



Research Article

# Variation in Spring Harvest Rates of Male Wild Turkeys in New York, Ohio, and Pennsylvania

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**ABSTRACT** Spring harvest rates of male wild turkeys (*Meleagris gallapavo*) influence the number and proportion of adult males in the population and turkey population models have treated harvest as additive to other sources of mortality. Therefore, hunting regulations and their effect on spring harvest rates have direct implications for hunter satisfaction. We used tag recovery models to estimate survival rates, investigate spatial, temporal, and demographic variability in harvest rates, and assess how harvest rates may be related to management strategies and landscape characteristics. We banded 3,266 male wild turkeys throughout New York, Ohio, and Pennsylvania during 2006–2009. We found little evidence that harvest rates varied by year or management zone. The proportion of the landscape that was forested within 6.5 km of the capture location was negatively related to harvest rates; however, even though the proportion forested ranged from 0.008 to 0.96 across our study area, this corresponded to differences in harvest rates of only 2–5%. Annual survival was approximately twice as high for juveniles ( $\hat{S} = 0.64–0.87$ ) as adults ( $\hat{S} = 0.30–0.41$ ). In turn, spring harvest rates for adult turkeys were greater for adults ( $\hat{H} = 0.35–0.39$ ) than juveniles ( $\hat{H} = 0.17–0.27$ ). We estimated the population of male turkeys in New York and Pennsylvania ranged from 104,000 to 132,000 in all years and ranged from 63,000 to 75,000 in Ohio. Because of greater harvest rates for adult males, the proportion of adult males in the population was less than in the harvest and ranged from 0.40 to 0.81 among all states and years. The high harvest rates observed for adults may be offset by greater recruitment of juveniles into the adult age class the following year such that these states can sustain high harvest rates yet still maintain a relative high proportion of adult males in the harvest and population. © 2011 The Wildlife Society.

**KEY WORDS** harvest rate, hunting mortality, *Meleagris gallapavo*, New York, Ohio, Pennsylvania, spring hunting, survival, wild turkey.

Understanding harvest and harvest-related mortality is important for demographic assessment of exploited populations because these parameters represent the most readily available information for wildlife managers. For male wild turkeys (*Meleagris gallapavo*), spring harvest is the single greatest mortality factor (Godwin et al. 1991, Paisley et al. 1996, Wright and Vangilder 2005) and is thought to be additive to other sources of mortality because most natural mortality occurs during the spring breeding season (Thogmartin and Schaeffer 2000, Holdstock et al. 2006, Moore et al. 2008). Although fall harvest is thought to have the greatest influ-

ence on population growth (Vangilder and Kurzejeski 1995, Alpizar-Jara et al. 2001, McGhee et al. 2008), spring harvest can influence the number and proportion of adult gobblers in the population (Vangilder and Kurzejeski 1995). For example, Vangilder and Kurzejeski (1995) modeled a wild turkey population and by increasing overall spring harvest rates from 25% to 50%, the proportion of the population composed of adults declined from 72% to 56%.

Social surveys indicate that turkey hunters favor a large proportion of adult males in the population, and that hearing a gobbler, seeing turkeys, and calling turkeys contribute more to hunter satisfaction than killing a bird (Cartwright and Smith 1990, Vangilder et al. 1990, Siemer et al. 1996, Little et al. 2000, Swanson et al. 2007). Harvest management strategies that seek to maximize both hunter success and

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hunter satisfaction require information on harvest rates and age structure of the male turkey population. Although the ratio of adults:juveniles in the harvest may provide insight into the age structure of the population, if harvest rates differ between age classes and vary over time then the age structure of the harvest may not be a reliable index to the age structure of the population (Healy and Powell 1999). Therefore, a population model developed by Vangilder and Kurzejeski (1995) typically has been used as a guideline for interpreting male turkey harvest rates in relation to hunter satisfaction (e.g., Healy and Powell 1999, Hubbard and Vangilder 2005, Wright and Vangilder 2005).

Most studies conducted on male wild turkeys to estimate survival and harvest rates have relied on radio-telemetry. However, because of logistics, study areas usually are small relative to the size of land units for which turkeys are managed by natural resource agencies, or only a single management unit may be studied. Consequently, making statewide inferences about age structure and harvest rates for management may be limited. In contrast, band-recovery studies permit stronger inferences regarding population parameters over larger areas because turkeys can be captured throughout the defined area of interest and do not need to be intensively monitored (Brownie et al. 1985). Although fates of all individual turkeys are not known, proper study design permits estimation of harvest rates and survival rates (Brownie et al. 1985, Williams et al. 2002). Despite the advantages of band-recovery study designs, few attempts have been made to use band-recovery data to estimate survival or harvest rate parameters of wild turkeys (but see Lewis 1980, Lint et al. 1993, Vangilder and Kurzejeski 1995, Norman et al. 2004).

We banded male wild turkeys throughout New York, Ohio, and Pennsylvania, USA to estimate harvest rates with the intent of gaining a better understanding of variability in harvest rates, and how harvest rates may be related to management strategies and landscape factors. New York, Ohio, and Pennsylvania exhibit variation in hunter numbers (80,000–228,000), hunter density (1.0–2.3 hunters/km<sup>2</sup>), and hunter success rates (0.17–0.26 turkeys/hunter) for spring turkey hunting. Also, we investigated how landscape factors (e.g., percent forest cover, forest configuration, etc.) may be related to harvest rates. Our objectives were to estimate for male wild turkeys: 1) harvest rates during the spring season; 2) annual survival rates; 3) annual mortality from all sources other than spring harvest; 4) band reporting rates by hunters who harvested banded wild turkeys with no reward; and 5) abundance and age structure of male wild turkeys in each state.

## STUDY AREA

Our study area encompassed the range of wild turkeys in New York, Ohio, and Pennsylvania (Fig. 1). We captured turkeys throughout upstate New York (except Essex County) north of the counties that comprise New York City. We attempted to capture turkeys throughout Pennsylvania and captured turkeys in 62 of 67 counties. Based on movements estimated from capture and harvest locations of banded

turkeys, 20% moved >6.4 km from the banding location and it is likely that banded turkeys occurred in nearly every county in Pennsylvania and all of upstate New York (D. R. Diefenbach, U.S. Geological Survey, unpublished data). The range of wild turkeys in Ohio is expanding, in part because of translocation efforts. Wild turkey restoration was completed in 2008 and wild turkeys now occupy approximately 77,000 km<sup>2</sup> in part or all of 88 Ohio counties. We trapped wild turkeys in 28 Ohio counties in 4 physiographic regions (Fig. 1).

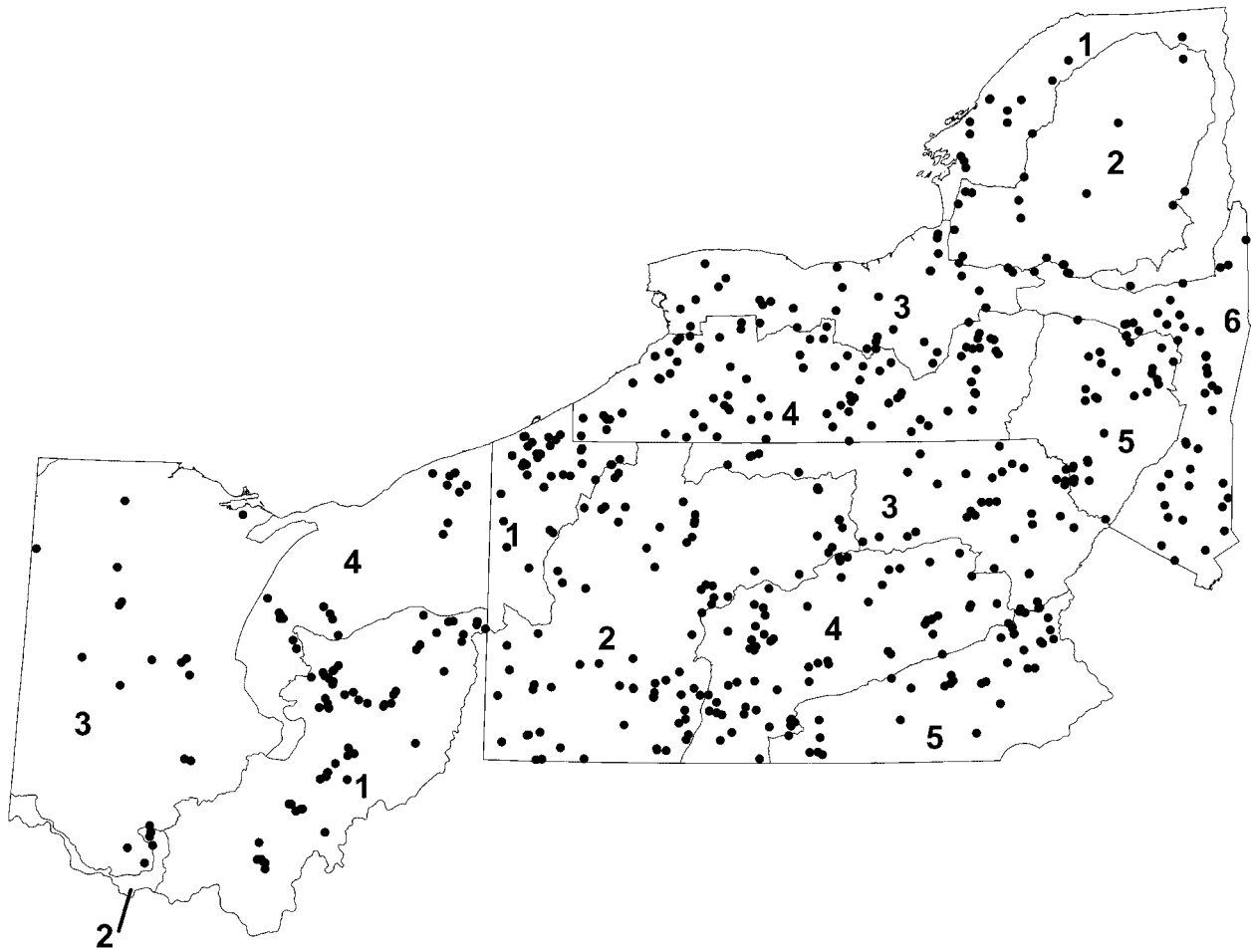
The spring hunting season in New York during 2006–2009 was 1–31 May and included a youth hunting Saturday and Sunday the weekend before 1 May. In Pennsylvania the spring hunting season opened the Saturday closest to 1 May, was open for 31 days, and included a youth hunt the Saturday before the regular season opened. No wild turkey hunting is allowed on Sunday in Pennsylvania. In Ohio, spring turkey season started on the Monday closest to 21 April and lasted for 28 days. A 2-day youth season was held on Saturday and Sunday immediately before the spring turkey season opened.

The bag limit in New York and Ohio was 2 bearded turkeys (1/day). In Pennsylvania the bag limit was 1 bearded turkey unless a second tag was purchased prior to the spring season. New York required hunters to purchase a permit to hunt turkeys whereas in Ohio a turkey permit was required for each turkey harvested and could be purchased at any time prior to and during the spring season. In Pennsylvania, all regular license buyers obtained a tag to harvest 1 turkey during the spring season. All 3 states have either-sex fall hunting for wild turkeys that range from 2 weeks to 7 weeks in New York (1–2 bird bag limit) and 0–3 weeks in Pennsylvania (1 bird bag limit) depending on the management unit. In Ohio, the fall season is 7 weeks with a 1 bird bag limit.

## METHODS

### Capture and Banding

We trapped turkeys during December–April, 2006–2009 using rocket nets baited with corn, although nearly all captures occurred January–March. In New York, we established county-level banding goals in which we apportioned the overall statewide goal to band 300 male turkeys among counties proportional to the estimated spring harvest in each county. In Pennsylvania, we attempted to capture 50 male turkeys in each of 6 administrative regions. In Ohio, we distributed the statewide capture quota of 300 male turkeys among 9 trapping crews. We released all wild turkeys at the capture site except 49 banded adult male turkeys were translocated to 7 western Ohio counties (Allen, Henry, Mercer, Paulding, Putnam, Shelby, and Union counties) as part of wild turkey restoration efforts. We translocated 1 banded male wild turkey captured in Pennsylvania because of nuisance complaints. In 2009, we did not band turkeys in Ohio although we continued to record band recoveries and pay rewards for bands reported to us before the end of July 2009.



**Figure 1.** Map of New York, Ohio, and Pennsylvania indicating where male wild turkeys were captured and leg banded and the numbered management zones within each state that were delineated based on a combination of physiographic regions and wildlife management units. We used these management zones to evaluate how harvest rates may have varied spatially, 2006–2009.

We determined age of captured male turkeys (juveniles <1 yr old, adults  $\geq$ 1-yr old; Pelham and Dickson 1992) and fitted them with an aluminum rivet band (Model 1242FR9 National Band and Tag, Newport, KY) below the spur. Also, on the other leg below the spur we fitted each turkey with 1 of 4 types (aluminum, anodized aluminum, enameled aluminum, and stainless steel) of butt-end leg bands (Size 28, National Band and Tag) during the first 3 years of the study to assess butt-end leg band retention (Diefenbach et al. 2009).

Each band was imprinted with a unique alphanumeric sequence and listed a toll-free number for reporting recovery of a band. Approximately half the rivet bands were imprinted with “\$100 reward” because Nichols et al. (1991) and Diefenbach et al. (2001) found that rewards  $>$ \$75 led to 100% reporting of bands by hunters. In 2009, we banded only juveniles with reward bands because there were a sufficient number of wild turkeys banded in previous years alive that were adults during the 2009 spring turkey season.

### Survival Between Capture and Spring Harvest

Band-recovery models assume no mortality between the time of banding and the first hunting season after banding; otherwise, harvest and survival rates are underestimated. Other

studies have found a relatively small proportion of annual mortality in males occurs during the months we trapped birds (e.g., Godwin et al. 1991, Wright and Vangilder 2005). However, we were able to explicitly test this assumption in Ohio in 2007 by fitting 83 male wild turkeys (71 also were leg banded) with 85 g backpack-style radio-transmitters (Advanced Telemetry Systems, Isanti, MN) to estimate the proportion of birds that survived January–April to the spring hunting season. We used the Kaplan–Meier product-limit estimator to estimate survival for 7-day intervals.

### Survival and Harvest Rate Modeling

We used tag-recovery models using the Brownie et al. (1985) parameterization to estimate annual survival and spring harvest rates in Program MARK (White and Burnham 1999). We classified each bird into 1 of 6 age-state groups: 2 age classes (adult, juvenile) for each of 3 states (NY, OH, PA). We assigned each bird an individual covariate indicating whether it was fitted with a reward band (0) or not (1).

To investigate if different hunting regulations and hunter participation affected harvest rates by management zone, we created a Geographic Information System (GIS) polygon layer to assign each capture location to a management zone in

each state. We delineated management zones based on a combination of physiographic provinces and state wildlife management units. We identified 6 zones in New York, 4 zones in Ohio, and 5 zones in Pennsylvania (Fig. 1). We used 14 indicator variables to designate which of the 15 management zones (6 in NY, 4 in OH, 5 in PA) a bird was banded. We could not investigate effects of hunter density on harvest rates because hunter density by management unit was not available for Ohio; however, to some extent management zones should have reflected differences in hunter density. Using estimates of hunter effort by management zones (hunter-days/km<sup>2</sup>) for New York and Pennsylvania, we constructed a model in which harvest rate varied by hunter effort.

We obtained GIS polygon layers identifying state and federal public lands and landcover types from the Multi-Resolution Land Characteristics Consortium (MRLCC 2009). We reclassified the land cover layer into forest, agriculture and open lands, and all other land uses, and we used a majority filter to reduce the complexity and number of misclassified raster cells based on the nearest neighbor function. For each capture location, we extracted 4 landscape characteristics within a 6.45-km radius buffer, which corresponded to the distance within which approximately 70% of harvested turkeys were recovered. We calculated percent forest cover (FOREST) and percent public land (PUBLIC) using Zonal Statistics of the Hawth's Tool extension for ArcMap (ESRI, Redlands, CA) and mean forest patch size (MFPS), and the Interspersion Juxtaposition Index (IJI) using Spatial Statistics through the Patch Analyst Extension for ArcMap (Patch Analyst 4, <http://flash.lakeheadu.ca/~rrempe/patch/index.html>, accessed 1 Sep 2009).

We could not assess goodness-of-fit of our most general model (survival and harvest rates varied by state, age of turkey, year, and type of leg band) in Program MARK because no birds were banded in Ohio in 2009 and the effect of rewards on recovery rates was modeled as an individual covariate. Consequently, we combined reward and non-reward band data in a model that estimated age and year-specific survival rates in Program BROWNIE (model H1) within Program MARK and used the goodness-of-fit test from this model to assess model fit for data from each state separately. If data from each state fit model H1, we assumed that a global model using data from all 3 states fit the data.

When constructing models of survival and harvest rates, not all parameters were estimable because we did not band birds in Ohio in 2009. However, by constraining some parameters (e.g., removing annual variation in survival rates or constructing additive models of temporal variation) all model parameters were estimable and we could use information provided by 2009 recoveries of Ohio turkeys that were banded 2006–2008 in the analysis. Our primary interest in this study was to identify patterns in harvest rates so we constructed models using the Brownie et al. (1985) parameterization rather than the Seber (1970) parameterization. Consequently, we did not investigate how landscape covariates may affect survival because survival ( $S$ ) is a component of the recovery rate ( $f$ ) and it is unclear how to model the

survival portion of the  $f$  parameter the same as the  $S$  parameter (Otis and White 2002).

We used a hierarchical approach to identify a model that best explained variation in reporting, harvest, and survival rates because of the large number of potential models. First, we constructed a series of models in which survival always varied by age, state, and year to investigate how reporting rates varied by using an indicator variable (1 = non-reward band, 0 = reward band) as an individual covariate to estimate the reporting rate for non-reward bands. In particular, we investigated whether reporting rates differed among states, over time, or by age class. We then constructed reduced parameter models in which survival and harvest rates always included an age effect but did not vary by 1 or both variables for state and year. Also, we investigated additive effect models because these models have a reduced number of parameters and are logical if survival or harvest rates varied across years or among states in a similar pattern for adults and juveniles.

For the best model that included the state where banded, we replaced state with 15 management zones (Fig. 1). We investigated variation in harvest rates across the 15 management zones because these zones varied in their landscape characteristics and fall harvest regulations and potentially could have explained within-state variation in harvest rates. Finally, we investigated whether landscape variables PUBLIC, FOREST, MFPS, and IJI modeled as individual covariates explained variation in harvest rates in the top models. The a priori hypotheses were that wild turkeys on public lands and those that inhabit fragmented forests may experience greater harvest rates. We expected FOREST and MFPS to be negatively associated with harvest rate and PUBLIC and IJI to be positively associated with harvest rate.

We used the log link for all models because it allowed us to estimate a constant multiplicative difference between reward and non-reward bands (i.e., reporting rate). We selected the best model as the model with the lowest Akaike's Information Criterion corrected for small sample size ( $AIC_c$ ) value. We estimated all other annual mortality ( $\hat{M}$ ), which included unretrieved kills, illegal harvest, and fall hunting mortality, as  $1 - \hat{S} - \hat{H}$  and used a Taylor series approximation to estimate  $\hat{S}E(\hat{M})$  (Seber 1982:7–9).

### Population Estimates and Age Structure

We used number of turkeys harvested and harvest rate data for each state to estimate age structure and statewide abundance of male turkeys. In New York, hunters who harvested a turkey were required to report their kill via internet or phone and provide body mass, beard length, and spur length of the bird to classify birds as adults or juveniles. In addition, after the spring turkey season, New York conducted a mail survey of 12,000 randomly selected hunters who purchased turkey permits to estimate harvest, hunting participation, and hunting effort statewide and among major geographic regions of the state. Ohio obtained harvest estimates via mandatory check stations, at which successful hunters were required to present the harvested turkey the day of harvest. At the check station, the turkey was sexed and aged according to

guidelines provided by the Ohio Division of Natural Resources. Criteria used to assign the age of male turkeys included spur length, beard length, and molt pattern of tail feathers (spurs  $\leq 12.5$  mm, beards  $< 150$  mm, and a tail fan with a broken contour were classified as juveniles). Compliance with harvest reporting was unknown in Ohio. Pennsylvania obtained harvest estimates via a mail survey in which hunters self-reported spur and beard length, which were used to estimate age class of harvested turkeys. Pennsylvania's survey was mailed to approximately 13,000 hunters and conducted during April–June the year following the spring hunting season.

We used harvest estimates ( $\hat{n}$ ), by age class, from each state and the harvest rates ( $\hat{H}$ ), by age class, from this study to estimate a statewide population size ( $N$ ), where

$$\hat{N} = \frac{\hat{n}_{\text{adults}}}{\hat{H}_{\text{adults}}} + \frac{\hat{n}_{\text{juveniles}}}{\hat{H}_{\text{juveniles}}}$$

No estimates of precision associated with age-specific harvest statistics were available so we were not able to estimate standard errors or confidence intervals associated with  $\hat{N}$ . However, standard errors of estimates of total harvest for New York and Pennsylvania were small (approx. 5% of the harvest estimate).

We used these population estimates to estimate the proportion of adults ( $\hat{p}_{\text{adults}}$ ) in the population as

$$\hat{p}_{\text{adults}} = \frac{(\hat{n}_{\text{adults}}/\hat{H}_{\text{adults}})}{\hat{N}}$$

Also, we used the annual survival rates estimated in this study to calculate the predicted proportion of adults in the population ( $\tilde{p}_{\text{adults}}$ ) assuming a stable and stationary population (i.e., recruitment into the population and age-specific survival was constant over time). If all assumptions were met and

harvest and survival rate estimates were accurate,  $\tilde{p}_{\text{adults}}$  and  $\hat{p}_{\text{adults}}$  should be similar.

## RESULTS

We banded 3,266 wild turkeys over the 4 winters (650–1,001 turkeys per year) of which 1,559 were adults and 1,707 were juveniles. By state, we banded 1,333 turkeys in New York, 663 turkeys in Ohio, and 1,270 turkeys in Pennsylvania. We monitored 83 turkeys fitted with radio-transmitters at 2 locations in Ohio during January–April 2007. Two birds died during this period and the best model indicated the survival rate was 0.969 (SE = 0.021, 95% CI = 0.884–0.992). Consequently, we assumed mortality that occurred between date of capture and first spring hunting season and under-estimation of direct recovery rates was minimal.

Goodness-of-fit tests under model H1 of Program BROWNIE indicated the model fit the data for each state (NY:  $\chi^2_4 = 7.60$ ,  $P = 0.107$ ; OH:  $\chi^2_2 = 0.77$ ,  $P = 0.681$ ; PA:  $\chi^2_6 = 8.02$ ,  $P = 0.236$ ). The best model included variation in both survival and harvest rates by age class and state where banded and harvest rates declined as FOREST increased (Table 1). However, this model was only slightly better than a model that did not include FOREST ( $\Delta\text{AIC}_c = 0.25$ ) and the variation in harvest rate across the range of FOREST values (0.8–96.5% forest cover) was 2–5% depending on age of bird and state where banded (Fig. 2). Hunter effort (hunter-days/km<sup>2</sup>) used as a covariate for harvest rate, using only New York and Pennsylvania data, did not explain variation in harvest rates ( $\Delta\text{AIC}_c = 2.03$ ) better than management zone. We present point estimates of  $\hat{S}$ ,  $\hat{H}$ , and  $\hat{M}$  for average forest cover, which was equivalent to the best model that did not include a landscape covariate. Other models that included landscape covariates were within 3  $\text{AIC}_c$  units but these models did not improve model fit and

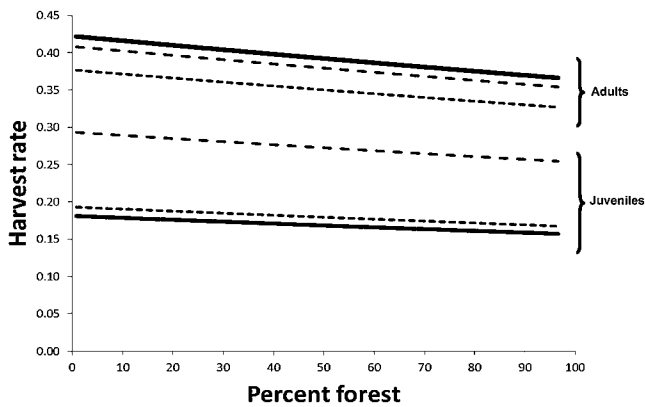
**Table 1.** Model selection results using Akaike's information criterion corrected for small sample size ( $\text{AIC}_c$ ) for Brownie et al. (1985) tag recovery models for wild turkeys banded in New York, Ohio, and Pennsylvania, 2006–2009. Survival ( $S$ ) and harvest rates ( $H$ ) were modeled as a function of age of bird (age: juvenile or adult), state where banded (state), year of banding (yr), 15 areas within states defined by management units and physiographic regions (zone), and whether fitted with a reward band (reward). Landscape covariates within 6.45 km of the capture location included percent forest (forest), mean forest patch size, percent public land, and an interspersed juxtaposition index of land cover types. Only the model containing the covariate forest is presented in the table because no other landscape covariates improved model fit.

Model	Log( $l^a$ )	$\Delta\text{AIC}_c^b$	$\text{AIC}_c$ weights	$K^c$
{ $S(\text{age} \times \text{state})H(\text{age} \times \text{state} + \text{reward} \times \text{age} + \text{forest})$ }	–3,223.8	0.00	0.49	15
{ $S(\text{age} \times \text{state})H(\text{age} \times \text{state} + \text{reward} \times \text{age})$ }	–3,224.9	0.25	0.44	14
{ $S(\text{age} \times \text{state})H(\text{age} \times \text{zone} + \text{reward} \times \text{age})$ }	–3,203.5	5.38	0.03	38
{ $S(\text{age})H(\text{age} \times \text{state} + \text{reward} \times \text{age})$ }	–3,232.6	7.49	0.01	10
{ $S(\text{age} + \text{yr})H(\text{age} \times \text{state} + \text{reward} \times \text{age})$ }	–3,230.7	7.66	0.01	12
{ $S(\text{age} \times \text{state})H(\text{age} + \text{zone} + \text{reward} \times \text{age})$ }	–3,219.2	8.74	<0.01	24
{ $S(\text{age} + \text{state})H(\text{age} \times \text{state} + \text{reward} \times \text{age})$ }	–3,231.5	9.39	<0.01	12
{ $S(\text{age} \times \text{yr})H(\text{age} \times \text{state} + \text{reward} \times \text{age})$ }	–3,230.0	10.39	<0.01	14
{ $S(\text{age} \times \text{state} \times \text{yr})H(\text{age} \times \text{state} + \text{reward} \times \text{age})$ }	–3,219.8	13.88	<0.01	26
{ $S(\text{age} + \text{state} \times \text{yr})H(\text{age} \times \text{state} + \text{reward})$ }	–3,231.0	14.29	<0.01	15
{ $S(\text{age} \times \text{state} \times \text{yr})H(\text{age} \times \text{state} + \text{reward})$ }	–3,221.3	15.02	<0.01	25
{ $S(\text{age} \times \text{state} \times \text{yr})H(\text{age} + \text{yr} \times \text{state} + \text{reward})$ }	–3,217.4	19.12	<0.01	31
{ $S(\text{age} \times \text{state} \times \text{yr})H(\text{age} + \text{yr} \times \text{state} + \text{reward} \times \text{age})$ }	–3,215.7	19.84	<0.01	33
{ $S(\text{age} \times \text{state} \times \text{yr})H(\text{age} + \text{yr} \times \text{state} + \text{reward} \times \text{state})$ }	–3,216.9	22.12	<0.01	33
{ $S(\text{age} \times \text{state} \times \text{yr})H(\text{age} + \text{yr} + \text{reward})$ }	–3,227.3	24.95	<0.01	24
{ $S(\text{age} \times \text{state} \times \text{yr})H(\text{age} + \text{yr} \times \text{state} + \text{reward} \times \text{yr})$ }	–3,217.4	25.10	<0.01	34

<sup>a</sup> Log-likelihood.

<sup>b</sup> Difference in  $\text{AIC}_c$  values between current model and model with lowest  $\text{AIC}_c$  value.

<sup>c</sup> No. parameters.



**Figure 2.** Spring harvest rates of adult and juvenile male wild turkeys in New York (dotted lines), Ohio (solid lines), and Pennsylvania (dashed lines) as a function of percent forest cover within 6.45 km of the banding location, 2006–2009.

85% confidence intervals of estimated coefficients encompassed zero.

Reporting rate of non-reward bands did not vary over time or among states but was greater for adults (0.869, 95% CI = 0.80–0.95) than juveniles (0.710, 95% CI = 0.58–0.87). Annual survival of juveniles ( $\hat{S} = 0.64$ –0.87) was approximately twice that of adults ( $\hat{S} = 0.30$ –0.41; Table 2). In turn, spring harvest rates for adult turkeys were greater for adults ( $\hat{H} = 0.35$ –0.39) than juveniles ( $\hat{H} = 0.17$ –0.27; Table 2). However, differences in survival and harvest rates between adults and juveniles were not consistent across states and additive models were not competitive ( $\Delta\text{AIC}_c > 7.5$ ; Table 1). Estimates of all other mortality ( $\hat{M}$ ) ranged from  $-0.03$  to  $0.19$  for juveniles and  $0.22$ – $0.31$  for adults (Table 2).

We estimated the population of male turkeys in New York and Pennsylvania ranged from 104,000 to 132,000, and in Ohio 63,000–75,000 (Table 3). The proportion of adult males in the spring harvest varied from 0.56 to 0.86 among states and years (Table 3), in which Pennsylvania had a greater proportion of adult males (0.79–0.86) than both Ohio (0.65–0.72) and New York (0.56–0.72). Because of greater harvest rates for adult males, the proportion of adult males in the population ( $\hat{p}_{\text{adults}}$ ) was less than in the harvest (0.40–0.81 among all states and years; Table 3).

Estimates of the proportion of adult males in the population based on annual survival rates and assuming a stable and stationary population ( $\tilde{p}_{\text{adults}}$ ) were similar to  $\hat{p}_{\text{adults}}$  for New York and Ohio (Table 3). However, in Pennsylvania the

proportion of adult males in the population based on survival rates ( $\tilde{p}_{\text{adults}} = 0.525$ ) was much lower than the estimate based on harvest data ( $\hat{p}_{\text{adults}} = 0.73$ – $0.80$ ).

## DISCUSSION

Understanding the harvest rate and proportion of adult males in the population can provide useful information for making management decisions to best meet hunter desires and maximize hunter satisfaction (Healy and Powell 1999). Most mortality in male turkeys occurs during the spring (Godwin et al. 1991, Thogmartin and Schaeffer 2000, Holdstock et al. 2006) and spring hunting mortality is generally considered to be additive to other sources of mortality (Alpizar-Jara et al. 2001, McGhee et al. 2008, Moore et al. 2008). Consequently, spring hunting-related mortality rates (legal harvest, illegal kills, and crippling loss) of more than 30–35% of the male population are thought to adversely affect hunter satisfaction because the proportion of adults in the population and harvest are predicted to decline (Vangilder and Kurzejeski 1995). Based on our age-specific harvest rates and population estimates (Tables 2 and 3), the overall harvest rate of the male population was 24–28% in New York and Ohio and 35% in Pennsylvania. In a radio-telemetry study, Ohio estimated illegal kills were an additional spring hunting-related mortality that was equivalent to 14% of the legal harvest (M. Reynolds, Ohio Department of Natural Resources, unpublished data). Consequently, it is possible that the additional mortality from illegal kills and crippling loss could result in an overall spring hunting mortality rate of 30–35% in New York and Ohio and >40% in Pennsylvania.

The overall hunting mortality rates we observed may exceed what Vangilder and Kurzejeski (1995) indicated may lead to a shift to a younger age structure. However, their conclusions were based on a population model with annual survival rates of approximately 40% for adults and 45% for juveniles, such that approximately 65–70% of the spring harvest was composed of adult males. In comparison, we found that annual survival of adults was 30–40%, which was similar to what was modeled by Vangilder and Kurzejeski (1995), but annual survival rates for juveniles were 20–40% greater. Because annual survival rates were higher and harvest rates were lower for juveniles, the high harvest rates we observed for adults may be sustainable because a greater proportion of juveniles recruit into the adult population the following year. Consequently, the high harvest rates on adult males observed in this study may not adversely affect hunter satisfaction.

**Table 2.** Annual survival ( $\hat{S}$ ), harvest rate ( $\hat{H}$ ), and other mortality ( $\hat{M}$ ) estimates and measures of precision for male wild turkeys banded in New York, Ohio, and Pennsylvania, 2006–2009.

Age	State	Survival			Harvest			Other mortality		
		$\hat{S}$	SE	95% CI	$\hat{H}$	SE	95% CI	$\hat{M}$	SE	95% CI
Juvenile	NY	0.635	0.053	0.53–0.73	0.179	0.018	0.15–0.22	0.187	0.053	0.08–0.29
	OH	0.865	0.077	0.64–0.96	0.169	0.024	0.13–0.22	-0.033	0.074	-0.18–0.11
	PA	0.653	0.053	0.54–0.75	0.270	0.023	0.23–0.32	0.077	0.053	-0.03–0.18
Adult	NY	0.340	0.031	0.28–0.40	0.347	0.021	0.31–0.39	0.312	0.028	0.26–0.37
	OH	0.302	0.032	0.24–0.37	0.389	0.027	0.34–0.44	0.307	0.029	0.25–0.36
	PA	0.409	0.031	0.35–0.47	0.376	0.021	0.34–0.42	0.218	0.025	0.17–0.27

**Table 3.** Spring harvest estimates and proportion of adult male turkeys in the spring harvest ( $\hat{p}_{\text{adult harvest}}$ ), population estimates and proportion of adult males in the population ( $\hat{p}_{\text{adults}}$ ) prior to the hunting season, and proportion of adult males in the population prior to the hunting season assuming a stable and stationary population ( $\tilde{p}_{\text{adults}}$ ) for New York, Ohio, and Pennsylvania, 2006–2009.

State	Year	Spring harvest				Spring population				
		Adults	Juveniles	Total	$\hat{p}_{\text{adult harvest}}$	Adults	Juveniles	Total	$\hat{p}_{\text{adults}}$	$\tilde{p}_{\text{adults}}$
NY	2006	15,523	11,977	27,500	0.564	44,612	67,083	111,695	0.399	0.490
	2007	24,186	11,076	35,262	0.686	69,508	62,037	131,545	0.528	0.490
	2008	22,565	10,254	32,819	0.688	64,850	57,433	122,283	0.530	0.490
	2009	24,698	9,867	34,565	0.715	70,980	55,265	126,245	0.562	0.490
OH	2006	13,611	5,920	19,531	0.697	34,285	35,132	69,416	0.494	0.553
	2007	13,076	5,015	18,091	0.723	32,937	29,761	62,698	0.525	0.553
	2008	13,786	6,095	19,881	0.693	34,725	36,170	70,896	0.490	0.553
	2009	13,070	7,070	20,140	0.649	32,922	41,956	74,878	0.440	0.553
PA	2006	32,479	5,364	37,843	0.858	86,996	19,908	106,904	0.814	0.525
	2007	29,697	6,599	36,296	0.818	77,741	26,187	103,927	0.748	0.525
	2008	32,796	7,687	40,483	0.810	85,853	30,504	116,357	0.738	0.525
	2009	28,906	7,855	36,761	0.786	76,878	29,093	105,971	0.725	0.525

Our estimates of the size and age structure of the population assume that harvest estimates are accurate. Ohio relies on hunters to report their harvest at check stations and recorders at check stations accurately determine turkey age and sex, but compliance and accuracy of these data have not been verified. New York and Pennsylvania rely on a mail survey and hunter self-reporting of turkey characteristics (beard and spur length and body mass in New York, beard and spur length in Pennsylvania), which is then used to age birds. We found that the 2 different methods of estimating the proportion of adults in the population ( $\hat{p}_{\text{adults}}$  and  $\tilde{p}_{\text{adults}}$ ) provided similar results for New York and Ohio (Table 3), which suggested that harvest estimates were accurate. In contrast, these 2 approaches provided inconsistent results for Pennsylvania and may indicate that harvest data may not be accurate (Table 3). Because the Pennsylvania Game Commission surveyed hunters almost a year after the spring hunting season, we suspect memory bias and confusion regarding which spring hunting season the survey addressed may have affected responses. Implementation of a computerized licensing system in 2009 would allow the agency to mail surveys immediately after the spring hunting season and eliminate this potential source of response error.

Most studies of harvest rates of male wild turkeys monitored <100 birds via radio-telemetry on areas <1,000 km<sup>2</sup>, in which the largest study areas were similar in size to a single turkey management unit. Previous band recovery studies of wild turkeys did not estimate harvest rates either because they did not use reward bands (Lewis 1980) or the reward was unlikely to result in 100% reporting (\$10; Norman et al. 2004). In contrast, we banded turkeys across multiple management units and throughout the range of wild turkeys in all 3 states and used \$100 rewards to ensure hunter cooperation. We identified sample size goals with the intent to obtain precise estimates of statewide harvest rates (CV = 10–15%; Table 2) even if harvest rates varied temporally. Additionally, we investigated spatial variation in harvest rates and constructed models in which harvest rates varied among management zones (combinations of turkey management units and physiographic regions) within states. These models were

not competitive, but we note that the best model that included management zone was within 6 AIC<sub>c</sub> units of the top model even though it had more than twice as many parameters (Table 1). We suspect that differences in harvest rates among management zones may be large enough to have biological and management significance but we lacked sufficient sample size for accurate estimates and simpler models were parsimonious.

Also, we investigated whether landscape factors that transcend state boundaries or management units may be related to harvest rates and hypothesized that turkeys that inhabit fragmented forest landscapes might be at greater risk of harvest. Foster et al. (1997) found that white-tailed deer (*Odocoileus virginianus*) hunters were more efficient in landscapes with fragmented forests. Our hypothesis was supported by a negative relationship between harvest rates and percent forest cover (Fig. 2), but this relationship had little effect on harvest rates. One possible reason why we found this landscape factor had little effect on harvest rates was because of substantial movements turkeys made between location of banding and location of recovery. We used a 6.45-km buffer around each capture location to describe landscape characteristics because we did not know the location of turkeys not recovered and had to condition our analysis on location of banding. Consequently, the scale at which we evaluated landscape metrics may not have matched the scale at which these metrics are related to harvest rates.

Annual survival rates for adults in this study were comparable to what has been reported for telemetry studies (0.26–0.46; Little et al. 1990, Godwin et al. 1991, Hubbard and Vangilder 2005, Wright and Vangilder 2005) and were similar to a banding study in Virginia and West Virginia (0.31, Norman et al. 2004). The annual survival rates we observed for juveniles represent the highest rates reported in the literature and were 3 times what was reported by Norman et al. (2004), although fall seasons were liberal (6–9 weeks) and they may have underestimated survival for both adults and juveniles because they used butt-end leg bands (Diefenbach et al. 2009). Harvest rate estimates in our study were comparable to what has been reported for

radio-telemetry studies (adults = 0.23–0.56; juveniles = 0.11–0.20; Godwin et al. 1991, Hubbard and Vangilder 2005, Wright and Vangilder 2005).

Other mortality was low for juveniles (0–0.20), especially compared to adults (0.21–0.31; Table 2), which included illegal kills, crippling loss, harvest during the fall hunting season, and natural causes of mortality (predation, disease, etc.). We suspect few birds were harvested in the fall because over the 4 years only 4.7% ( $n = 727$ ) of reward bands were reported as legal harvests during the fall hunting seasons; however, we could not estimate a harvest rate for the fall hunting season because this would require capturing and banding additional birds in late summer. Fall turkey hunting seasons in the 3 states ranged from 2 weeks to 7 weeks and none were concurrent with the firearms season for deer, potentially contributing to the low annual mortality we observed for juvenile male turkeys.

For adult males, because of high harvest rates and relatively high mortality from other sources, annual survival rates of 0.30–0.41 indicated that once a male wild turkey became an adult, its mean lifespan was approximately 1 year. Natural mortality likely was greater for adults than juveniles unless illegal kill of adults was much greater than for juveniles. Few studies have separately estimated mortality causes of adult and juvenile males, but Wright and Vangilder (2005) reported lower non-human causes of mortality for juveniles.

## MANAGEMENT IMPLICATIONS

The lack of temporal and limited spatial variation in harvest rates during the spring male wild turkey hunting season indicates that harvest data may provide useful information for monitoring wild turkey populations even though the proportion of adults in the harvest is overestimated because harvest rates are greater for adults. However, harvest estimates must be accurate (i.e., sex-age determination) and assumptions should be verified (e.g., harvest report compliance; Rosenberry et al. 2004). The greater survival and lower harvest rates of juveniles observed in this study indicated the recommended maximum harvest rates from the population model developed by Vangilder and Kurzejeski (1995) are conservative for New York, Ohio, and Pennsylvania.

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