Evaluation of Wild Turkey Population Estimation Methods

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Abstract: To determine effects of land use and management practices on wild turkey (*Meleagris gallapovo*) populations, managers need reliable, low-cost methods to estimate absolute and relative densities. Therefore, we evaluated estimation ability of 4 models using wild turkey capture data from 1986–1993 and summer bait site observations from 1990–1993 in Kemper County, Mississippi. Capture-mark-recapture models performed worse (i.e., higher coefficients of variance) than capture-mark-resight models. Estimates from 1 resighting model were biased from non-homogenous capture probabilities in most intervals (4 of 6) for both sexes. Estimates from a second resighting model required restriction of marked population to active radio-equipped hens. This model performed well in 1990 and 1991, but likely overestimated population size in 1992 and 1993 when marked/sighted samples were only 9 and 4 individuals. A 3-stage resighting-based sampling design was suggested for turkey census. Minimum counts of individuals, from concomitant bait site monitoring, agreed with estimates for hens, but were less consistent for gobblers. More precise estimates for longer periods are required to adequately assess reliability of minimum counts as population indices. Density estimates of hens were between 0.95 and 3.21 hens/km^2 and were generally higher than those from more "traditional" habitats.

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A central problem in many studies involving mobile animals is obtaining accurate and/or precise estimates of population size. Effective wildlife management requires accurate estimates to determine impact of land-use activities, such as wild turkey (*Meleagris gallopavo*) management, on population parameters. Similarly, basic ecological research requires accurate estimates, as population size influences many aspects of a species' life history.

The wary nature and high mobility of wild turkeys have limited past researcher's abilities to accurately estimate population densities. Various methods have been employed, but, for the most part, have met with limited success. Early studies relied on estimates from band returns (Bailey 1959, Lewis and Kelly 1973). Observational surveys have been employed (Shaw 1973, Graves 1982) to monitor population trends. Several researchers (Hon et al. 1978, Hayden 1985, Speake et al. 1975) used bait-facilitated observations to either directly enumerate or index population size. Mark-recapture estimates have been investigated by Exum et al. (1987), Wright (1975), Gribben (1986) and Lint (1990). Success of these studies has been limited by large variances of estimates, which prohibits using them for anything but crude indices.

Reliable estimates of population sizes would enable incorporating factors such as fitness, weather, and habitat into predictive models, greatly increasing current knowledge. Land use practices are changing at increasingly rapid rates throughout the Southeast. Without knowledge of how these changes affect turkey populations, management will be limited to reactive rather than proactive measures. Therefore, we analyzed long-term population data using traditional techniques with the goal of suggesting designs for future projects which may provide more accurate population estimates.

Methods

Study Area

The study area was located in east-central (Kemper County) Mississippi in the Interior Flatwoods land resource area (Pettry 1977). In 1991, 56% of the area was loblolly pine (*Pinus taeda*) plantations, 24% mature pine-hardwood forest, 13% streamside management zones and other hardwood forests, and 7% was classified as non-forest (croplands and pastures). Weyerhaeuser Company (WeyCo) owned 72% of the area. Management included clearcutting, site preparation, planting pine seedlings, pine release through herbicide application, precommercial and commercial thinning, fertilizing, controlled burning, pruning, and a 30–35 year rotation. Average plantation size was 26.83 ha (0.46–129.23 ha) (Stys et al. 1992).

The area was traversed by several all-weather roads and gaited spur roads extended into most plantations. Most spur roads were unimproved, rarely used, and were covered with herbaceous vegetation (Smith et al. 1990). Some roadsides were disked during late summer and early fall, and were planted to winter wheat (*Triticum aestivum*) or rye grass (*Lolium sp.*) by hunting clubs that leased rights from WeyCo.

Capture of Wild Turkeys

We captured turkeys from the third week of January until the second week of March 1986–1992, during the first 2 weeks of March 1993, and from late June through mid-August 1986–1989. Turkeys were captured at permanent bait sites using cannon nets (Bailey 1976). We monitored bait sites in the evening to determine use (i.e., presence of droppings, tracks, feathers). Sites used by turkeys for 2 consecutive days were equipped with nets and monitored.

To minimize capture stress, we placed captured turkeys immediately into turkey transport boxes, provided by the National Wild Turkey Federation. We individually marked turkeys using color-coded, numbered cattle ear tags placed patagially (Knowlton et al. 1964). We determined age class and sex from coloration and banding pattern of the ninth and tenth primary feathers (Williams 1981). Females were equipped back-pack style with 108 g motion sensitive radio-transmitters (Wildl. Materials, Inc., Carbondale, Ill.). We released all turkeys at the capture site immediately after processing.

Telemetry

We monitored hens with a Telonics, Inc. (Mesa, Ariz.), TR-2 or a Wildlife Materials, Inc. (Carbondale, Ill.), TRX-1000S receiver and a hand-held 3-element yagi directional antenna. We determined locations by triangulation (Cochran and Lord 1963) from the 2 closest, if possible, permanent stations ($N = 144$). Locations were converted to an x,y coordinate system using TELEBASE (Wynn et al. 1990).

We located hens thrice daily, thrice weekly during spring (March–June), and as often as possible, usually twice daily, twice weekly, throughout the rest of the year. With exception of hens during incubation periods, all hens found in the same location 3 consecutive times and inactive were assumed dead. We attempted to locate the turkey immediately after the third time, and the area of death was searched for possible cause.

Summer Bait Site Observation

From early July to mid-August, 1990–1993, we maintained bait sites ($N =$ 25–28) similar to winter capture sites. We checked sites for use at mid-day (1100–1300) and evening (after 1800). All bait sites that received use during 2 out of the preceding 4 periods (i.e., am and pm) were placed into a pool from which as many bait sites as possible were randomly chosen to be monitored from a nearby blind. Observation periods were from 0600–1100 and 1300–1800. Regardless if turkeys were observed, we reset the selection criterion such that the bait site must have been used twice in succession before it could be placed back in the pool. On the last day of the summer observation period (14–18 Aug), we observed all bait sites simultaneously during the morning and afternoon periods.

We recorded age class (poult, juvenile, adult), sex, marked status, tag number, number of poults, arrival and departure time, if turkeys were disturbed, and weather conditions. All other pertinant observations made were recorded. To standardize observations among bait sites, we only included turkeys that entered a 10×20 m sighting area, centered on the corn pile, in analyses.

Population Estimates

We employed capture-mark-recapture and capture-mark-resight methods to estimate population densities and trends during 1986–1993. These techniques are considered to be established sampling methodologies to derive parameter estimates from fairly mobile populations (Cormack 1979, Blower et al. 1981, Stokes 1984). Animals are captured, marked, and released. Using data gained from subsequent recaptures (resightings) of marked animals, inferences concerning population parameters, including population size and survival rates, are made (Caughley 1977). Reviews of these techniques are provided by Lint (1990) and Pollock et al. (1990).

Capture-Mark-Recapture

For capture-mark-recapture analyses, only open population estimators were deemed applicable as the long period of the study precluded assumption of closure. We chose 2 models, Jolly-Seber full (Jolly 1965) (JSF) and Buckland (Buckland 1980) (BU) for analyses. We selected JSF for its general nature and comparatively good performance in simulations (Lint 1990). We chose BU because it included known deaths in analyses and limited estimation of births to only biological reasonable intervals.

JSF is a stochastic model that allows survival rates to vary and birth rates calculated between sampling periods. Population estimates are calculated for each sampling period. A multinomial distribution is assumed which allows maximum likelihood estimates of population size, survival probability, capture probability, and gains and losses, from an estimation of marked animals at risk. JSF allows for between sample intervals to vary in temporal length, BU does not. It was primarily for this reason that we used 2 models.

BU is a modification of JSF which enables use of known deaths in analyses. Also significant is that this model enables birth estimation to be excluded from intervals where no births are known to occur. This restriction further improves variance of estimates. Lint (1990) compared performance of several models empirically using data from a wild turkey population in central Mississippi and found this model to provide best estimates of population size.

We performed separate analyses for gobbler and hen segments of the population. This reduced biases from subgroup capture heterogeneity. Within sexes, we pooled all age groups to enable larger sample sizes (few gobblers or juvenile hens were captured which would have made their population inestimable without pooling). Both JSF and BU distinguish between numbers captured and numbers released. We considered animals lost on capture if they were known to die within 3 weeks of capture.

Capture-Mark-Resight

Capture-mark-resight methodologies represent extensions of capture-mark-recapture models where observed proportion of animals marked provides a surrogate for capture. These methods offer several possible advantages. Resightings involve little or no stress to the animal under observation. Capture employing more than 1 technique reduces biases associated with capture heterogeneity. Sightings are often more cost-effective to obtain than captures and, in some instances, may be obtained concomitant with other tasks. A final benefit is that sightings may be obtained by less highly trained personnel than captures.

Summer bait site observation periods enabled use of 2 capture-mark-resight methodologies. These were the Minta and Mangel (1990) (MM) and Arneson et al. (1991) (AR) methods. These models are variants of closed population methodologies.

MM is based on Monte-Carlo simulation of resightings. It assumes number of marked individuals in a population is known. From observed frequencies of resighting of known individuals, a maximum likelihood estimator of population size is determined. Confidence intervals are obtained through simulation. It is suggested that >45% of small populations be marked for adequate model performance (Bartmann et al. 1987). Because exact knowledge of marked population size is necessary for this model, we could only class hens with active radiotransmitters as marked.

AR provides maximum likelihood estimates of number of marked individuals in the population as well as population size. A simple Lincoln-Peterson type model is then used to generate population size. Number of marked individuals was not assumed known, allowing estimation of both hen and gobbler populations and inclusion of all marked animals observed in the marked sample (not just hens with active radios as MM). Resighting frequencies were compared with expected values from the zero-truncated poisson distribution to assess problems associated with sighting heterogeneity. Cell values with observed values of <2 were pooled.

Williams (1989) suggested use of simultaneous observations of bait stations as a means of obtaining a minimum population count (MC). Counts, by sex, of all turkeys observed in pm of the final observation day of each year are presented.

Density Calculation

Population estimates reported as number of individuals occurring in various age or sex classes are useful only for within-site comparisons. To enable comparisons with estimates from other areas, population estimates must be converted to densities, which requires an estimate of area. Many researchers arbitrarily assign a value to study area size. An area so defined may have no direct relationship with the population under study (Caughley 1977). This may result in biased estimates, which may lead to erroneous conclusions. Therefore, we used quantitative estimates of study area size (JSF, BU, MM, AR) and area of effective census (MC) to compute density (Weinstein 1994).

Results

We obtained 74 captures of 64 individual gobblers and 302 captures of 233 individual hens during 12 periods. Of these, no gobblers and 13 (4.3% of captures) hens were considered lost on capture. Over 4 years of summer bait site observations, 535 gobblers and 1,193 hen observations were recorded. Of these, 108 gobblers (20.2%) and 337 hens (28.3%) were patagially marked. During this same period 14 of 30, 12 of 26, 9 of 22, and 4 of 17 individual hens with active transmitters were observed 51, 42, 22, and 10 times in 1990, 1991, 1992, and 1993, respectively (these constituted the marked sample for MM).

Population estimates were generally similar among models, with capture-mark-recapture models having the widest confidence intervals (Tables 1, 2). Small sample sizes for males precluded estimation of confidence limits. Because of the poor performance of BU and JSF (minimum coefficient of variation for hen estimation exceeded 24% for both models), additional tests to evaluate accuracy were not performed. Even if these estimates were unbiased, which was unlikely, their poor precision would preclude any meaningful use. In 4 of 6 intervals, significant deviation from homogenous sighting probabilities (required for AR) was detected (Table 3). Two tests could not be performed due to 0 degrees of freedom.

Table 1. Gobbler population estimates (individuals) based on models derived by Jolly-Seber (Jolly 1965), Buckland (1980), Arneson et al. (1991), and Williams (1989), Kemper County, Mississippi, 1986–1993.

	Model			
Sample period	Jolly-Seber	Buckland	Arneson et al.	Williams
86w[a]				
86s[b]	6[c]	0		
87w	8	47		
87s	14	24		
88w	19	19		
88s	3	16		
89w	25	102		
89s	6	38		
90s	12	35	21 (15–28)[d]	43
91s	100	146	64 (49–86)	29
92s	8	189	37 (20–82)	49
93s			50 (30–92)	18

[a]"w" indicates winter capture period (Jan–Mar) 1986–1993.
[b]"s" indicates summer capture period (July–Aug) 1986–1993.
[c]Confidence intervals not available due to small sample size.
[d]Numbers in parentheses indicate 95% confidence intervals.

Table 2. Hen population estimates (individuals) based on models derived by Jolly-Seber (1965), Buckland (1980), Arneson et al. (1991), Minta and Mangel (1989), and Williams (1989), Kemper County, Mississippi, 1986–1993.

	Models				
Sample period	Jolly-Seber	Buckland	Arneson et al.	Minta and Mangel	Williams
86w[a]					
86s[b]	17	17 (0– 27)[c]			
87w	126	281 (139–487)			
87s	129 (0–303)	266 (115–406)			
88w	154 (27–282)	244 (130–373)			
88s	154 (71–379)	172 (74–302)			
89w	100 (27–173)	131 (72–279)			
89s	117 (44–278)	98 (55–199)			
90s	124 (40–209)	160 (86–243)	100 (83–121)	132 (114–153)	75
91s	112 (37–188)	127 (70–225)	104 (87–127)	154 (144–173)	67
92s	218 (0–462)	189 (84–439)	107 (87–133)	244 (228–269)	103
93s			85 (67–108)	288 (255–322)	60

[a]"w" indicates winter capture period (Jan–Mar) 1986–1993.
[b]"s" indicates summer capture period (Jul–Aug) 1986–1993.
[c]Numbers in parentheses indicate 95% confidence intervals.

Table 3. Degrees of freedom (df) and probabilities (P-value) of observing a larger chi-squared statistic due to random variation for sex-specific tests of homogeneity of resighting probability (Arneson et al. 1991), 1990–1993, Kemper County, Mississippi.

Sex	Year	df	P-value
Gobbler	1990	0	
	1991	1	0.100
	1992	0	
	1993	1	0.042
Hen	1990	7	0.003
	1991	4	0.259
	1992	3	0.656
	1993	3	0.045

Discussion

Estimates of turkey numbers using JSF and BU were generally poor. Confidence intervals were usually several times wider than estimates. Robson and Reiger (1968) recommended estimates within $0.1 \times N$ for adequate estimation. Small sample sizes precluded use of goodness-of-fit tests of assumptions included within program JOLLY (Hines 1987). Due to poor performance of these models, additional quantification of assumption violations was deemed unnecessary and, therefore, not attempted.

Qualitatively, the assumption of equal catchability was most likely violated, as were assumptions of equal survival functions and instantaneous sampling. Gribben (1987) discussed probable assumption violations when analyzing turkey capture-mark-recapture studies. Assumptions of no tag loss, equal knowledge of death, and equal trapping mortality likely were not seriously violated.

Estimation using AR generally performed well. Average coefficient of variation was 9.75 (8.88–10.64) for hen estimates and 23.53 (15.10–35.65) for gobbler estimates. However, in most (4/6) instances, the assumption of independent resighting probability was violated (Table 3). Violations in the direction observed resulted in negatively biased estimates (i.e., true population sizes are probably larger than estimates). It is also important to note that even in years where no deviation was detected, small sample sizes may have prevented detecting deviations from randomness (type I error).

Estimates from MM performed well in years when marked sample was largest (estimates of 132 and 154 hens), but in 1992 and 1993 when the marked sample was 9 and 4, confidence intervals expanded and resulting estimates (244 and 288 hens) were likely inflated. Although a 0.45 mark/unmarked ratio has been suggested (Bartman et al. 1987), estimates from approximately 0.10 (marked individuals/estimate of population, 1990 and 1991) provided biologically reasonable estimates with fairly narrow confidence intervals.

Minimum counts of population size are difficult to evaluate without a known population for comparison. Generally, changes in hen population estimates reflected well in minimum counts. Gobbler estimates and counts diverged greatly. However, with such small sample sizes for estimates, it is impossible to determine if counts or estimates more accurately reflect population changes. These counts were not complete censuses (several radio-equipped hens were never observed).

Estimated densities (Figs. 1, 2) were at the lower end of values (1.1 to 12.4 turkeys/km^2) reported by Speake et al. (1975) in Alabama, consistent with or higher than densities reported for Alabama (Everett et al. 1979) (0.7 to 1.7 turkeys/km^2), and higher than average densities of 0.61 hens and 0.51 for gobblers in central Mississippi (Lint 1990). These studies were conducted within pine, pine-hardwood, or bottomland hardwood forests.

Density estimates derived from MC and effective census area were consistant with those from other methods, which provides evidence that concomitant counts of turkeys at bait sites do provide reasonable indices of population size.

Research and Management Recommendations

Five methods (2 capture-based, 2 resighting-based, and a minimum count) to estimate or index population sizes of wild turkeys were compared. As in other

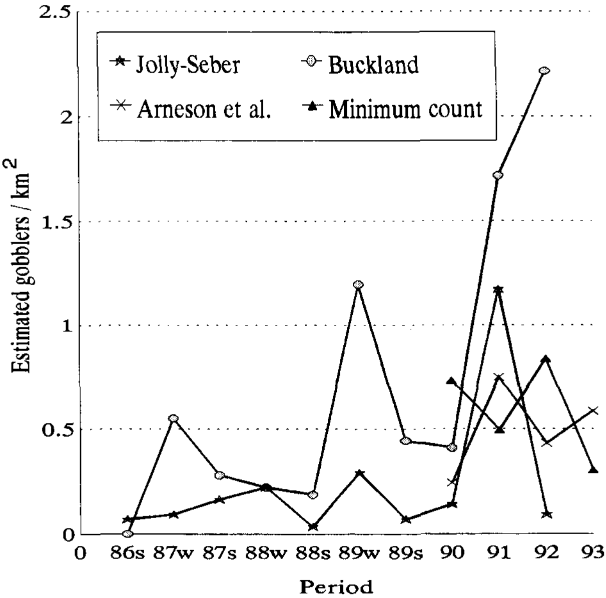

Figure 1. Gobbler density estimates (individuals/km^2) from models derived by Jolly-Seber (Jolly 1965), Buckland (1980), Arneson et al. (1991), and Williams (1989), Kemper County, Mississippi, 1986–1993.

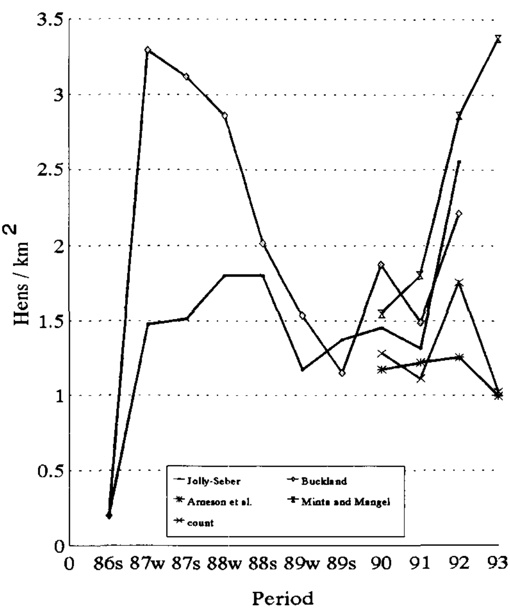

Figure 2. Hen density estimates (individuals/km^2) from models derived by Jolly-Seber (Jolly 1965), Buckland (1980), Minta and Mangel (1989), Arneson et al. (1991), and Williams (1989), Kemper County, Mississippi, 1986–1993.

studies (Exum et al. 1987, Gribben 1986, Lint 1990) capture-mark-recapture methods were inadequate to estimate wild turkey population sizes. Large economic and personnel resources were required to obtain sample sizes that were inadequate. Capture-mark-resight methodologies, however, were promising. Although there is still a large cost associated with initial capture, ability to use less skilled personnel, coupled with efficient sampling designs suggests that these methods may have a broader applicability than techniques requiring multiple captures. AR provided estimates with narrow confidence intervals, but were negatively biased. High bait site fidelity displayed by turkeys makes it difficult to envision designs for turkeys where this method may be applicable.

As conducted, MM estimates were highly variable. This variability comes from the restriction imposed by requisite knowledge of marked population size. In our study, this required using only hens with active radio-transmitters.

Future work needs to investigate reliability and feasibility of a 3-stage sampling design. After an initial capture period, 2 stages of observation could be employed. All marked individuals observed in the first sample would serve as the marked population in the second sample. Bait sites should be relocated between samples and samples should be spaced temporally to allow site-attached turkeys to normalize movement. These measures would increase independence of samples and, therefore, provide more reliable results. Studies designed in this manner could use either concomitant monitoring of bait stations, allowing standard Lincoln-Peterson type estimation of an essentially closed population. Another option would be to use multiple resightings in both periods, or only the second period enabling efficient use of MM.

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