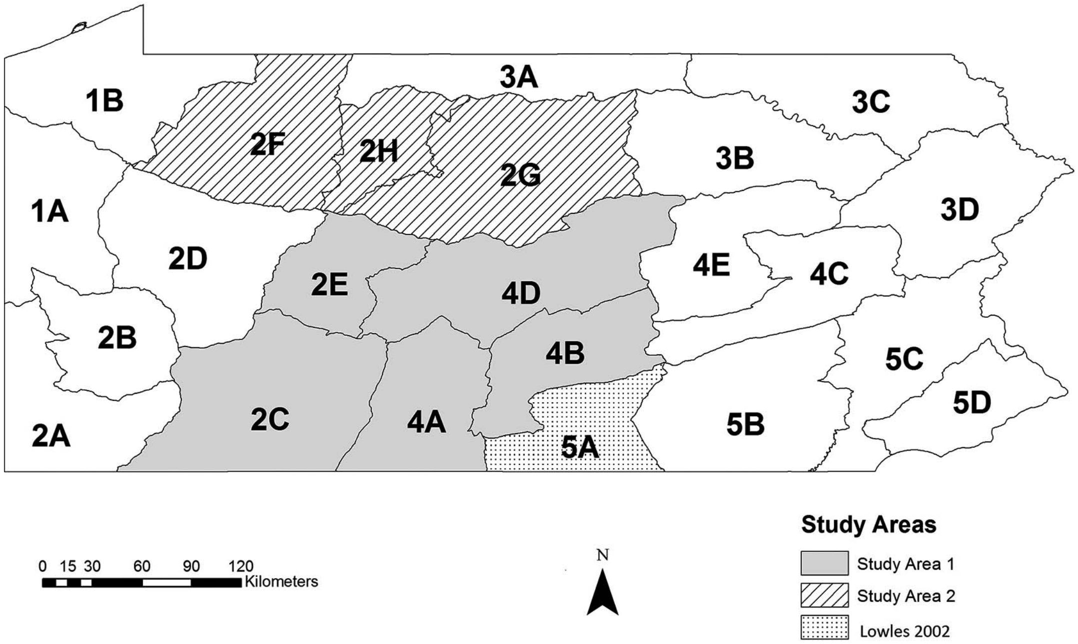

Figure 1. Pennsylvania Game Commission Wildlife Management Units (WMUs) and study areas. We trapped and equipped female eastern wild turkeys with satellite transmitters in WMUs 2C, 2E, 4A, 4B and 4D (Study Area 1) and WMUs 2F, 2G, 2H (Study Area 2) during 2010–2014. Lowles (2002) equipped female turkeys with VHF radiotransmitters in WMU 5A during 1999–2001.

study area (SA 2; Fig. 1). The southern study area consisted of WMUs 2C, 2E, 4A, 4B, and 4D. The northern study area consisted of WMUs 2F, 2G, and 2H. Wildlife Management Units were delineated based on land use, human density, and land ownership (public versus private), with boundaries being recognizable physical features such as major roads and rivers (Rosenberry and Lovallo 2002). Elevations ranged from 95 m to 979 m. Study Area 1 was 31% forested and 47% cultivated and SA 2 was 65% forested and 14% cultivated, with the remaining 21–22% composed of open water, developed land, strip mines, shrub land, herbaceous cover, and wetland. Primary forest types in both study areas were northern hardwood forest (co-dominant maple [*Acer* spp.], birch [*Betula* spp.], and American beech [*Fagus grandifolia*]) and Appalachian oak (*Quercus* spp.) forest (Rhoads and Black 2005). Weather conditions in both study areas were variable, although SA 2 experienced more precipitation, cooler temperatures, and more variable weather than SA 1 (National Oceanic and Atmospheric Administration 2014).

We compared dates of incubation initiation from this study to previous Pennsylvania studies conducted statewide (119,282 km^2) during 1953–1963 (Rinell et al. 1965) and 2000–2001 in WMU 5A (1,906.8 km^2) in south–central Pennsylvania (Lowles 2002). Elevation, vegetation, and climatic conditions in WMU 5A were similar to that in SA 1 of the current study.

METHODS

We trapped female turkeys during 2010–2014 using electronic command-detonated rocket nets (Bailey et al. 1980, Delahunt et al. 2011) during winter (Jan–Mar) and autumn (Aug–Oct) on both private and public lands. We aged turkeys as juvenile (<1 year old) or adult (≥ 1 year old; Healy and Nenno 1980, Delahunt et al. 2011) and leg-banded each turkey with either 1 or 2 aluminum rivet bands (Model 1242FR8A, National Band and Tag, Newport, Kentucky, USA). Leg bands were imprinted with "$100 REWARD $100" and a toll-free telephone number to maximize reporting recoveries (Diefenbach et al. 2001). We equipped females with 80-g backpack-style satellite platform transmitter terminal (PTT) units (Model 80G, North Star Science and Technology, LLC, King George, Virginia, USA; Model KiwiSat 303, Sirtrack, Havelock North, New Zealand), with a goal of fitting 60 females with PTTs prior to nesting each year. We affixed a sticker to each satellite transmitter with the same toll-free number as leg bands and a reward message to maximize reporting of recoveries. During autumn trapping, we placed PTTs on juvenile females ≥ 1.9 kg and adults. Trapping teams were sufficiently trained and handled turkeys according to standards recommended by The Ornithological Council guidelines on handling birds (Fair et al. 2010).

Satellite transmitters were equipped with temperature and movement sensors and transmitted data based on a duty cycle of 6 hours during every 72-hr period. This duty cycle ensured battery life for the 5-yr study. Data were transmitted from PTTs to satellites from 0600 to 1200 hours at 60-sec increments. Temperature readings were influenced by weather conditions, but living hens maintained PTTs above ambient temperature. Temperature readings varied most when hens were moving, but stabilized when hens were stationary. An activity sensor in each transmitter recorded how often a mercury switch was opened and closed by movement of each transmitter; the counter recorded values 0–255, then reset to 0. From March through July, we used patterns in both temperature and activity to assess when a turkey was incubating. We used first instance of recorded temperatures being lower

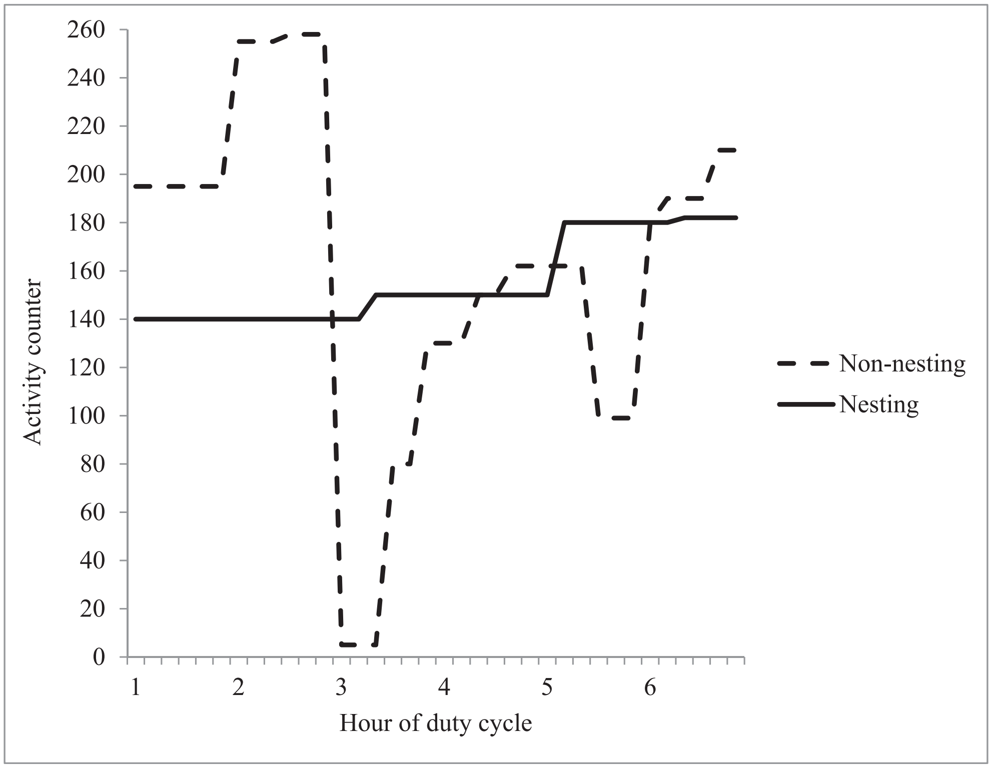

Figure 2. Example of activity counter readings during a 6-hr duty cycle, for satellite transmittered female eastern wild turkeys in Pennsylvania, comparing non-nesting movement with reduced movement during nest incubation.

than previously observed but above ambient temperature (about 17–40°C) and activity counter having less variability than previously observed (counter increments were <100), as date of incubation initiation (Fig. 2). Delay in our detecting incubation initiation was 0 days (PTT transmitted data the day of actual initiation), 1 day, or 2 days due to the 72-hr duty cycle of PTTs. Thus, on average, we were 1 day late in identifying date of incubation initiation. Consequently, we subtracted 1 day from every date of incubation initiation for our analyses.

We estimated median date of incubation initiation of first nests by study area and year. We estimated median dates instead of mean dates because dates of incubation initiation for turkeys tend to be right-skewed (Roberts 1993, Miller et al. 1997). We tested the hypothesis that median date of incubation initiation did not differ by age (adult versus juvenile) and study area within each year using a 1-sided Wilcoxon rank-sum (*R*) test with Bonferroni adjusted alpha levels of 0.01 per test (NPAR1WAY Procedure, Statistical Analysis System, SAS Inc., Cary, North Carolina, USA). We converted dates of incubation initiation to Julian dates for analyses. If we found no difference between age classes, we used a Kruskal–Wallis test to test the hypothesis that median date of incubation initiation did not vary among years with age classes combined (NPAR1WAY Procedure, Statistical Analysis System).

Rinell et al. (1965) back-dated dates of nest initiation using turkey brood sighting data collected statewide by Pennsylvania Game Commission personnel May–August, 1953–1960, and May–September, 1961–1963. Poults were classified into 4 age groups (0–3 weeks, 3–6 weeks, 6–9 weeks, and 9–12 weeks) and these ages were back-dated by 10 days, 31 days, 52 days, and 73 days, respectively, to calculate hatching dates. We estimated their dates of mean and median incubation initiation by back-dating mean and median hatch date by 28 days, which is mean incubation period length of turkeys (Blankenship 1992). Rinell et al. (1965) only provided dates when 53% of nests had hatched, but we assumed this was similar to median date because of the large sample size (6,119 brood sightings).

Lowles (2002) examined nest initiation date from 113 radiotransmittered hens in WMU 5A in south–central Pennsylvania, calculating incubation dates via daily monitoring of ground-based very high frequency (VHF) signals. During nesting season (Mar–Jul), after 2 successive days of an inactive, but non-mortality, signal from the same location, Lowles (2002) assumed a hen was incubating. Incubation initiation date was recorded as the first day of such a signal. Mean dates of incubation initiation were presented in Lowles (2002) by year and age class. We calculated median dates for each year and both years combined.

We did not conduct statistical tests for differences in incubation initiation among the 3 studies because we did not have raw data for Rinell et al. (1965) and Lowles (2002). Instead, we qualitatively compared median incubation initiation dates. Methods of determining incubation initiation differed among the 3 studies and became more accurate over time (least accurate using back-dating of broods, more accurate with VHF radiotransmitters, most accurate with PTT transmitters). Back-dating to hatch date from brood sightings by Rinell et al. (1965), followed by back-dating to incubation date, resulted in a variance of

Table 1. Median and mean dates of incubation initiation of eastern wild turkey nests in 3 Pennsylvania studies based on age class of hen being monitored or both age classes combined. Incubation initiation was determined via back-dating turkey broods sighted during 1953–1963 (Rinell et al. 1965), VHF radiotelemetry during 2000–2001 (Lowles 2002), and satellite PTT telemetry during 2010–2014 (present study).

Year(s)	Median date of incubation initiation			Mean date of incubation initiation		
	Adult	Juvenile	Combined	Adult	Juvenile	Combined
1953–1963			4 May ($n = 6{,}119$)			27 April ($n = 6{,}119$)
2000			13 May ($n = 33$)	10 May ($n = 24$)	19 May ($n = 9$)	
2001			6 May ($n = 56$)	5 May ($n = 48$)	11 May ($n = 8$)	
2000–2001			11 May ($n = 89$)			
2010–2014	2 May ($n = 168$)	5 May ($n = 34$)	2 May ($n = 202$)			

estimating incubation initiation from 10 days prior to 11 days after initiation. Variance of estimating incubation initiation via VHF radiotelemetry (Lowles 2002) was assumed to be minimal due to daily monitoring and incubation initiation recorded as the first day of hen inactivity. The 6 research technicians who conducted radiotelemetry for Lowles (2002) had an unknown variance among themselves due to individual experience levels, although all technicians were trained and assisted during their initial incubation detections. Satellite PTTs used in the current study allowed, at most, a 2-day misclassification of initiation of nest incubation.

RESULTS

We collected data from 254 hens (53 for >1 nesting season) with PTTs and identified 202 dates of first incubation initiation. We failed to detect a difference in incubation initiation date between age classes during 2010 ($R = 26.0$, $n_{juv} = 3$, $n_{ad} = 40$, $P = 0.97$), 2011 ($R = 315.5$, $n_{juv} = 14$, $n_{ad} = 24$, $P = 0.10$), 2012 ($R = 87.0$, $n_{juv} = 6$, $n_{ad} = 25$, $P = 0.67$), 2013 ($R = 180.0$, $n_{juv} = 6$, $n_{ad} = 42$, $P = 0.16$), or 2014 ($R = 158.0$, $n_{juv} = 5$, $n_{ad} = 37$, $P = 0.03$; Table 1). We also failed to detect a difference in date of incubation initiation between study areas during 2010 ($R = 457.0$, $n_1 = 21$, $n_2 = 22$, $P = 0.54$), 2011 ($R = 336.5$, $n_1 = 21$, $n_2 = 17$, $P = 0.45$), 2012 ($R = 224.0$, $n_1 = 17$, $n_2 = 14$, $P = 0.50$), or 2013 ($R = 486.0$, $n_1 = 27$, $n_2 = 21$, $P = 0.28$). However, during 2014, median date of incubation initiation was earlier in SA 1 (1 May) than in SA 2 (14 May; $R = 344.5$, $n_1 = n_2 = 21$, $P = 0.004$).

Given lack of differences among age classes and study areas except 2014, we pooled data for further analyses. Median date of incubation initiation pooled across study areas and years was 2 May (Table 1) but differed among years ($\chi^2_4 = 26.6$, $P < 0.001$; 23 Apr in 2010, 3 May in 2011, 2 May in 2012, 3 May in 2013, and 11 May in 2014; Table 2; Fig. 3). Median date occurred 8 days prior to opening date of spring turkey season (not including youth hunts) during 2010 (Fig. 3), but during the other 4 years, it occurred 3 to 8 days after opening date of spring turkey season.

Based on 6,119 broods observed during 1953–1963, 53% of hens began incubating by 4 May (Table 1; Rinell et al. 1965). Rinell et al. (1965) noted peak hatching dates varied considerably among years, such that only 39% of nests hatched by June in 1956, compared to 67% in 1955. Median date of incubation for Lowles (2002) was 11 May for data pooled across years, but varied between years (13 May in 2000, 6 May in 2001; Table 1). Earliest dates of

Table 2. Ranges of median dates of eastern wild turkey nest incubation initiation during multi-year studies across states (USA) or provinces (Canada) of eastern North America. Studies are listed in chronological order by year study began, then by state or province. Methods to determine initiation date varied among studies.

State/Province	Years	Range of medians	Sample size	Source
Vermont	1980–1993	5 May–13 May[a]	1,425	D. Blodgett, Vermont Department of Fish and Wildlife (unpublished data)
Missouri	1981–1988	28 April–26 May	126	Vangilder et al. (1987), Vangilder and Kurzejeski (1995)
Mississippi	1984–1995	12 April–3 May	235	Miller et al. (1995), Miller et al. (1998)
North Carolina	1985–1989	28 April–14 May	25	Davis (1992)
New York	1990–1991	6 May–11 May	90	Roberts (1993)
Virginia	1990–1994	27 April–15 May	232	Norman et al. (2001)
West Virginia	1990–1994	29 April–10 May	209	Norman et al. (2001)
Arkansas	1993–1996	28 April–24 May	58	Thogmartin and Johnson (1999)
Oklahoma	1995–1997	30 April–6 May	82	Stewart et al. (1998)
Pennsylvania	2000–2001	6 May–13 May	89	Lowles (2002)
New Hampshire	2001–2002	13 May–20 May[a]	16	Timmins (2003)
Arkansas	2012–2013	15 April–3 May	49	Pittman (2014)
Pennsylvania	2010–2014	23 April–11 May	202	Present study
Ontario	1999–2000	27 May–13 June	19	Nguyen et al. (2001)

[a] Mean dates.

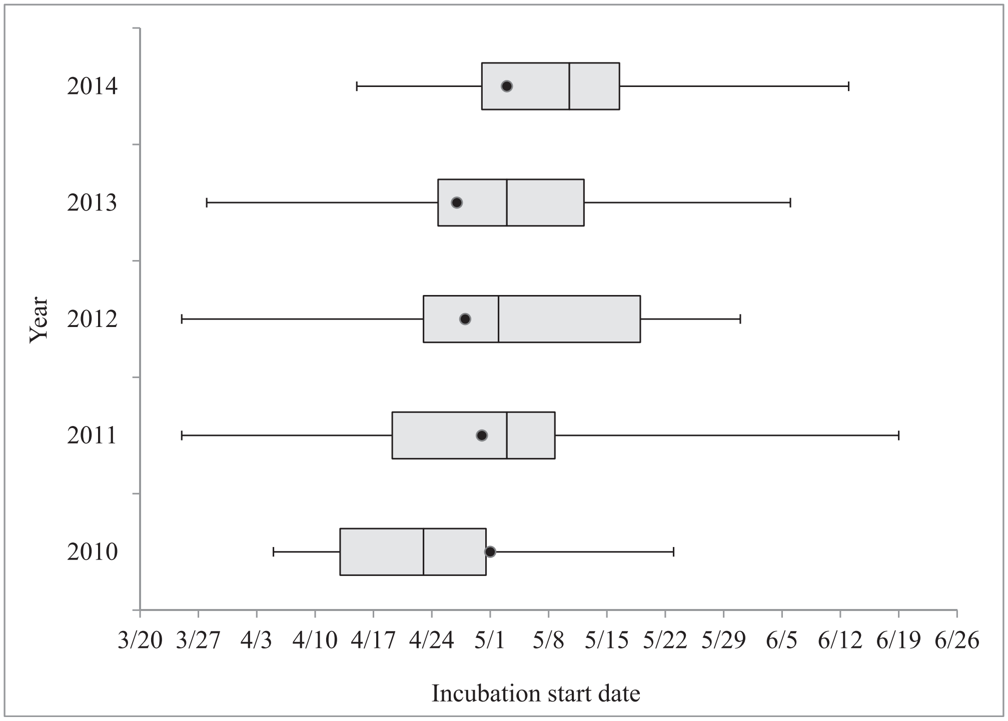

Figure 3. Median date of incubation initiation of first nests (vertical line inside the 25th–75th percentile box) of satellite transmittered eastern wild turkey hens in Pennsylvania, 2010–2014 ($n = 202$) with whiskers indicating earliest and latest dates of initiation. Circles represent spring turkey hunting season opening date each year (not including youth season).

incubation initiation were 27 April in 2000 and 19 April in 2001 (Lowles 2002). Median incubation initiation date in the current study was 2 days earlier than Rinell et al. (1965) and 9 days earlier than Lowles (2002).

DISCUSSION

Median date of incubation initiation of 2 May during 2010–2014 in central Pennsylvania continued to coincide with the Pennsylvania Game Commission's method of setting opening date of spring hunting season as Saturday closest to 1 May. However, median date of incubation initiation varied among the 5 years, with earliest and latest median dates occurring 18 days apart, demonstrating natural variability in nesting and the need for long-term studies to account for variability due to weather and food availability (Porter et al. 1983, Vander Haegen et al. 1988, Thogmartin and Johnson 1999, Steffen et al. 2002, Pekins 2007, Porter 2007). For example, in Pennsylvania, the 9-day difference in median date reported by Lowles (2002) was likely influenced by the shorter study period (2 years), differences in winter severity and mast crops between years, and the smaller study area (4% of this study). This also demonstrates a need to account for spatial variability via large scale studies. Differences in methodologies also likely account for some among study variability, demonstrating a need for additional research with latest locational technology (GPS) to obtain the most accurate estimates of incubation initiation possible (see below).

Other relatively recent studies of turkeys, from early 1980s to 2000s, also have reported variation in nest initiation dates among years (Table 2), and these studies varied considerably in length and sample size. Ranges of median nest incubation initiation dates were as variable as 21 days during a 12-year period in Mississippi (Miller et al. 1995, Miller et al. 1998), 26 days during 4 years in Arkansas (Thogmartin and Johnson 1999), and 28 days during 8 years in Missouri (Vangilder et al. 1987, Vangilder and Kurzejeski 1995). Ranges were as brief as 8 days in Vermont over a 14-year period (D. Blodgett, Vermont Department of Fish and Wildlife, unpublished data), and 7 days in New Hampshire during a 2-year period (Timmins 2003).

Mean annual temperatures in Pennsylvania have increased 1°C since the 1960s (Ross et al. 2013). However, due to known variability in nest initiation dates and techniques used to determine these dates between Rinell et al. (1965) and this study, we were unable to ascertain whether a perceived 2-day advancement in incubation initiation compared to 50 years ago was due, at least in part, to climate change (Dunn and Winkler 2010). Regardless, a 2-day difference is not sufficient to warrant a change in harvest regulations. Of possibly greater concern than warming temperatures, climate change has increased annual variability in weather (Magnuson et al. 2000, Ross et al. 2013), which could lead to greater variation in nest initiation dates and more years when the season opening date may be suboptimal for hunter satisfaction.

Variability in incubation dates from our study resulted in spring hunting season opening prior to median date of incubation initiation in 4 of 5 years. As a result, more non-incubating hens during those 4 years were at risk of harvest or nest abandonment due to potential disturbance from hunters early in hunting season. To further minimize

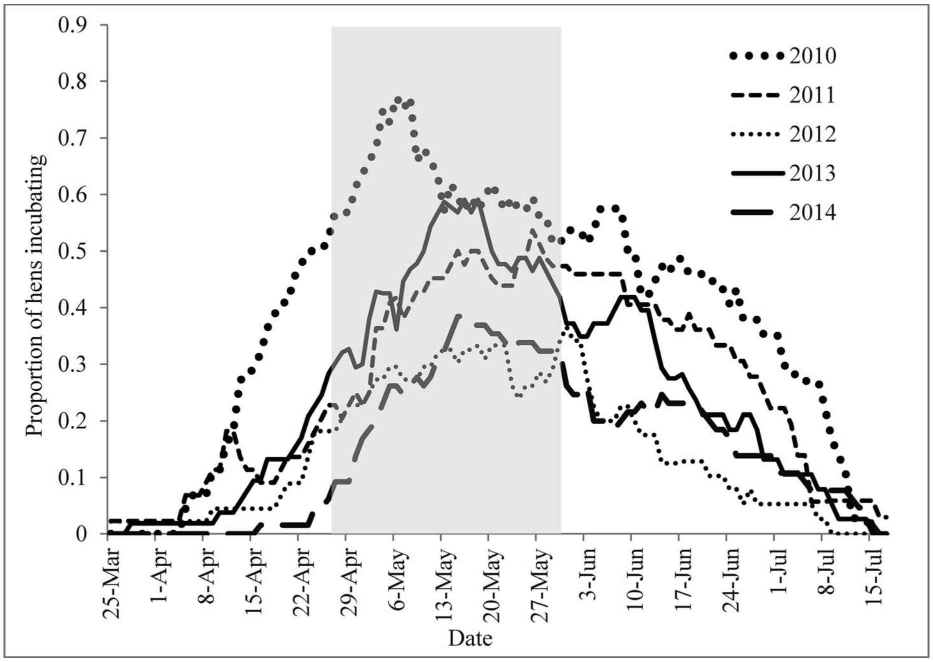

Figure 4. Proportion of satellite transmittered eastern wild turkey hens incubating eggs by day in Pennsylvania, 2010–2014. Shaded area represents duration of spring turkey hunting season (not including youth season), from earliest season opening date of the 5 years represented, 27 April, to latest closing date of 31 May.

disturbance and illegal harvest, a conservative management approach would be to move season opening date to later in the reproductive period. However, that would result in lesser hunter satisfaction and a shorter season if the current 31 May closing date was maintained. Hens initiated incubation over a time period of >2 months (Fig. 3) and maximum proportion of hens beginning incubation typically varied by several days (2010 and 2012; Fig. 4) to >1 week (2011, 2013 and 2014). Consequently, a constant season opening date set near the long-term median date of incubation initiation exposes few additional hens to risk during years of late incubation, and hunter satisfaction is likely maintained at greater levels than with a more conservative approach. Thus, variability in incubation initiation dates among hens protects against additional risk during years of late incubation.

Opening spring season prior to median date of incubation initiation has potential to increase illegal hen harvest. Pennsylvania is currently 1 of 8 states that typically opens spring turkey season close to mean incubation initiation (i.e., within 1–14 days; Whitaker et al. 2007). Norman et al. (2001) concluded that the great (6.0% $\pm$ 1.3 SE, $n = 383$) rate of illegal hen kill in Virginia during 1989–1994 was related to spring hunting season opening during peak mating season rather than during peak incubation. Researchers suspected that females were more vulnerable to illegal kill during mating season due to their tendency to associate with gobbling males, which the researchers speculated increased their likelihood of being harvested. Illegal hen kill in West Virginia was less during the same study at 2.5% ($\pm$ 0.80 SE, $n = 596$) and their spring season generally opened during the hen egg-laying period (Norman et al. 2001). Illegal hen kill in Pennsylvania during this study was 1.4% (SE = 0.56, $n = 254$, D. R. Diefenbach, U.S. Geological Survey, unpublished data). Norman et al. (2001) concluded that likelihood of illegal female kill is probably less during egg-laying than during mating period (as observed with opening of West Virginia's season) and least during nest incubation initiation (as observed with opening of Pennsylvania's season).

Mississippi (Miller et al. 1998) and Iowa (Hubbard et al. 1999) have early spring seasons and lesser rates of hen kill, but also lesser hunter densities (Eriksen et al. 2015). Whether their lesser rates of hen kill were due to lesser hunter densities or hunter attitude is unknown. However, spring hunter density (2.0 hunters/km^2; Casalena 2015*b*) and male harvest rates in Pennsylvania (0.35–0.39; Diefenbach et al. 2012) are the greatest in the mid-Atlantic region (New York State Department of Environmental Conservation 2014). Therefore, an earlier spring season could have potential negative effects on population dynamics if hen kill increased, which could lead to negative effects on future harvests and hunter satisfaction. Great hunter density could also increase risk of nest abandonment due to disturbance if the season began earlier. Research on this topic is lacking for turkeys, but research on waterfowl has shown risk of nest abandonment due to human disturbance is greater during egg-laying than during incubation (Gloutney et al. 1993). Additionally, Norman et al. (2001) and Healy and Powell (1999) noted illegal hen kill may be most important for states that offer a fall either-sex season. Due to additive effect of harvest on natural mortality in turkey populations, Vangilder and Kurzejski (1995) and Healy and Powell (1999) cautioned that small changes in illegal female kill during spring have potential to limit a population's capacity for sustained fall harvest.

Advancements in locational technology, i.e., satellite and GPS transmitters with a continuous duty cycle during nesting season, provide precise determination of onset of incubation, which allow researchers to ask and answer questions that have proven difficult in the past (Collier and Chamberlain 2011). As indicated above, long-term and large scale studies are needed when examining timing of nest initiation. Satellite transmitters accommodate large scale studies by eliminating daily monitoring of hens by teams of technicians. We deployed 16–20 turkey trapping crews, each consisting of 2–5 workers and volunteers, to capture turkeys. However, only 1 technician was needed to monitor and download daily data of all transmittered hens and 3 agency staff plus 1 part-time technician were able to retrieve transmitters from dead hens and determine mortality causes.

As indicated above, some of the variability in incubation timing reported with previous studies likely was related to inaccurate estimation of when incubation began due to uncertainty of data collected via VHF radiotransmitters and its subjectivity due to remotely evaluating hen behavior (i.e., interpreting signal fluctuation of whether a hen is stationary or moving). However, more accurate estimates of variability in incubation initiation, particularly in conjunction with predicted increased variability in weather conditions expected from climate change, will allow wildlife managers to better identify the most appropriate timing of spring turkey seasons.

MANAGEMENT IMPLICATIONS

We found no evidence that changes to timing of spring hunting season in Pennsylvania are warranted relative to incubation initiation due to annual variability of median date of incubation initiation. However, long-term and large scale studies using latest technology should provide more accurate estimates for monitoring changes in timing of nesting activity by hens.

Many states and regions have expressed concern about recent turkey population declines (e.g, Byrne et al. 2014, Casalena et al. 2015, Eriksen et al. 2015, Parent et al. 2015). Because reasons for decline are currently unknown, it is the responsibility of wildlife managers to consider hunting season regulations to ensure that hunter harvest is not contributing to declines. In absence of data on timing of illegal harvest, effects of great hunter densities on nest abandonment, and effectiveness of hunter education and law enforcement on protecting hens from harvest, maintaining a conservative opening date for spring turkey season may be warranted. Research regarding effects on turkey population trends of spring seasons opening prior to, versus in conjunction with, median incubation initiation date is likely warranted.

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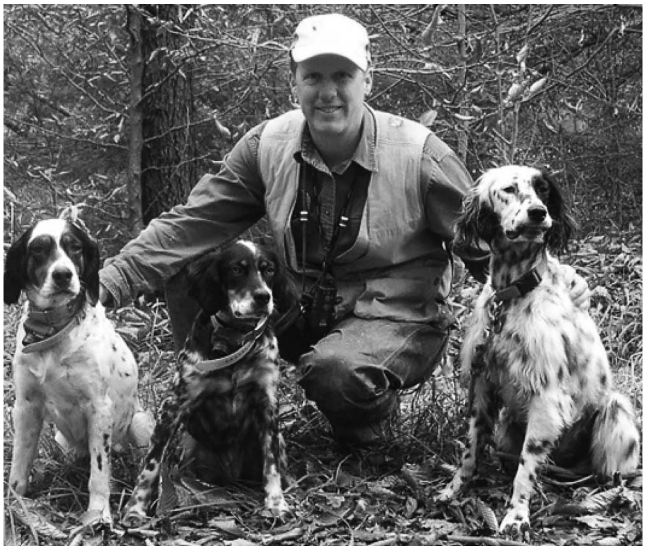

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