Annual Survival and Spring Harvest Rates of Male Wild Turkeys in New York, Ohio, and Pennsylvania

by

Duane R. Diefenbach, Ph.D.
U.S. Geological Survey
Pennsylvania Cooperative Fish and Wildlife Research Unit
Pennsylvania State University
University Park, Pennsylvania

Wendy C. Vreeland
Pennsylvania Cooperative Fish and Wildlife Research Unit
Pennsylvania State University
University Park, Pennsylvania

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EXECUTIVE SUMMARY

This study estimated spring harvest rates and annual survival rates of male wild turkeys (*Meleagris gallapavo*) in New York, Ohio, and Pennsylvania. We designed this study as a band-recovery study so that data could be collected from all management units in all 3 states during the 2006-2009 spring hunting seasons. Also, we evaluated the retention of butt-end leg bands.

Harvest rates vary between juvenile and adult male wild turkeys and can influence the number and proportion of adult gobblers in the spring population and harvest. Research on attitudes and opinions of turkey hunters indicates that 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. Ohio and Pennsylvania are increasing hunting opportunity (e.g., all-day hunting) for gobblers during the spring hunting season in 2010 and 2011. Thus, because of the large number of turkey hunters in Pennsylvania and the relatively newly-established turkey populations in Ohio, it could be important to obtain estimates of the age structure and number of males in the population to better assess the effects of changes in spring hunting regulations. All 3 states lacked accurate estimates of spring harvest rates or annual survival rates.

During 2006-2009, we banded 3,266 wild turkeys of which 1,559 were adults and 1,707 were juveniles. Ohio did not band turkeys in 2009. We monitored 74 turkeys fitted with radio-transmitters at two locations in Ohio during January-April 2007. Two birds died during this period and the estimated survival rate was 0.969 (SE = 0.021, 95% CI = 0.884–0.992). Consequently, we assumed non-hunting mortality that occurred between the date of capture and the first spring hunting season was minimal and had little influence on harvest rate estimates.

We estimated band loss rates of butt-end leg bands from 887 turkeys recovered between 31 days and 570 days after release ($\bar{x}$ = 202 days). Band retention was <50% for all age classes and band types 15 months after banding. The use of butt-end bands could lead to underestimates of harvest and survival rates, which may explain why previous band recovery studies obtained lower estimates of survival than other studies. The use of rivet bands in this study eliminated bias caused by band loss.

The model that best explained variation in survival and harvest rates did not include annual variation but survival and harvest rates did vary among states and age classes of turkeys. Annual survival for juveniles ($\hat{S}$ = 0.64–0.87) was approximately twice that of adults ($\hat{S}$ = 0.30–0.40). In turn, spring harvest rates were greater for adults ($\hat{H}$ = 0.36–0.40) than juveniles ($\hat{H}$ = 0.16–0.25). Estimates of mortality outside the spring hunting season ranged from 0–0.20 for juveniles and 0.21–0.31 for adults.

We modeled survival and harvest rates for each state at different spatial scales by estimating these parameters by management zones, which were spatial units defined by combinations of physiographic features and wildlife management units. In both New York and Ohio, survival only varied by age class and in Pennsylvania annual survival

differed by age class and management zone. Harvest rates in New York varied by age, year, and management zone at all spatial scales (6 and 16 management zones and 5 fall turkey hunting zones). Harvest rates in Ohio differed by age class and across years. Harvest rates in Pennsylvania varied by age and management zone at both spatial scales investigated (5 and 8 management zones), but models that included 8 management zones had problems with estimation of some parameters.

We used spring harvests and estimates of harvest rates to estimate population size of male wild turkeys and percent of adult males in the population. During 2006–2009, we estimated New York had 115,000–134,000 males of which 38–54% were adults. Ohio had 64,000–77,000 males of which 43–51% were adults, and Pennsylvania had 103,000–116,000 males of which 74–80% were adults. However, we also estimated the percent of males in the population using estimated annual survival rates from this study and assuming a stable and stationary population. This approach to estimating the proportion of males in the population provided similar estimates for New York (49.0% adults) and Ohio (55.4%) but differed for Pennsylvania (52.4%). The fact that the proportion of adults in the male population was much greater for Pennsylvania than New York and Ohio, yet we estimated similar survival and harvest rates, suggests that Pennsylvania's method of obtaining information on the age structure of the harvest may be biased.

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 will decline (Vangilder and Kurzejeski 1995). In this study, 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 than what was used in their model. 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 of greater recruitment of juveniles into the adult population the following year. Consequently, the high harvest rates on adult males in this study could still maintain hunter satisfaction.

In general, annual survival rates for adults in this study were comparable to what has been reported for other studies and annual survival rates for juveniles included some of the highest rates reported. We estimated that overall 24–28% of the male population was harvested in New York and Ohio and 35% was harvested in Pennsylvania. In a radio-telemetry study, Ohio estimated that illegal kills were 14% of the legal harvest (M. Reynolds, personal communication). Consequently, it is possible that 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.

We failed to identify any landscape factors related to harvest rates. One hypothesis proposed was that turkeys that inhabited fragmented forest landscapes might be at greater risk of harvest; however, percent forest cover, an interspersion index, and mean forest patch size did not explain variation in harvest rates. One possible reason why we failed to detect any landscape factors that were related to harvest was because 80% of turkeys were harvested up to 6.45 km from the banding location. We used a 6.45 km buffer around each capture location to describe the landscape characteristics; consequently, the scale at which we evaluated landscape metrics may not have matched the scale at which these metrics influence harvest rates.

We estimated other sources of mortality as $\hat{M} = 1 - \hat{S} - \hat{H}$, which included illegal kills, crippling loss, and harvest during the fall hunting season in addition to natural causes of mortality (predation, disease, etc.). Other sources of mortality were low for juveniles ($\hat{M}$ = 0–0.20), especially compared to adults ($\hat{M}$ = 0.21–0.31; Table 8). For adult males, because of high harvest rates and relatively high mortality from other sources, the annual survival rates of 0.30–0.41 indicated that once a male wild turkey becomes an adult its mean lifespan is 1 year. Over the 4 years, 34 of 727 reward bands recovered (4.7%; 2.6% of all reward bands released) were reported as legal harvests during fall hunting seasons. Also, 24 of 34 fall harvest reward band recoveries were from juveniles, which suggested fall harvest rates were greater for juveniles than adults. The few recoveries reported suggested relatively low harvest rates during the fall hunting season, perhaps <0.10, but to estimate a fall harvest rate would have required additional banding of male wild turkeys immediately prior to the fall hunting season.

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INTRODUCTION

Harvest rates vary between juvenile and adult male wild turkeys (*Meleagris gallapavo*) and can influence the number and proportion of adult gobblers in the spring population and harvest (Vangilder and Kurzejeski 1995, Swanson and Stoll 1996). For example, Vangilder and Kurzejeski (1995) modeled a population with a spring harvest rate of 25% and the result was the male population was composed of 72% adults, whereas a harvest rate of 50% resulted in the male population composed of only 56% adults. Surveys of turkey hunters indicate that 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).

Ohio in 2010 and Pennsylvania in 2011 are increasing hunting opportunity (e.g., all-day hunting) for gobblers during the last two weeks of the spring hunting season. Thus, because of the large number of turkey hunters in Pennsylvania and the relatively newly-established turkey populations in Ohio, it will be useful to managers to obtain estimates of the age structure and number of males in the population to assess the effects of changes in spring hunting regulations. In Ohio, recoveries of banded birds have been used to estimate harvest rates but no monetary reward was provided and these recovery rates likely under-estimate the actual harvest rate. Harvest rates for male wild turkeys in New York and Pennsylvania are unknown.

This study focused on estimating harvest rates of male wild turkeys during the spring hunting season in New York, Ohio, and Pennsylvania. We designed this study as a band-recovery study so that data could be collected from all management units in all three states. However, for band-recovery studies to permit accurate estimates of survival and harvest rates the retention rate of leg bands must be 100%. Therefore, we used rivet bands as permanent marks and evaluated band retention of butt-end leg bands, which have traditionally been used on wild turkeys.

Most studies to estimate population parameters of wild turkeys, such as survival and harvest rates, have relied on radio-telemetry (e.g., Kurzejeski et al. 1987, Pack et al. 1999). Such studies are effective because they allow researchers to monitor the fate of every individual and determine time-specific and cause-specific sources of mortality. However, such studies are expensive because of the equipment, time, and personnel required to continuously monitor fates of turkeys. Moreover, because of logistics, study areas usually are small relative to the size of land units for which turkeys are managed by natural resource agencies.

The ability to make inferences from single, small study areas to large management units 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 can partition survival rates into multiple periods of the year, if desired (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, Vangilder and Kurzejeski 1995, Norman et al. 2004). However, data obtained from leg bands have been the basis for estimates of longevity (e.g., Cardoza 1995). Nearly all studies report fitting aluminum butt-end bands to turkeys, even for radiotelemetry studies; however, we are not aware of any estimates of band retention for wild turkeys even though Thomas and Marburger (1964) and Lewis (1980) noted problems with loss of aluminum butt-end bands.

Also, band-recovery studies that do not use rewards to solicit reporting by hunters can only estimate survival rates. However, by using a combination of reward and non-reward bands an estimate of the reporting rate (proportion of harvested birds reported by hunters if no reward is offered) can be obtained as well as estimates of harvest rates. This approach to estimating harvest rates has been used successfully for pheasants and waterfowl (Nichols et al. 1991, Diefenbach et al. 2000, Zimmerman et al. 2009).

This study was designed to encompass multiple states with the intention of gaining a better understanding of the variability in harvest rates and how variability may be related to harvest management strategies and landscape factors. New York, Ohio, and Pennsylvania exhibit large variation in hunter numbers and density, harvest success rates, and landscape characteristics (Table 1). Therefore, not only did we investigate how harvest rates may vary by state and management zone but we investigated how select landscape factors (e.g., percent forest cover) may be related to harvest and survival rates.

Table 1. Average statewide spring turkey hunter and harvest information for Ohio, New York and Pennsylvania, 2006–2009.

				Harvest density (turkeys/km^2)		Hunter density (hunters/ km^2)	
State	Spring harvest	No. hunters	Harvest/ hunter	Total area	Forested area	Total area	Forested area
New York	32,743	103,241	0.26	0.72	1.20	2.26	3.84
Ohio [a]	19,927	80,417	0.25	0.26	0.61	1.03	2.46
Pennsylvania	39,275	228,561	0.17	0.33	0.52	1.95	3.02

[a] Within the range of wild turkeys in Ohio.

The objectives of this study were to estimate (1) harvest rates of male wild turkeys during the spring season, (2) annual survival rates of male wild turkeys, (3) band reporting rates by hunters of harvested wild turkeys when no reward is offered, (4) abundance of male wild turkeys in each state, and (5) retention of butt-end leg bands. Also, we investigated how landscape factors (e.g., percent forest cover, patchiness of forested areas, etc.) were related to harvest rates.

STUDY AREA

The study area encompassed the range of wild turkeys in New York, Ohio, and Pennsylvania (Figure 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 movement data we collected on tagging and harvest locations of banded turkeys (D. R. Diefenbach, U.S. Geological Survey, unpublished data), it is likely that banded turkeys occurred in nearly every county in Pennsylvania and all of upstate New York.

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 occupy approximately 78,000 km^2 in all 88 Ohio counties. We trapped wild turkeys in 28 Ohio counties in 4 physiographic regions. In the Glaciated Allegheny Plateau region (see region 4 in Figure 1), we trapped wild turkeys in Ashtabula, Geauga, Holmes, Knox, Lake, Medina, Richland, Trumbull, and Wayne counties. In the Allegheny Plateau region (see region 1 in Figure 1), we trapped wild turkeys in Athens, Carroll, Columbiana, Coshocton, Guernsey, Harrison, Jackson, Jefferson, Meigs, Monroe, Morgan, Muskingum, and Stark counties. In the Till Plains (region 3 in Figure 1) and Bluegrass (region 2 in Figure 1) regions, we trapped wild turkeys in Adams, Brown, Champaign, Highland, Logan, and Pickaway counties.

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 and 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 starts on the Monday closest to April 21 and lasts for 28 days. A 2-day youth season is held on Saturday and Sunday immediately before the spring turkey season opens.

The bag limit in New York and Ohio was 2 bearded turkeys (1 per 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.

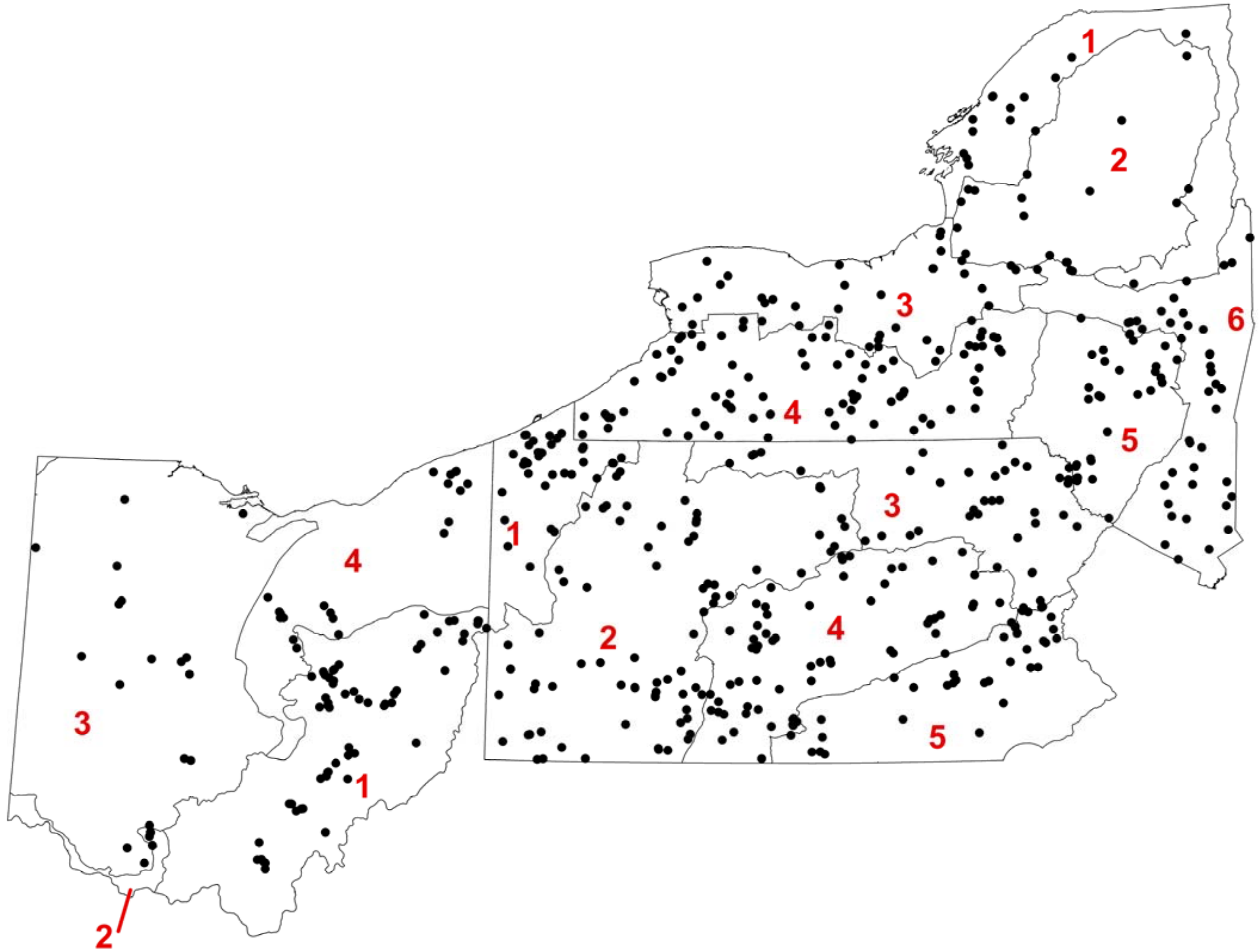

Figure 1. Map of New York, Ohio, and Pennsylvania indicating where male wild turkeys were captured and leg banded and the zones within each state that that were used to evaluate how harvest and survival rates may have varied spatially, 2006-2009. See Methods for description of zones for each state.

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 turkeys among counties proportional to the estimated spring harvest in each county. In Pennsylvania, we attempted to capture 50 turkeys in each of 6 administrative regions. In Ohio, we distributed the statewide capture quota of 300 turkeys among 9 trapping crews. We released all wild turkeys at the capture site except we translocated 49 banded adult male turkeys to unoccupied habitat in 7 western Ohio counties as part of wild turkey restoration efforts. We translocated turkeys to Henry, Paulding, and Putnam counties in the Lake Plains region and Allen, Mercer, Shelby, and Union counties in the Till Plains regions. One banded wild turkey captured in Pennsylvania was translocated because of nuisance complaints. We included translocated birds in our analysis of harvest and survival rates.

We determined age of captured turkeys (adults >1 yr old, juveniles <1 yr old) based on the criteria used by Pelham and Dickson (1992). Each turkey was fitted 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). Also, in 2009 we double-banded (1 band per leg) 270 wild turkeys with rivet bands in New York and Pennsylvania to assess retention of this type of leg band.

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 Diefenbach et al. (2000) found that rewards >$75 led to 100% reporting of bands by hunters. The bands also were imprinted with an expiration date, July 2009, after which rewards would not be paid. In 2009 we only banded jakes with reward bands because there were a sufficient number of wild turkeys banded in previous years alive that were adult gobblers during the 2009 spring turkey season. We used logistic regression to model the relationship between retention of butt-end bands and age at capture, type of leg band, and time between release and recovery.

Survival between Capture and Spring Harvest

In Ohio in 2007 we fitted 83 wild turkeys (71 also were leg banded) with radio-transmitters 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. In 2009, we did not band turkeys in Ohio although we continued to pay rewards for bands reported to us before the end of July 2009.

Landscape Data

We obtained Geographic Information System (GIS) polygon layers identifying state and federal public lands and landcover types from the Multi-Resolution Land Characteristics Consortium (http://www.mrlc.gov/). The landcover layer was reclassified into forest, agriculture, and other land use and we used a majority filter to reduce the complexity and reduce the number of misclassified raster cells based on the nearest neighbor function. For each capture location, we extracted landscape characteristics based on 6.45-km radius buffer circles because we found that approximately 80% of harvested turkeys were recovered within 6.45 km of the capture location. Because dispersal distances exhibited a negative exponential distribution 6.45 km encompassed the bulk of the dispersal distances and beyond this distance to encompass an additional 1 percent of recoveries required much larger radii. Percent forest cover was calculated using Zonal Statistics of the Hawth's Tool extension for ArcMap. Mean forest patch size and the Interspersion Juxtaposition Index were extracted using Spatial Statistics through the Patch Analyst Extension for ArcMap.

Also, we created a GIS polygon layer to assign each capture location to a physiographic zone in each state, which was defined based on a combination of physiographic provinces and state wildlife management units. In New York we identified 6 zones, 4 in Ohio, and 5 in Pennsylvania (Figure 1).

Data Analysis for All 3 States

We used Brownie et al. (1987) type models to estimate annual survival and spring harvest rates in Program MARK (White and Burnham 1999). We used the LDLD encounter history input format and classified each bird into one of 6 age-state groups: 2 age classes (adult, juvenile) for each of 3 states (NY, OH, PA). Birds banded as juveniles were classified as adult birds if they survived to the second spring hunting season after capture. To each bird we assigned an individual covariate indicating whether it was fitted with a reward band (0) or not (1). Also, we used 14 indicator variables to indicate which of 15 physiographic zones (6 in NY, 4 in OH, 5 in PA) based on a reference-level design matrix. Finally, we included landscape covariates based on the location of banding. Using a GIS we measured within a 6.45 km radius of each trapping location the amount of public land (PUBLIC), forest cover (FOREST), mean forest patch size (MFPS), and calculated an interspersion and juxtaposition index (IJI) among 3 landcover types (forest, agriculture and open lands, and all other; McGarigal et al. 2002).

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 Ohio did not band birds 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 and estimated age and year-specific survival rates in Program Brownie (model H1) 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 Ohio did not band birds 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 include 2009 recoveries of Ohio turkeys that were banded 2006-2008 in the analysis. We first investigated a series of models in which survival 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 a covariate to adjust for the non-reporting of some bands when no reward was offered. We then constructed models in which survival and harvest rates varied by age, state, year, and physiographic region. Finally, we included individually the landscape variables PUBLIC, FOREST, MFPS, and IJI as covariates to explain variation in survival and harvest rates in place of variation by state. We used the logit link function for all models and selected the best model as the model with the lowest Akaike's Information Criterion corrected for small sample size (AICc) 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 (Seber 1982:7-9) to estimate the standard error of $\hat{M}$.

Data Analysis for Each State

We obtained survival and harvest rate estimates for different groupings of management units and physiographic units by analyzing data from each state separately. We used the same approach to constructing and analyzing models described heretofore. For New York, we used wildlife management units consolidated into 6 units (Table 2, Figure 1), wildlife management units consolidated into 16 units (Table 2, Figure 2) , and fall turkey hunting season zones (Table 2, Figure 3). For Ohio, we analyzed the first 3 years of data grouped into the 4 physiographic regions in the state (Figure 1), in which region 1 is the Allegheny Plateau, region 2 is the Bluegrass, region 3 is the Till Plains, and region 4 is the Glaciated Allegheny Plateau. For Pennsylvania, we analyzed the data by consolidating the agency's 22 wildlife management units (Table 3) into 5 units (Figure 1) and 8 units (Figure 4). A detailed description of the Pennsylvania Game Commission's wildlife management units is available at http://pgc.state.pa.us.

Population Estimates and Age Structure

We used harvest data from each state to estimate statewide abundance of male turkeys. New York conducts a mail survey after the close of the hunting season of 12,000 randomly selected hunters who purchased turkey permits. Survey responses in which hunters self-report beard length, spur length, and body mass are used to classify birds as adult or juveniles and estimate the harvest. Ohio obtains harvest estimates via data collected at mandatory check stations, at which successful hunters are required to present the turkey the day of harvest. At the check station, the turkey is sexed and aged and spur length is measured and recorded as <0.5 in, 0.5–1.0 in, and >1.0 in. Compliance with harvest reporting is unknown in Ohio. Pennsylvania obtains harvest estimates via a mail survey in which hunters report spur and beard length and age is estimated based on spur and beard length. Pennsylvania's survey is sent to approximately 18,000 hunters but is conducted during April-June the year following the spring hunting season. The effect of memory bias (i.e., hunters incorrectly reporting that they harvested a bird or overstating the size of the spur and beard) is unknown. Also, it is possible hunters report their harvest of the current spring season rather than the previous year.

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

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

None of the state agencies was able to provide estimates of precision associated with their age-specific harvest statistics so we were not able to estimate standard errors or confidence intervals associated with $\hat{N}$.

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

$$\hat{p}_{adults} = \frac{\hat{n}_{adults} / \hat{H}_{adults}}{\hat{N}}.$$

Also, we used the annual survival rates estimated in this study to calculate the predicted proportion of adult gobblers in the population ($\tilde{p}_{adults}$) assuming a stable and stationary population (i.e., recruitment into the population and age-specific survival was constant over time). If harvest and survival rate estimates were accurate, $\tilde{p}_{adults}$ and $\hat{p}_{adults}$ should be similar.

Table 2. Description of physiographic zones (consolidated groups of wildlife management units and fall turkey hunting zones) by which spring harvest and annual survival rates for male wild turkeys were estimated for New York, 2006-2009. Zone numbers correspond to labels in Figures 1-3.

Zones	Wildlife management unit group description for Figure 2	Wildlife management unit group description for Figure 1	Fall season zone description for Figure 3
1	St. Lawrence & Champlain valleys	St. Lawrence & Champlain valleys	Adirondacks
2	Adirondacks	Adirondacks & Tug Hill	Lake Plains
3	East Ontario Plain	Lake Plains	Appalachian Hills
4	Tug Hill & Transition	Appalachian Hills & Plateau	Catskills & Hudson Valley
5	Great Lakes Plain & Oswego Lowlands	Catskills & Delaware Hills	St. Lawrence Valley
6	Oneida Lake Plains	Hudson Valley Mohawk Valley Taconic Highlands	
7	Mohawk Valley		
8	Taconic Highlands		
9	North Appalachian Hills		
10	West Appalachian Hills		
11	Central Appalachian Plateau		
12	East Appalachian Plateau		
13	Otsego-Delaware Hills		
14	Catskills		
15	Hudson Valley		
16	Neversink-Mongaup Hills		

Table 3. Description of physiographic zones (consolidated groups of wildlife management units) by which spring harvest and annual survival rates for male wild turkeys were estimated for Pennsylvania, 2006-2009. Zone numbers correspond to labels in Figures 1 and 4.

Zone	Wildlife management units for Figure 1	Wildlife management units for Figure 4
1	1A, 1B	1A, 1B
2	2A, 2B	2A, 2B, 2C, 2D, 2E, 2F, 2G
3	2C, 2D, 2E	3A, 3B, 3C, 3D
4	2F, 2G	4A, 4B, 4D, 4C, 4E
5	3A, 3B, 3C, 3D	5A, 5B, 5C, 5D
6	4A, 4B, 4D	
7	4C, 4E	
8	5A, 5B, 5C, 5D	

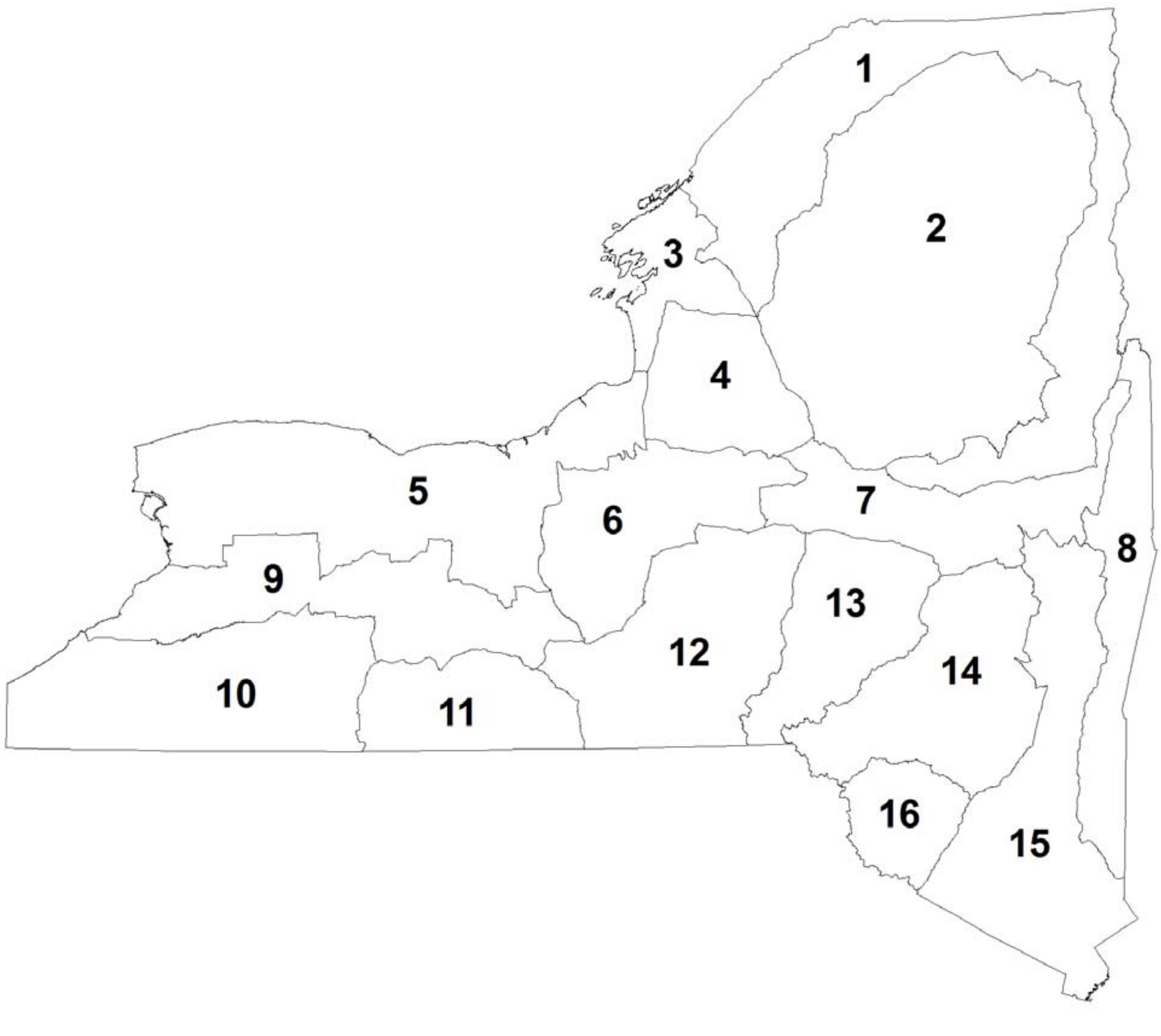

Figure 2. Sixteen zones based on groups of physiographic regions for which male wild turkey harvest and survival rates were estimated using data from New York, 2006-2009.

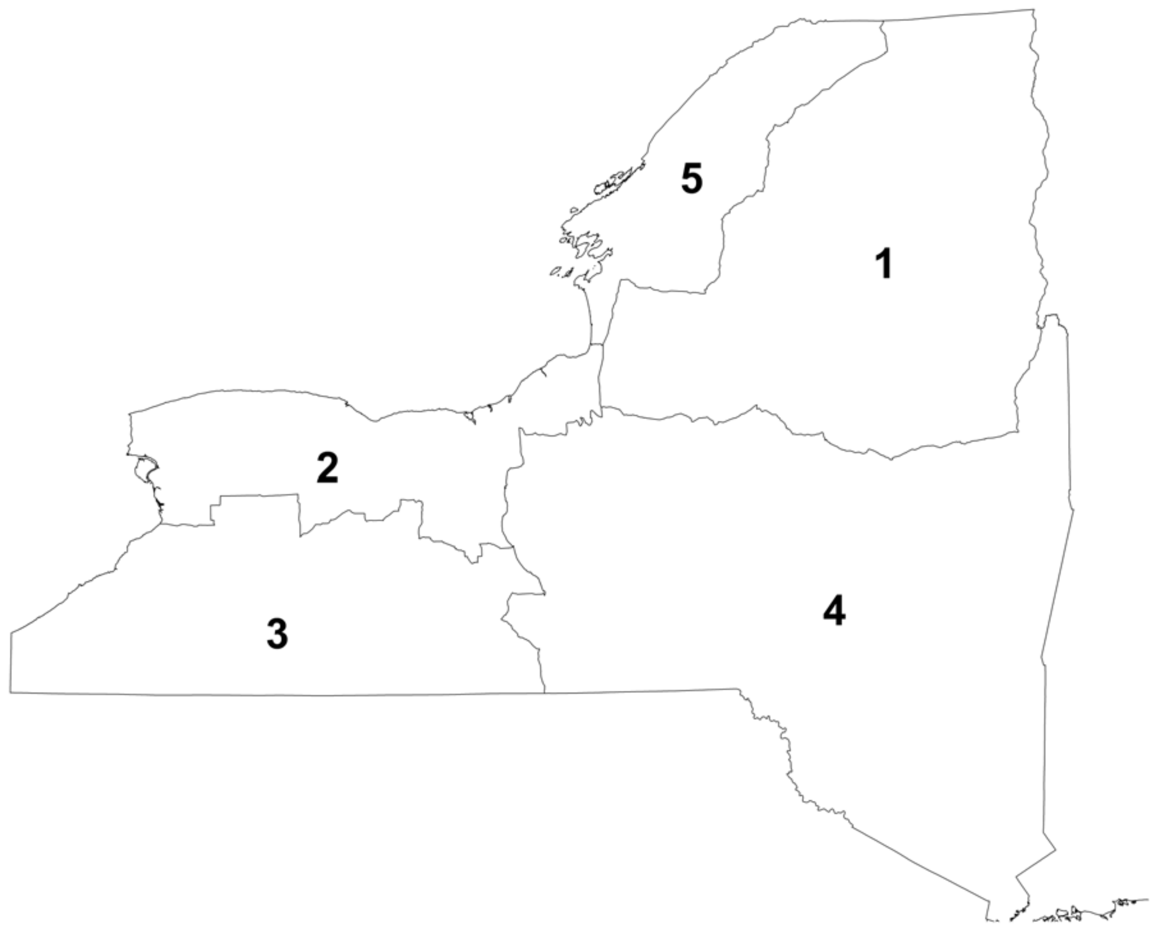

Figure 3. Fall hunting season zones for which male wild turkey harvest and survival rates were estimated using data from New York, 2006-2009.

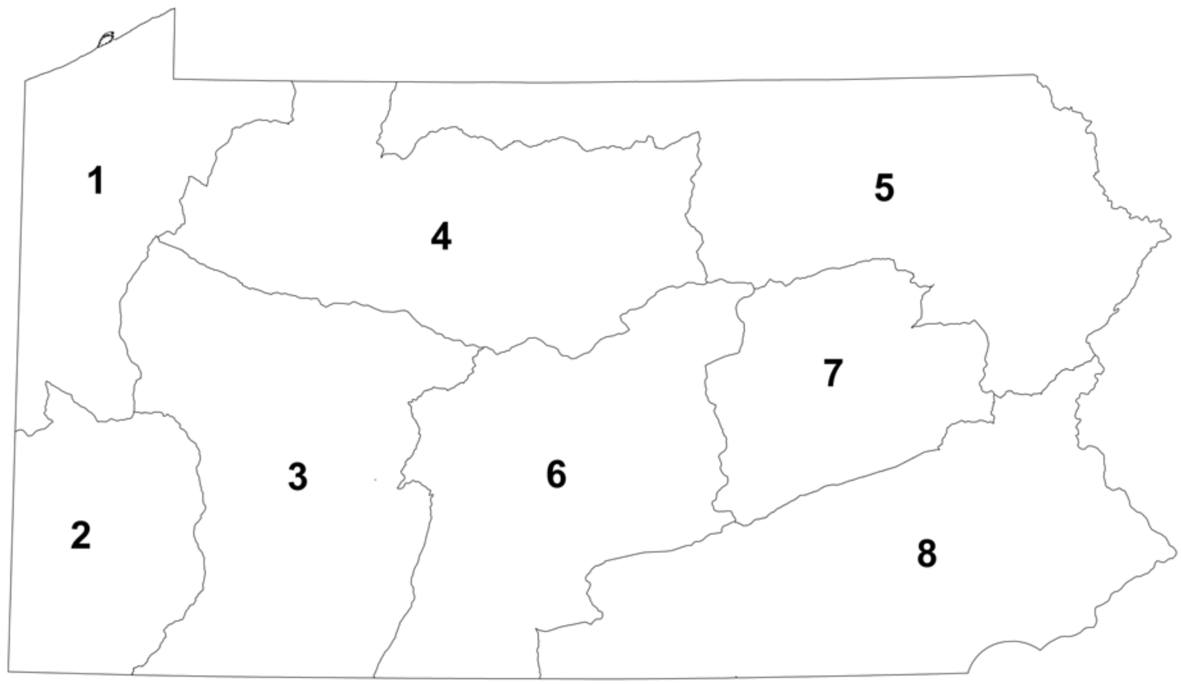

Figure 4. Groups of wildlife management unit for which male wild turkey harvest and survival rates were estimated using data from Pennsylvania, 2006-2009.

RESULTS

Captures and Survival to Spring Harvest

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 jakes. By state, we banded 1,333 turkeys in New York, 663 turkeys in Ohio, and 1,270 turkeys in Pennsylvania. Banding and recovery summary tables are provided for each state by age class in Appendix II.

We monitored 83 turkeys fitted with radio-transmitters at two 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 non-hunting mortality that occurred between the date of capture and the first spring hunting season was minimal and had little influence on harvest rate estimates.

Table 4. Number of wild turkeys leg banded in New York, Ohio, and Pennsylvania with $100 reward and non-reward leg bands, 2006-2009.

	Reward			Non-reward			
Year	NY	OH	PA	NY	OH	PA	Total
2006	154	97	135	143	70	111	710
2007	153	131	145	239	144	189	1,001
2008	137	94	143	215	127	189	905
2009	55	0	76	237	0	282	650
2006–2009	499	322	499	834	341	771	3,266

Leg Band Retention

We used butt-end band loss information from 887 turkeys recovered between 31 days and 570 days after release ($\bar{x}$ = 202 days). Band loss was greater for turkeys banded as adults (>1 yr old) than juveniles and was greater for aluminum than stainless steel bands. We estimated band retention was 79–96%, depending on age at banding and type of band, for turkeys recovered 3 months after release. Band retention was <50% for all age classes and band types 15 months after banding. See Appendix I for a complete analysis of the retention of butt-end leg bands.

We banded 270 turkeys with a rivet band on each leg in New York and Pennsylvania in winter 2009 and 54 of those birds were recovered during the 2009 spring season. Three birds were reported as missing one of the leg bands, which represents a 97.2% retention rate. Of the more than 900 birds fitted with butt-end bands we never recovered a bird missing a rivet-band but still retained a butt-end band.

Harvest, Survival, and Reporting Rates

Goodness of fit tests under model H1 of program BROWNIE indicated the model fit the data for each state (NY χ^2_4 = 7.60, P = 0.107; OH χ^2_2 = 0.77, P = 0.681; PA χ^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 (Table 5). Also, non-reward bands were 1.31 times less likely to be reported than reward bands (95% CI = 1.17 – 1.46), which corresponds to an approximate 82% reporting rate for non-reward bands.

Annual survival was approximately twice as high for juveniles ($\hat{S}$ = 0.64–0.87) as adults ($\hat{S}$ = 0.30–0.40; Table 6). In turn, spring harvest rates were greater for adults ($\hat{H}$ = 0.36–0.40) than juveniles ($\hat{H}$ = 0.16–0.25; Table 7). Estimates of all other mortality ($\hat{M}$) ranged from -0.03–0.20 for juveniles and 0.21–0.31 for adults but precision was poor (Table 8).

Table 5. Model selection results using Akaike's Information Criterion corrected for small sample size (AICc) for Brownie et al. (1987) tag recovery models for wild turkeys banded in New York, Ohio, Pennsylvania, 2006-2009. Survival (*S*) and harvest rates (*H*) were modeled as a function of age of bird (age), state where banded (state), year of banding (yr), and whether fitted with a reward band (reward).

Model	ΔAICc	AICc weights	Model likelihood	*k* [a]
{S(age×state) H(age×state+reward)}	0.00	0.53	1.00	13
{S(age) H(age+yr×state+reward)}	2.70	0.14	0.26	16
{S(age×state) H(age+yr×state+reward)}	3.59	0.09	0.17	20
{S(age×state) H(age+state+reward+forest)}	4.58	0.05	0.10	12
{S(age×state) H(age+yr+zone+reward)}	4.81	0.05	0.09	26
{S(age×state) H(age+zone+reward)}	4.94	0.04	0.08	23
{S(age×state) H(age+state+reward+mfps)}	5.56	0.03	0.06	12
{S(age) H(age×state+reward)}	6.97	0.02	0.03	9
{S(age×state) H(age+state+yr+reward)}	7.33	0.01	0.03	15
{S(age×state) H(age+state+reward+iji)}	7.71	0.01	0.02	12
{S(age+state) H(age×state+reward)}	8.06	0.01	0.02	11
{S(age×yr) H(age+yr×state+reward)}	8.11	0.01	0.02	20
{S(age×state) H(age+state+reward+public)}	9.16	0.01	0.01	13
{S(age+state+yr) H(age×state+reward)}	12.86	<0.01	<0.01	15
{S(age×yr×state) H(age+yr×state+reward)}	15.23	<0.01	<0.01	31
{S(age×yr×state) H(age+yr×state+reward×state)}	18.12	<0.01	<0.01	33
{S(age×yr×state) H(age+yr×state+reward×age)}	18.70	<0.01	<0.01	32
{S(age×yr×state) H(age+yr×state+reward×yr)}	19.07	<0.01	<0.01	33
{S(age+zone) H(age×state+reward)}	20.80	<0.01	<0.01	22
{S(age×yr×state) H(age+yr+reward)}	21.79	<0.01	<0.01	23
{S(age×yr×state) H(age×year×state)}	34.68	<0.01	<0.01	41

[a] No. parameters

Table 6. Annual survival ($\hat{S}$) estimates and measures of precision for male wild turkeys banded in New York, Ohio, and Pennsylvania, 2006-2009.

Age	State	$\hat{S}$	$\hat{SE}(\hat{S})$	CV [a]	95% CI
Juvenile	NY	0.636	0.053	8.3	0.526 – 0.732
	OH	0.867	0.077	8.9	0.639 – 0.960
	PA	0.654	0.053	8.1	0.544 – 0.750
Adult	NY	0.339	0.031	9.1	0.281 – 0.402
	OH	0.302	0.032	10.6	0.242 – 0.368
	PA	0.405	0.031	7.7	0.347 – 0.467

[a] $\hat{SE}(\hat{S})/\hat{S} \times 100\%$

Table 7. Harvest rate ($\hat{H}$) estimates and measures of precision for male wild turkeys banded in New York, Ohio, and Pennsylvania, 2006-2009.

Age	State	$\hat{H}$	$\hat{SE}(\hat{H})$	CV[a]	95% CI
Juvenile	NY	0.168	0.015	8.9	0.140 – 0.199
	OH	0.160	0.021	13.1	0.123 – 0.206
	PA	0.252	0.019	7.5	0.217 – 0.291
Adult	NY	0.356	0.020	5.6	0.317 – 0.397
	OH	0.397	0.026	6.5	0.348 – 0.448
	PA	0.382	0.020	5.2	0.344 – 0.421

[a] $\hat{SE}(\hat{S})/\hat{S} \times 100\%$

Table 8. Annual other mortality ($\hat{M}$) estimates and measures of precision for male wild turkeys banded in New York, Ohio, and Pennsylvania, 2006-2009.

Age	State	$\hat{M}$	$\hat{SE}(\hat{M})$	CV[a]	95% CI
Juvenile	NY	0.197	0.033	16.8	0.131–0.262
	OH	-0.027	0.066	244.4	-0.155–0.102
	PA	0.094	0.034	36.2	0.028 – 0.160
Adult	NY	0.305	0.078	25.6	0.152 – 0.457
	OH	0.301	0.083	27.6	0.139 – 0.464
	PA	0.213	0.088	41.3	0.040 – 0.386

[a] $\hat{SE}(\hat{S})/\hat{S} \times 100\%$

New York Harvest and Survival Rates

When we estimated harvest and survival rates based on 6 physiographic zones (Figure 1) we found that the best model was one in which survival differed by age class and harvest rates varied by age class, year and physiographic zone in an additive model (Table 9). An additive model is one in which harvest rates vary over time but the difference among each age class and physiographic zone is constant. Annual survival was 0.65 (SE = 0.056, 95% CI = 0.53–0.75) for juveniles and 0.34 (SE = 0.032, 95% CI = 0.28–0.41) for adults. Harvest rates varied from 0.11–0.29 for juveniles and 0.29–0.56 for adults (Table 10).

Table 9. Model selection results for harvest and survival rates of male wild turkeys in New York based on 6 physiographic zones, 2006-2009.

Model	ΔAICc	AICc weights	Model likelihood	k[a]
{S(age) f(age+year+reward+zone)}	0.00	0.98	1.00	12
{S(age) f(age+reward+zone)}	8.32	0.02	0.02	9
{S(age) f(age×year+reward)}	11.63	<0.01	0.01	11
{S(age) f(age+reward)}	17.00	<0.01	<0.01	5
{S(age×year) f(age×year+reward)}	17.64	<0.01	<0.01	15
{S(age×year) f(age+reward)}	24.17	<0.01	<0.01	9

[a] No. parameters.

When we estimated harvest and survival rates based on 16 physiographic regions (Figure 2) the best model was the same as for the analysis based on 6 physiographic regions (Table 11). Annual survival was 0.65 (SE = 0.057, 95% CI = 0.53–0.75) for juveniles and 0.34 (SE = 0.031, 95% CI = 0.28–0.40) for adults. Harvest rates varied from 0.09–0.33 for juveniles and 0.24–0.61 for adults (Table 12).

Table 10. Harvest rates of male wild turkeys in New York based on 6 physiographic zones, 2006-2009.

Zone	Year	Juveniles			Adults		
		$\hat{H}$	$SE(\hat{H})$	95% CI	$\hat{H}$	$SE(\hat{H})$	95% CI
1	2006	0.21	0.040	0.14–0.30	0.45	0.061	0.34–0.57
1	2007	0.11	0.026	0.07–0.18	0.29	0.050	0.20–0.39
1	2008	0.13	0.029	0.09–0.20	0.32	0.052	0.23–0.43
1	2009	0.14	0.031	0.09–0.21	0.33	0.056	0.23–0.45
2	2006	0.21	0.042	0.14–0.31	0.46	0.063	0.34–0.58
2	2007	0.12	0.025	0.08–0.18	0.29	0.047	0.21–0.39
2	2008	0.13	0.028	0.09–0.20	0.33	0.051	0.24–0.43
2	2009	0.14	0.030	0.09–0.21	0.34	0.054	0.24–0.45
3	2006	0.29	0.038	0.22–0.37	0.56	0.049	0.47–0.66
3	2007	0.17	0.026	0.12–0.23	0.39	0.043	0.31–0.47
3	2008	0.19	0.028	0.14–0.25	0.43	0.043	0.34–0.51
3	2009	0.20	0.030	0.15–0.26	0.44	0.046	0.35–0.53
4	2006	0.25	0.030	0.20–0.31	0.51	0.042	0.43–0.59
4	2007	0.14	0.020	0.10–0.18	0.34	0.034	0.27–0.40
4	2008	0.16	0.022	0.12–0.21	0.37	0.035	0.31–0.44
4	2009	0.17	0.024	0.12–0.22	0.38	0.039	0.31–0.46
5	2006	0.20	0.029	0.15–0.27	0.44	0.045	0.36–0.53
5	2007	0.11	0.019	0.08–0.15	0.28	0.035	0.22–0.35
5	2008	0.13	0.021	0.09–0.17	0.31	0.037	0.24–0.39
5	2009	0.13	0.023	0.09–0.18	0.32	0.042	0.25–0.41
6	2006	0.21	0.031	0.16–0.28	0.46	0.044	0.37–0.55
6	2007	0.12	0.019	0.08–0.16	0.29	0.033	0.23–0.36
6	2008	0.13	0.022	0.10–0.18	0.33	0.036	0.26–0.40
6	2009	0.14	0.024	0.10–0.19	0.34	0.040	0.26–0.42

Table 11. Model selection results for harvest and survival rates of male wild turkeys in New York based on 16 physiographic zones, 2006-2009.

Model	ΔAICc	AICc weights	Model likelihood	k^a
{S(age) f(age+year+reward+zone) }	0.00	0.66	1.00	23
{S(age) f(age×year +reward+zone)}	2.27	0.21	0.32	26
{S(age) f(age×year +reward)}	3.37	0.12	0.18	11
{S(age×year) f(age×year +reward)}	9.28	<0.01	0.01	15
{S(age) f(age+reward+zone)}	10.37	<0.01	0.01	20

[a] No. parameters.

Table 12. Harvest rates of male wild turkeys in New York based on 16 physiographic zones, 2006-2009.

Zone	Year	Juveniles $\hat{H}$	Juveniles $SE(\hat{H})$	Juveniles 95% CI	Adults $\hat{H}$	Adults $SE(\hat{H})$	Adults 95% CI
1	2006	0.20	0.052	0.12–0.32	0.44	0.079	0.30–0.60
1	2007	0.11	0.031	0.06–0.18	0.28	0.062	0.17–0.41
1	2008	0.12	0.033	0.07–0.20	0.31	0.064	0.20–0.45
1	2009	0.13	0.035	0.07–0.21	0.32	0.067	0.20–0.46
2	2006	0.23	0.054	0.14–0.35	0.49	0.080	0.34–0.64
2	2007	0.12	0.035	0.07–0.21	0.31	0.070	0.19–0.46
2	2008	0.14	0.040	0.08–0.24	0.34	0.075	0.22–0.50
2	2009	0.14	0.042	0.08–0.25	0.35	0.079	0.22–0.52
3	2006	0.26	0.056	0.17–0.39	0.54	0.075	0.39–0.68
3	2007	0.15	0.036	0.09–0.23	0.36	0.067	0.24–0.49
3	2008	0.17	0.041	0.10–0.26	0.39	0.071	0.26–0.53
3	2009	0.17	0.043	0.10–0.27	0.40	0.073	0.27–0.55
4	2006	0.17	0.049	0.10–0.29	0.40	0.081	0.26–0.57
4	2007	0.09	0.027	0.05–0.16	0.24	0.058	0.15–0.37
4	2008	0.10	0.031	0.06–0.18	0.27	0.063	0.17–0.41
4	2009	0.11	0.032	0.06–0.19	0.28	0.066	0.17–0.43
5	2006	0.33	0.044	0.25–0.42	0.61	0.053	0.50–0.71
5	2007	0.19	0.031	0.13–0.26	0.43	0.050	0.33–0.53
5	2008	0.21	0.032	0.16–0.28	0.47	0.049	0.37–0.56
5	2009	0.22	0.034	0.16–0.29	0.48	0.052	0.38–0.58
6	2006	0.24	0.048	0.16–0.35	0.51	0.065	0.38–0.63
6	2007	0.13	0.031	0.08–0.20	0.33	0.056	0.23–0.45
6	2008	0.15	0.035	0.09–0.23	0.36	0.060	0.26–0.49
6	2009	0.16	0.036	0.10–0.24	0.37	0.062	0.26–0.50
7	2006	0.19	0.037	0.13–0.28	0.44	0.057	0.33–0.55
7	2007	0.10	0.022	0.07–0.15	0.27	0.042	0.20–0.36
7	2008	0.12	0.024	0.08–0.17	0.30	0.044	0.22–0.39
7	2009	0.12	0.027	0.08–0.18	0.31	0.050	0.22–0.42
8	2006	0.21	0.063	0.11–0.35	0.46	0.094	0.29–0.64
8	2007	0.11	0.039	0.05–0.21	0.29	0.077	0.16–0.46
8	2008	0.13	0.043	0.06–0.24	0.32	0.082	0.18–0.49
8	2009	0.13	0.045	0.07–0.25	0.33	0.084	0.19–0.51
9	2006	0.31	0.042	0.24–0.40	0.60	0.048	0.50–0.69
9	2007	0.18	0.029	0.13–0.25	0.42	0.045	0.33–0.51
9	2008	0.20	0.031	0.15–0.27	0.45	0.045	0.37–0.54
9	2009	0.21	0.034	0.15–0.29	0.46	0.050	0.37–0.56
10	2006	0.27	0.038	0.20–0.35	0.54	0.050	0.44–0.64
10	2007	0.15	0.024	0.11–0.20	0.36	0.043	0.28–0.45
10	2008	0.17	0.027	0.12–0.23	0.40	0.045	0.31–0.49
10	2009	0.17	0.030	0.12–0.24	0.41	0.050	0.31–0.51

Table 12. Continued.

		Juveniles			Adults		
Zone	Year	$\hat{H}$	$SE(\hat{H})$	95% CI	$\hat{H}$	$SE(\hat{H})$	95% CI
11	2006	0.21	0.041	0.14–0.30	0.46	0.063	0.34–0.58
11	2007	0.11	0.026	0.07–0.17	0.29	0.052	0.20–0.40
11	2008	0.13	0.029	0.08–0.20	0.32	0.056	0.22–0.44
11	2009	0.13	0.032	0.08–0.21	0.33	0.061	0.23–0.46
12	2006	0.18	0.035	0.12–0.26	0.41	0.059	0.30–0.53
12	2007	0.09	0.020	0.06–0.14	0.25	0.042	0.18–0.34
12	2008	0.11	0.022	0.07–0.16	0.28	0.045	0.20–0.37
12	2009	0.11	0.024	0.07–0.17	0.29	0.047	0.20–0.39
13	2006	0.20	0.039	0.14–0.29	0.45	0.062	0.33–0.57
13	2007	0.11	0.025	0.07–0.17	0.28	0.051	0.19–0.39
13	2008	0.12	0.028	0.08–0.19	0.31	0.054	0.22–0.43
13	2009	0.13	0.030	0.08–0.20	0.32	0.059	0.22–0.45
14	2006	0.18	0.035	0.12–0.26	0.42	0.058	0.31–0.54
14	2007	0.10	0.022	0.06–0.15	0.26	0.046	0.18–0.36
14	2008	0.11	0.025	0.07–0.17	0.29	0.049	0.20–0.39
14	2009	0.12	0.026	0.07–0.18	0.30	0.052	0.21–0.41
15	2006	0.23	0.046	0.15–0.33	0.49	0.064	0.37–0.61
15	2007	0.13	0.028	0.08–0.19	0.32	0.050	0.23–0.42
15	2008	0.14	0.031	0.09–0.21	0.35	0.054	0.25–0.46
15	2009	0.15	0.033	0.09–0.23	0.36	0.058	0.26–0.48
16	2006	0.23	0.036	0.17–0.31	0.49	0.051	0.39–0.59
16	2007	0.13	0.023	0.09–0.18	0.32	0.041	0.24–0.40
16	2008	0.14	0.026	0.10–0.20	0.35	0.045	0.27–0.44
16	2009	0.15	0.028	0.10–0.21	0.36	0.048	0.27–0.46

When we estimated harvest and survival rates based on 5 fall turkey hunting zones (Figure 3) the best model was the same as for the analysis based on 6 physiographic regions (Table 13). Annual survival was 0.62 (SE = 0.051, 95% CI = 0.51–0.71) for juveniles and 0.36 (SE = 0.031, 95% CI = 0.30–0.42) for adults. Harvest rates varied from 0.13–0.34 for juveniles and 0.33–0.63 for adults (Table 14).

Table 13. Model selection results for harvest and survival rates of male wild turkeys in New York based on 5 fall turkey hunting zones, 2006-2009.

Model	ΔAICc	AICc Weights	Model Likelihood	k[a]
{S(age) f(age+year+reward+zone) Estimates for Zone 4}	0.00	0.98	1.00	12
{S(age) f(age+reward+zone)}	8.32	0.02	0.02	9
{S(age) f(age×year+reward)}	11.63	<0.01	<0.01	11
{S(age) f(age+reward)}	17.00	<0.01	<0.01	5
{S(age×year) f(age×year+reward)}	17.64	<0.01	<0.01	15
{S(age×year) f(age+reward)}	24.17	<0.01	<0.01	9

[a] No. parameters.

Table 14. Harvest rates of male wild turkeys in New York based on 5 fall turkey hunting zones, 2006-2009.

		Juveniles			Adults		
Zone	Year	$\hat{H}$	$SE(\hat{H})$	95% CI	$\hat{H}$	$SE(\hat{H})$	95% CI
1	2006	0.22	0.042	0.15–0.31	0.48	0.062	0.37–0.60
1	2007	0.13	0.027	0.09–0.19	0.33	0.049	0.25–0.44
1	2008	0.14	0.028	0.09–0.20	0.35	0.051	0.26–0.45
1	2009	0.14	0.030	0.09–0.21	0.36	0.054	0.26–0.47
4	2006	0.22	0.026	0.17–0.27	0.48	0.039	0.40–0.55
4	2007	0.13	0.018	0.10–0.17	0.33	0.030	0.27–0.39
4	2008	0.14	0.019	0.10–0.18	0.34	0.031	0.29–0.41
4	2009	0.14	0.021	0.10–0.19	0.35	0.036	0.29–0.43
3	2006	0.27	0.031	0.22–0.34	0.55	0.041	0.47–0.63
3	2007	0.17	0.023	0.13–0.22	0.40	0.037	0.33–0.47
3	2008	0.18	0.024	0.13–0.23	0.42	0.037	0.34–0.49
3	2009	0.18	0.027	0.14–0.24	0.43	0.042	0.35–0.51
2	2006	0.34	0.043	0.26–0.43	0.63	0.050	0.52–0.72
2	2007	0.21	0.033	0.16–0.29	0.47	0.050	0.38–0.57
2	2008	0.22	0.032	0.17–0.29	0.49	0.047	0.40–0.58
2	2009	0.23	0.035	0.17–0.31	0.50	0.051	0.40–0.60
5	2006	0.23	0.042	0.16–0.32	0.50	0.061	0.38–0.61
5	2007	0.14	0.030	0.09–0.21	0.35	0.054	0.25–0.46
5	2008	0.15	0.031	0.09–0.22	0.36	0.054	0.26–0.47
5	2009	0.15	0.033	0.10–0.23	0.37	0.058	0.26–0.49

Ohio Harvest and Survival Rates

When we estimated harvest and survival rates for 4 physiographic regions in Ohio the best model indicated survival differed between age classes and harvest rates varied among age and years (Table 15). However, because we conducted this analysis to estimate harvest and survival rates by physiographic zone we provide results for the best model in which physiographic zone was included. Because no birds were banded in Ohio in the fourth year of the study we could only estimate harvest and survival rates for 2006-2008.

The best model that included physiographic zone as an explanatory variable had survival differ between age classes and harvest rates vary by age class and physiographic zone in an additive manner (Table 15). Annual survival was 0.73 (SE = 0.080, 95% CI = 0.55–0.86) for juveniles and 0.27 (SE = 0.031, 95% CI = 0.21–0.34) for adults. Harvest rates varied from 0.15–0.21 for juveniles and 0.38–0.48 for adults (Table 16).

Table 15. Model selection results for harvest and survival rates of male wild turkeys in Ohio based on 4 physiographic regions, 2006-2008.

Model	ΔAICc	AICc weights	Model likelihood	k[a]
{S(age) f(age×year+reward)}	0.00	0.44	1.00	10
{S(age+year) f(age×year +reward)}	1.84	0.18	0.40	12
{S(age+zone) f(age×year +reward)}	1.85	0.17	0.40	13
{S(age) f(age+year+reward)}	2.48	0.13	0.29	8
{S(age×year) f(age×year +reward)}	4.88	0.04	0.09	13
{S(age) f(age+reward+zone)}	5.07	0.03	0.08	8
{S(age) f(age+year+reward+zone)}	7.47	0.01	0.02	11

[a] No. parameters.

Table 16. Harvest rates of male wild turkeys in Ohio for 4 physiographic regions, 2006-2008.

	Juveniles			Adults		
Region	$\hat{H}$	$SE(\hat{H})$	95% CI	$\hat{H}$	$SE(\hat{H})$	95% CI
1	0.16	0.022	0.12–0.20	0.39	0.031	0.33–0.45
2	0.21	0.053	0.13–0.33	0.48	0.075	0.34–0.63
3	0.15	0.030	0.10–0.22	0.38	0.045	0.30–0.47
4	0.16	0.026	0.12–0.22	0.40	0.039	0.33–0.48

Pennsylvania Harvest and Survival Rates

The best model when analyses were based on the consolidation of wildlife management units to 5 zones indicated that survival rates differed by age class and zone and harvest rates differed by age class and zone (Table 17). Both survival and harvest rates were modeled with additive effects. Harvest rates ranged from 0.18–0.33 for juveniles and 0.31–0.50 for adults (Table 18). Annual survival rates ranged from 0.51–0.77 for juveniles and 0.26–0.53 for adults (Table 19).

Table 17. Model selection results for harvest and survival rates of male wild turkeys in Pennsylvania based on 5 wildlife management zones, 2006-2009.

Model	ΔAICc	AICc weights	Model likelihood	k[a]
{S(age+zone) f(age+reward+zone)}	0.00	0.93	1.00	13
{S(age) f(age+reward+zone)}	5.37	0.06	0.07	9
{S(age) f(age+year+reward+zone)}	10.60	0.00	0.01	12
{S(age) f(age+year+reward)}	13.93	0.00	0.00	8
{S(age) f(age×year+reward)}	19.25	0.00	0.00	11
{S(age×year) f(age×year+reward)}	21.85	0.00	0.00	15

[a] No. parameters.

Table 18. Harvest rates of male wild turkeys in Pennsylvania for 5 wildlife management zones, 2006-2009.

	Juveniles			Adults		
Region	$\hat{H}$	$SE(\hat{H})$	95% CI	$\hat{H}$	$SE(\hat{H})$	95% CI
1	0.31	0.038	0.24–0.39	0.48	0.045	0.39–0.57
2	0.23	0.025	0.18–0.28	0.37	0.029	0.32–0.43
3	0.18	0.027	0.14–0.24	0.31	0.035	0.25–0.39
4	0.20	0.024	0.15–0.25	0.33	0.031	0.28–0.40
5	0.33	0.036	0.26–0.41	0.50	0.042	0.42–0.58

Table 19. Annual survival rates of male wild turkeys in Pennsylvania for 5 wildlife management zones, 2006-2009.

	Juveniles			Adults		
Region	$\hat{S}$	$SE(\hat{S})$	95% CI	$\hat{S}$	$SE(\hat{S})$	95% CI
1	0.51	0.081	0.36–0.67	0.26	0.063	0.15–0.40
2	0.69	0.066	0.54–0.80	0.41	0.052	0.32–0.52
3	0.77	0.068	0.62–0.88	0.53	0.077	0.38–0.67
4	0.72	0.067	0.57–0.83	0.46	0.057	0.35–0.57
5	0.53	0.080	0.38–0.68	0.27	0.054	0.18–0.39

Based on wildlife management units consolidated into 8 zones, the best model again indicated annual survival varied by age and zone. In addition, harvest rates were best modeled as differing by age, year, and management zone. However, for this model not all parameters were estimable because of sparse data, which means that some SEs were not estimable and point estimates should be regarded with caution. Annual survival rates ranged from 0.51–0.78 for juveniles and from 0.25–0.53 for adults (Table 21). Harvest rates were lowest in 2007 and similar in 2006 and 2008-2009 and ranged 0.17–0.35 for juveniles and 0.30–0.52 for adults (Table 22).

Table 20. Model selection results for harvest and survival rates of male wild turkeys in Pennsylvania based on 8 wildlife management zones, 2006-2009.

Model	ΔAICc	AICc weights	Model likelihood	k[a]
{S(age+zone) f(age+year+reward+zone)}	0	0.92	1.00	16
{S(age) f(age+year+reward+zone)}	5.19	0.07	0.07	12
{S(age) f(age+year+reward)}	8.52	0.01	0.01	8
{S(age) f(age*year+reward)}	13.8	<0.01	<0.01	11
{S(age*year) f(age*year+reward)}	16.4	<0.01	<0.01	15

[a] No. parameters.

Table 21. Annual survival rates of male wild turkeys in Pennsylvania for 8 wildlife management zones, 2006-2009.

	Juveniles			Adults		
Region	$\hat{S}$	$SE(\hat{S})$	95% CI	$\hat{S}$	$SE(\hat{S})$	95% CI
1	0.52	0.082	0.36–0.67	0.26	0.063	0.15–0.40
2	0.69	0.067	0.55–0.80	0.41	0.052	0.32–0.52
3	0.51			0.25		
4	0.51			0.25		
5	0.78	0.068	0.62–0.88	0.53	0.077	0.38–0.67
6	0.73	0.067	0.58–0.84	0.46	0.058	0.35–0.57
7	0.51			0.25		
8	0.54	0.081	0.38–0.69	0.27	0.054	0.18–0.39

Table 22. Harvest rates of male wild turkeys in Pennsylvania for 8 wildlife management zones, 2006-2009. Harvest rates lacking associated measures of precision had estimability problems and may not be accurate.

		Juveniles			Adults		
Zone	Year	$\hat{H}$	$SE(\hat{H})$	95% CI	$\hat{H}$	$SE(\hat{H})$	95% CI
1	2006	0.33	0.047	0.25–0.43	0.50	0.054	0.40–0.61
1	2007	0.30	0.042	0.22–0.39	0.46	0.051	0.37–0.56
1	2008	0.32	0.041	0.24–0.40	0.48	0.049	0.39–0.58
1	2009	0.31	0.043	0.23–0.40	0.48	0.052	0.38–0.58
2	2006	0.24	0.034	0.18–0.31	0.39	0.041	0.32–0.47
2	2007	0.21	0.029	0.16–0.28	0.36	0.035	0.29–0.43
2	2008	0.23	0.030	0.17–0.29	0.38	0.037	0.31–0.45
2	2009	0.22	0.029	0.17–0.28	0.37	0.036	0.30–0.44
3	2006	0.33			0.50		
3	2007	0.29			0.46		
3	2008	0.31			0.48		
3	2009	0.30			0.47		
4	2006	0.33			0.50		
4	2007	0.29			0.46		
4	2008	0.31			0.48		
4	2009	0.30			0.47		
5	2006	0.20	0.034	0.14–0.27	0.33	0.044	0.25–0.42
5	2007	0.17	0.029	0.12–0.24	0.30	0.038	0.23–0.38
5	2008	0.19	0.031	0.13–0.25	0.32	0.041	0.24–0.40
5	2009	0.18	0.030	0.13–0.25	0.31	0.040	0.24–0.39
6	2006	0.21	0.031	0.16–0.28	0.35	0.040	0.28–0.43
6	2007	0.19	0.027	0.14–0.25	0.32	0.035	0.25–0.39
6	2008	0.20	0.028	0.15–0.26	0.33	0.036	0.27–0.41
6	2009	0.19	0.029	0.14–0.26	0.33	0.038	0.26–0.41
7	2006	0.33			0.50		
7	2007	0.29			0.46		
7	2008	0.31			0.48		
7	2009	0.30			0.47		
8	2006	0.35	0.044	0.27–0.44	0.52	0.050	0.42–0.62
8	2007	0.31	0.041	0.24–0.40	0.48	0.048	0.39–0.58
8	2008	0.33	0.041	0.26–0.42	0.50	0.048	0.41–0.60
8	2009	0.32	0.042	0.25–0.41	0.49	0.049	0.40–0.59

Population Estimates and Age Structure

We estimated that the population of male turkeys in New York and Pennsylvania exceeded 106,000–134,000 in all years and ranged from 64,000–77,000 in Ohio (Table 23). The proportion of adult males in the spring harvest varied from 0.56–0.86 among states and years (Table 23), in which Pennsylvania had a greater proportion of adult males (0.81–0.86) 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 ($\hat{p}_{adults}$) was less than in the harvest (0.38–0.80 among all states and years; Table 23).

Estimates of the proportion of adult males in the population assuming a stable and stationary population ($\tilde{p}_{adults}$) indicated that the mail surveys of Pennsylvania hunters may produce biased estimates of the age structure of the harvest. Given the adult and juvenile annual survival rates estimated in this study, we estimated that approximately 52% of the male population is composed of adults, whereas harvest data suggested 75–80% were adults. In contrast, $\hat{p}_{adults}$ and $\tilde{p}_{adults}$ for New York and Ohio were similar (Table 23).

Table 23. Spring harvest estimates and proportion of adult male turkeys in the spring harvest ($\hat{p}_{adult\,harvest}$), population estimates and proportion of adult males in the population ($\hat{p}_{adults}$) prior to the hunting season, and proportion of adult males in the population prior to the hunting season assuming a stable and stationary population ($\tilde{p}_{adults}$) for New York, Ohio, and Pennsylvania, 2006-2009.

		Spring harvest				Spring population				
State	Year	Adults	Juveniles	Total	$\hat{p}_{adult\,harvest}$	Adults	Juveniles	Total	$\hat{p}_{adults}$	$\tilde{p}_{adults}$
NY	2006	15,523	11,977	27,500	0.564	43,604	71,292	114,896	0.380	0.490
	2007	24,186	11,076	35,262	0.686	67,938	65,929	133,867	0.508	0.490
	2008	22,565	10,254	32,819	0.688	63,385	61,036	124,421	0.509	0.490
	2009	24,698	9,867	34,565	0.715	69,376	58,732	128,109	0.541	0.490
OH	2006	13,611	5,920	19,531	0.697	34,285	37,000	71,285	0.481	0.554
	2007	13,076	5,015	18,091	0.723	32,937	31,344	64,281	0.512	0.554
	2008	13,786	6,095	19,881	0.693	34,725	38,094	72,819	0.477	0.554
	2009	13,070	7,070	20,140	0.649	32,922	44,188	77,109	0.427	0.554
PA	2006	32,479	5,364	37,843	0.858	85,024	21,286	106,309	0.800	0.524
	2007	29,697	6,599	36,296	0.818	77,741	26,187	103,927	0.748	0.524
	2008	32,796	7,687	40,483	0.810	85,853	30,504	116,357	0.738	0.524

DISCUSSION

Effects of Harvest Rates on Population Age Structure

The harvest rate of male wild turkeys during the spring hunting season affects the number and proportion of adult gobblers in the population and harvest (Vangilder and Kurzejeski 1995). Consequently, spring harvest rates have direct implications for hunter satisfaction. Vangilder et al. (1990) reported that Missouri turkey hunters preferred to harvest adult birds and preferred more restrictive regulations if these regulations resulted in a greater proportion of adult birds in the harvest. In contrast, Cartwright and Smith (1990) reported that National Wild Turkey Federation members from Arkansas were unwilling to support a reduction in hunting opportunity even if it resulted in improved turkey population levels. Because desires of turkey hunters with respect to hunting opportunity and factors that influence hunting satisfaction may vary among states, management objectives may differ as well. 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.

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 will decline (Vangilder and Kurzejeski 1995). However, these 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 this study, 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 than what was used in their model.

We found that in New York and Ohio 56–72% of the harvest was composed of adult males (65–72% for all years except 2006 in NY), and 81–86% in Pennsylvania (Table 23). This represented an overall 24–28% harvest rate of the male population for New York and Ohio and 35% for Pennsylvania. In a radio-telemetry study, Ohio estimated that illegal kills were 14% of the legal harvest (M. Reynolds, personal communication). 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.

Both Pennsylvania and Ohio have or will be expanding hunting hours in the latter half of the spring season to all day. How this will affect harvest rates or future hunter satisfaction if it reduces the number and proportion of adult males in the population is unknown. However, Backs (2005) reported minimal effects of all-day hunting on the proportion of the harvest composed of adults when comparing 4 year of data before all-day hunting was implemented to 2 years after all-day hunting was implemented. Furthermore, in this study annual survival rates were higher, and harvest rates were lower, for juveniles than in the population model constructed by Vangilder and Kurzejeski (1995). Consequently, the high harvest rates observed for adults may be sustainable because of greater recruitment of juveniles into the adult population the following year.

However, our estimates of the 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 estimate age and sex; however, compliance and accuracy of these data have not been verified. New York relies on a mail survey and hunter reporting of beard length, spur length, and weight, which is used to classify birds as adult or juveniles. However, we note for New York and Ohio that two different methods of estimating of the proportion of adults in the population provided similar results (Table 23). In contrast, Pennsylvania's method of estimating the age structure of the harvest may be biased because the two approaches to estimating the proportion of adults in the population provided inconsistent results (Table 23). Because the Pennsylvania Game Commission surveys hunters almost a year after the spring hunting season, we suspect memory bias and confusion regarding which spring hunting season the survey is addressing may affect results. This potential problem possibly could be resolved by taking advantage of the new electronic point-of-sale system in Pennsylvania and conducting a turkey harvest survey immediately after the spring turkey season.

Comparison to Other Studies

Most studies of harvest rates of male wild turkeys have used radio-telemetry on areas <1,000 km^2, which are equivalent, at best, to a single management unit, and monitored <100 wild turkeys per year. In contrast, this study banded >3,000 turkeys throughout the range of wild turkeys in all 3 states. In addition, because we recorded harvest locations of birds up to 59 km from the banding location, banded birds were widely distributed across the landscape and harvest rate estimates were probably the best representation of harvest and survival characteristics of male wild turkeys by management unit that can be obtained.

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). Also, in both cases these band recovery studies used butt-end bands that may have resulted in underestimates of recovery and survival rates (Diefenbach et al. 2009). In general, annual survival rates for adults in this study were comparable to what has been reported for other studies (Table 24). Annual survival for juveniles included some of the highest rates reported.

In addition, we note that the precision of these estimates are quite good, in which harvest rate estimates had a CV of 5.2–6.5% for adults and 7.5–13.1% for juveniles. This compares to predicted estimates of precision for harvest rates of 9–17% for adults and 11–22% for juveniles based on a sample size investigation conducted during the design phase of the project. The reason precision was better than predicted was because the best models did not include any temporal variation and so there were fewer parameters to estimate. Parameter estimates for Ohio had the poorest precision because fewer birds were captured each year and for only 3 of 4 years of the study.

Table 24. Estimates of average annual survival ($\hat{S}$) and average spring harvest rate ($\hat{H}$) for male wild turkeys. All studies are radio-telemetry studies except Lewis (1980), Norman et al. (2004), and this study.

Location	Age class	$\hat{S}$	$\hat{H}$	Source
Georgia	Both	0.51	0.45	Ielmini et al. 1992
Minnesota	Both	0.64		Porter 1978
Mississippi	Both		0.29	Palmer et al. 1990
Mississippi	Both		0.22	Lint et al. 1993
Missouri	Both	0.52	0.11	Lewis 1980
Wisconsin	Adult	0.51		Paisley et al. 1996
Iowa	Juvenile	0.17		Little et al. 1990
Kentucky	Juvenile	0.55	0.20	Wright and Vangilder 2001
Mississippi	Juvenile		0.15	Lint et al. 1993
Missouri	Juvenile	0.57	0.16	Hubbard and Vangilder 2001
Missouri	Juvenile	0.60	0.11	Hubbard and Vangilder 2001
New Jersey	Juvenile	0.81	0.12	Eriksen et al. (in press)
New York	Juvenile	0.64	0.17	This study
Ohio	Juvenile	0.87	0.16	This study
Pennsylvania	Juvenile	0.65	0.25	This study
Virginia & West Virginia	Juvenile	0.22		Norman et al. 2004
New Jersey				
Iowa	Adult	0.28		Little et al. 1990
Kentucky	Adult	0.26	0.52	Wright and Vangilder 2001
Mississippi	Adult[a]	0.46	0.56[b]	Godwin et al. 1991
Mississippi	Adult		0.35	Lint et al. 1993
Missouri	Both	0.36		Vangilder 1996
Missouri	Adult	0.44		Vangilder 1996
Missouri	Adult	0.37	0.23	Hubbard and Vangilder 2001
Missouri	Adult	0.37	0.30	Hubbard and Vangilder 2001
New Jersey	Adult	0.39	0.30	Eriksen et al. (in press)
New York	Adult	0.34	0.36	This study
Ohio	Adult	0.30	0.40	This study
Pennsylvania	Adult	0.41	0.38	This study
Virginia & West Virginia	Adult	0.31		Norman et al. 2004

[a] Most captured birds were adults but adult and juvenile data were combined in analysis.
[b] Includes all mortality (including illegal and nonhunting) during the spring hunting season.

Landscape Characteristics Related to Harvest Rates

We failed to identify any landscape factors related to harvest rates. One *a priori* hypothesis was that turkeys that inhabited fragmented forest landscapes might be at greater risk of harvest; however, percent forest cover, and interspersion index, and mean forest patch size did not explain variation in harvest rates. In addition, the tri-state analysis models that estimated harvest rates by management zones were ranked low (Table 5). One possible reason why we failed to detect any landscape factors that were related to harvest was because of the substantial movements turkeys made between location of banding and location of recovery. We found that 80% of turkeys were harvested up to 6.45 km from the banding location and so used a 6.45 km buffer around each capture location to describe the landscape characteristics. Consequently, the scale at which we evaluated landscape metrics may not have matched the scale at which these metrics influence harvest rates. However, we found substantial variation in all the metrics we used. For example, percent forest ranged from <1% to 96% ($\bar{x}$ = 56%, SD = 18.8%).

Other Sources of Mortality

We estimated other sources of mortality as $\hat{M} = 1 - \hat{S} - \hat{H}$, which included illegal kills, crippling loss, and harvest during the fall hunting season in addition to natural causes of mortality (predation, disease, etc.). Because of the structure of band recovery models using the Brownie parameterization, in rare instances $\hat{S} + \hat{H} > 1$, which occurred for the estimate of $\hat{M}$ for Ohio. Also, precision of estimates of $\hat{M}$ were poor (CV = 17–244%). However, other sources of mortality were low for juveniles (0–0.20), especially compared to adults (0.21–0.31; Table 8). 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 1 year. Also, unless illegal kill of adults was much greater than for juveniles, and accounted for most of the mortality other than legal harvest, it was likely that the natural mortality rate was greater for adults than juveniles. Wright and Vangilder (2005) reported that annual natural mortality (not caused by humans) was 24% for juveniles and 30% for adults.

Over the 4 years, 34 of 727 reward bands recovered (4.7%; 2.6% of all reward bands released) were reported as legal harvests during the fall hunting seasons. Also, 24 of 34 fall harvest reward band recoveries were from juveniles, which suggested fall harvest rates were greater for juveniles than adults. The few recoveries reported suggested relatively low harvest rates during the fall hunting season, perhaps <0.10, but to estimate a fall harvest rate would have required additional banding of male wild turkeys immediately prior to the fall hunting season.

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Appendix I

Loss of Butt-End Leg Bands on Male Wild Turkeys

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Duane R. Diefenbach
U.S. Geological Survey
Pennsylvania Cooperative Fish and Wildlife Research Unit
404 Forest Resources Bldg.
University Park, PA 16802
814/865-3992; Fax: 814/863-4710
ddiefenbach@psu.edu

RH: Band Loss in Wild Turkeys • Diefenbach et al.

Loss of Butt-End Leg Bands on Male Wild Turkeys

Duane R. Diefenbach, U.S. Geological Survey, Pennsylvania Cooperative Fish and Wildlife Research Unit, Pennsylvania State University, University Park, PA 16802, USA[1]

Mary Jo Casalena, Pennsylvania Game Commission, 2001 Elmerton Ave., Harrisburg, PA 17110, USA

Michael V. Schiavone, New York State Department of Environmental Conservation, Division of Fish, Wildlife, and Marine Resources, 625 Broadway, Albany, NY 12233, USA

David Swanson,[2] Ohio Department of Natural Resources, Division of Wildlife, 360 East State St., Athens, OH 45701, USA

Michael Reynolds, Ohio Department of Natural Resources, Division of Wildlife, 360 East State St., Athens, OH 45701, USA

Robert C. Boyd, Pennsylvania Game Commission, 2001 Elmerton Ave., Harrisburg, PA 17110, USA

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[1] E-mail: ddiefenbach@psu.edu

[2] Present address: Hocking College, Nelsonville, OH 45764

Robert Eriksen, National Wild Turkey Federation, 770 Augusta Road, Edgefield, SC 29824, USA

Bryan Swift, New York State Department of Environmental Conservation, Division of Fish, Wildlife, and Marine Resources, 625 Broadway, Albany, NY 12233, USA

ABSTRACT We estimated loss of butt-end leg bands on male wild turkeys (*Meleagris gallapavo*) captured in New York, Ohio, and Pennsylvania during December-March, 2006-2008. We used aluminum rivet leg bands as permanent marks to estimate loss of regular aluminum, enameled aluminum, anodized aluminum, and stainless steel butt-end leg bands placed below the spur. We used band loss information from 887 turkeys recovered between 31 and 570 days after release ($\bar{x}$ = 202 days). Band loss was greater for turkeys banded as adults (>1 yr old) than juveniles and was greater for aluminum than stainless steel bands. We estimated band retention was 79–96%, depending on age at banding and type of band, for turkeys recovered 3 months after release. Band retention was <50% for all age classes and band types 15 months after banding. We concluded that use of butt-end leg bands on male wild turkeys is inappropriate for use in mark-recapture studies.

KEY WORDS band loss, butt-end band, leg band, *Meleagris gallapavo*, rivet band, wild turkey

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Most studies to estimate population parameters of wild turkeys (*Meleagris gallapavo*), such as survival and harvest rates, have relied on radiotelemetry (e.g., Kurzejeski et al. 1987, Pack et al. 1999). Such studies are effective because they allow researchers to monitor fate of every individual and determine time-specific and cause-specific sources of mortality. However, such studies are expensive because of the equipment, time, and personnel required to continuously monitor fates of turkeys. Moreover, because of logistics, study areas usually are small relative to the size of land units for which turkeys are managed by natural resource agencies. The ability to make inferences from single, small study areas to large management units 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 partition survival rates into ≥2 periods of the year (Brownie et al. 1985, Williams et al. 2002). However, for band-recovery studies to permit accurate estimates of survival and harvest rates the retention rate of leg bands must be 100%.

Few attempts have been made to use band recovery data to estimate survival or harvest rate parameters of wild turkeys (but see Lewis 1980, Vangilder and Kurzejeski 1995, Norman et al. 2004), although they have been the basis for estimates of longevity (e.g., Cardoza 1995). Bands have been used to document turkey movements (Thomas et al. 1966, Lint et al. 1992) and results from such studies are not affected by band loss, although sample sizes are reduced. Nearly all studies report fitting aluminum butt-end bands to turkeys, even for radiotelemetry studies; however, we are not aware of any estimates of band retention for wild turkeys even though Thomas and Marburger (1964) and Lewis (1980) noted problems with loss of aluminum butt-end bands.

We banded adult and juvenile male wild turkeys during 3 winters in New York, Ohio, and Pennsylvania with 4 types of butt-end leg bands, using rivet bands as permanent marks, to estimate butt-end band loss rates for turkeys recovered 2–20 months after banding. We investigated whether age of turkeys at banding, type of band, and time between banding and recovery were related to band loss.

STUDY AREA

The study area encompassed the range of wild turkeys in New York, Ohio, and Pennsylvania. We captured turkeys throughout upstate New York (except Essex and Rensselaer counties) north of Rockland and Westchester counties. We attempted to capture turkeys throughout Pennsylvania and captured turkeys in 52 of 67 counties. Based on movement data we collected on tagging and harvest locations of banded turkeys (D. R. Diefenbach, U.S. Geological Survey, unpublished data), it is likely that banded turkeys occurred in nearly every county in Pennsylvania and all of upstate New York.

The range of wild turkeys in Ohio is expanding, in part because of translocation efforts. We trapped wild turkeys in 28 Ohio counties in 3 physiographic regions. In the Glaciated Allegheny Plateau region, we trapped wild turkeys in Ashtabula, Geauga, Holmes, Knox, Lake, Medina, Richland, Trumbull, and Wayne counties. In the Allegheny Plateau region, we trapped wild turkeys in Athens, Carroll, Columbiana, Coshocton, Guernsey, Harrison, Jackson, Jefferson, Meigs, Monroe, Morgan, Muskingum, and Stark counties. In the Till Plains region, we trapped wild turkeys in Adams, Brown, Champaign, Highland, Logan, and Pickaway counties.

METHODS

We trapped turkeys during December-April, 2006-2008 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 turkeys among counties proportional to the estimated spring harvest in each county. In Pennsylvania, we attempted to capture 50 turkeys in each of 6 administrative regions. In Ohio, we distributed the statewide capture quota of 300 turkeys among 9 trapping crews. We translocated 49 banded adult male turkeys to unoccupied habitat in 7 western Ohio counties as part of wild turkey restoration efforts. We translocated turkeys to Henry, Paulding, and Putnam counties in the Lake Plains region and Allen, Mercer, Shelby, and Union counties in the Till Plains regions.

We determined age of captured turkeys (ad: >1 yr old, juv: <1 yr old) 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 of butt-end bands (Size 28, National Band and Tag): regular aluminum (Style 1242) orange enameled aluminum (Style 1242), blue anodized aluminum (Style 1242), and stainless steel (Style 1242M-F9-SS). Each band was imprinted with a unique alphanumeric sequence and listed a toll-free number for reporting recovery of a band. We assumed retention of the aluminum rivet bands was 100%.

We used logistic regression (PROC LOGISTIC, SAS Institute, Cary, NC) to estimate proportion of butt-end bands that were lost (=1 – proportion of bands retained). We investigated models in which band loss was related to age of turkeys at time of banding (ad and juv), days between banding and recovery, and type of butt-end band (aluminum, anodized aluminum, enameled aluminum, and stainless steel). We used

Akaike's Information Criterion corrected for small sample sizes (AICc) to select the best model (Burnham and Anderson 1998) and the Hosmer-Lemeshow test for goodness-of-fit for the model with all covariates included (Hosmer and Lemeshow 2000). In addition, we investigated models in which we grouped similar band types. One model classified bands into 2 types (aluminum and stainless steel) and another classified bands into 3 types (aluminum, enameled or anodized aluminum, and stainless steel).

RESULTS

We obtained reports of recoveries of 930 turkeys, in which the interval between banding and recovery ranged from 6 to 868 days ($\bar{x}$ = 226 days). Most recoveries occurred during the spring hunting season 3-4 (49% of recoveries) months and 15-16 (24% of recoveries) months after banding. However, the general model did not fit the data (χ^2_8 = 18.69, *P* = 0.017) likely because of a sparse number of observations with band-recovery intervals of <30 days (*n* = 4) and $\geq$20 months (*n* = 39). By excluding these observations the general model fit the data (χ^2_8 = 11.38, *P* = 0.181) such that we conducted our analyses using data from 887 turkeys recovered 31–570 days after banding ($\bar{x}$ = 202 days). We recovered 311 turkeys from New York, 252 from Ohio, and 324 from Pennsylvania.

The best model included variables for age at banding of turkey, days between banding and recovery, and type of band grouped into 2 categories (aluminum or stainless steel, Table 1). There was evidence that band loss differed such that retention of stainless steel was greater than aluminum, which was greater than coated aluminum bands, but >60% of model weight was on the model in which bands were differentiated simply as either aluminum or stainless steel (Table 1). For every 30 days that elapsed between banding and recovery, a band was 1.3 times more likely to be lost. Birds banded as adults were 1.7 times more likely to lose a band than birds banded as juveniles, and aluminum bands were 3 times more likely to be lost than stainless steel bands (Table 2).

We estimated band retention was 79–96%, depending on age at banding and type of band, for turkeys recovered 3 months after release, which is approximately the time that elapses when turkeys are captured in winter and recovered during the first spring gobbler season (Table 3). By the second hunting season (approx. 15 months elapsed), we estimated <50% of bands were retained for all age classes and band type combinations (Table 3).

DISCUSSION

The rate of band loss we observed was unacceptably high and would result in underestimates of survival and harvest rates using band-recovery models. Nelson et al. (1980) investigated bias in band-recovery models with annual survival of 35% and found that a band loss function similar to ours resulted in percent relative bias in survival rates of -4–-6%, except that in their simulations band loss was >80% after 7 years compared to the 20 months in our study. Diefenbach and Alt (1998) estimated a 6% underestimate in annual survival estimates for male black bears (*Ursus americanus*) when 56% of bears lost both ear tags after 4.5–5.5 years. Band loss rates we observed would result in even greater underestimation of survival. Also, even if reward bands were used to result in 100% reporting rates by turkey hunters, harvest rates would be underestimated because 4–21% of bands would be lost before the first hunting season (Table 3). Norman et al.

(2004) used aluminum butt-end leg bands and band-recovery models and observed survival rates lower than many other studies, which may be partly explained by band loss.

One approach to reducing effects of band loss is to band individuals on both legs. However, even if loss of bands on double-banded turkeys were independent of each other, double banding would result in >23% of turkeys losing both bands after 15 months. Furthermore, the assumption of independence oftentimes may be violated, which results in greater loss rates of marks (Diefenbach and Alt 1998, Bradshaw et al. 2000).

An important assumption in our analyses is that the aluminum rivet bands that we used as permanent marks to assess butt-end band loss had 100% retention. We believe this assumption is reasonable, however, because we never recovered a turkey missing a rivet band. Consequently, we believe rivet bands, or some other type of locking leg band, should be used on wild turkeys. Moreover, field personnel found that attaching rivet bands was easier than fitting turkeys with butt-end bands.

An alternative to using leg bands is patagial tags but these tags may not always be detected by hunters (R. Eriksen, National Wild Turkey Federation, personal observation). Thus, if rewards are used to encourage reporting by hunters it would be essential that they observe the tag after the turkey is harvested so that it can be reported. Otherwise, patagial tags not detected by hunters would not be reported, which would be equivalent to band loss and underestimation of survival and harvest rates.

We cannot explain why birds banded as adults had a greater loss of butt-end leg bands than did birds banded as juveniles but suspect it may be related to behavior. Perhaps band loss is more likely to occur among dominant, adult turkeys that fight for breeding opportunities. Because we banded turkeys only once per year, we could not estimate when band loss rates of turkeys banded as juveniles become similar to turkeys banded as adults and simply used age at banding as an explanatory variable in our statistical model. Multiple banding times throughout the year would be required to attempt to estimate when juveniles have band loss rates similar to adults.

MANAGEMENT IMPLICATIONS

Band-recovery models can be used to estimate survival and harvest rates of wild turkeys but assume 100% retention of leg bands. Our data suggest butt-end leg bands should not be used on male wild turkeys; instead, managers and researchers should consider using some type of locking leg band.

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Table 1. Model selection criteria for loss of butt-end leg bands on male wild turkeys banded in New York, Ohio, and Pennsylvania, 2005-2008.

Variables[a]	No. parameters	AICc	ΔAICc	w_i [b]
Days, age, type (2 types) [c]	4	824.735	0.00	0.625
Days, age, type (3 types) [d]	5	826.476	1.72	0.265
Days, age, type	6	828.380	3.59	0.104
Days, type	3	833.736	9.02	0.007
Days, age	3	848.394	23.68	0.000
Days	2	853.839	29.14	0.000
Age, type	3	1114.239	289.52	0.000
Type	2	1123.904	299.20	0.000
Age	2	1131.617	306.91	0.000
Null (intercept only)	1	1141.076	316.38	0.000

[a] Age = age at banding (ad or juv), days = days between banding and recovery, and type = type of band (aluminum, enameled aluminum, anodized aluminum, and stainless steel).

[b] AICc model weight, $w_i = \exp\left(-\frac{1}{2}\Delta AICc_i\right) \Big/ \sum_i \exp\left(-\frac{1}{2}\Delta AICc_i\right)$

[c] We grouped band types into aluminum (including enameled and anodized aluminum) and stainless steel categories.

[d] We grouped band types into aluminum, coated (enameled or anodized aluminum), and stainless steel categories.

Table 2. Parameter estimates for a linear-logistic model of loss of butt-end leg bands for male wild turkeys (*n* = 887) banded in New York, Ohio, and Pennsylvania, 2005-2008.

Variable (category index values)	Parameter estimate	SE	Odds ratio	95% CI
Intercept	-3.7171	0.30885		
Days between banding-recovery [a]	0.0847	0.00584	1.29[b]	1.25–1.33
Age at banding (ad = 1, juv = 0)	0.5335	0.19860	1.71	1.16–2.52
Type (aluminum = 1, stainless = 0)	1.0967	0.22656	2.99	1.92–4.67

[a] No. of days divided by 30.

[b] We calculated odds of losing a band for each 30-day interval between banding and recovery.

Table 3. Estimated proportion of butt-end bands retained ($\hat{p}$) on male wild turkeys based on age at banding, type of band, and months since banding for turkeys banded in New York, Ohio, and Pennsylvania, 2005-2008.

			Months since banding							
			3 months		9 months		15 months		19 months	
Age[a]	Type[b]	*n*	$\hat{p}$	95% CI	$\hat{p}$	95% CI	$\hat{p}$	95% CI	$\hat{p}$	95% CI
A	Al	375	0.790	0.74–0.84	0.450	0.36–0.56	0.152	0.09–0.25	0.061	0.03–0.13
A	SS	122	0.918	0.88–0.96	0.710	0.60-0.84	0.348	0.22–0.55	0.162	0.08–0.33
J	Al	300	0.865	0.81–0.93	0.583	0.50-0.68	0.233	0.17–0.33	0.099	0.06–0.17
J	SS	90	0.961	0.93–0.99	0.807	0.72–0.91	0.477	0.34–0.66	0.248	0.15–0.42

[a] Age at banding; A=ad, J = juv.

[b] Type of band; Al = aluminum, SS = stainless steel.

Appendix II

Number of male wild turkeys banded (Dec-Apr) and released and recovered during the spring wild turkey hunting season in New York, Ohio, and Pennsylvania, 2006-2009.

				No. recovered				
State	Age	Year	No. banded	2006	2007	2008	2009	Total
New York	Juvenile	2006	192	35	35	13	8	91
		2007	204		28	46	8	82
		2008	192			22	42	64
		2009	160				25	25
Ohio	Juvenile	2006	69	12	20	4	0	36
		2007	131		24	44	8	76
		2008	136			12	52	64
		2009	0				0	0
Pennsylvania	Juvenile	2006	107	26	25	5	1	57
		2007	154		31	37	17	85
		2008	183			44	45	89
		2009	179				39	39
New York	Adult	2006	105	52	10	2	0	64
		2007	188		45	23	10	78
		2008	160			50	16	66
		2009	132				39	39
Ohio	Adult	2006	98	31	9	2	3	45
		2007	144		52	17	9	78
		2008	85			31	11	42
		2009	0				0	0
Pennsylvania	Adult	2006	139	53	21	8	5	87
		2007	180		59	21	15	95
		2008	149			57	19	76
		2009	179				51	51