Research Priorities for Monitoring Wild Turkeys Using Cameras and Infrared Sensors

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Abstract: A persistent shortcoming of wild turkey (*Meleagris gallopavo*) management programs is the inconsistency in survey techniques. One approach to standardize turkey population monitoring is to use cameras and infrared sensors. The 7 primary assumptions associated with using cameras and infrared sensors to monitor turkey populations can be grouped into those pertaining to baiting and those associated with sampling design. Because none of these assumptions have been tested, our objective is to outline an experimental design appropriate for determining which theoretical assumptions are practically valid. We recommend that testing these assumptions be a priority for additional research on using camera and infrared sensors for monitoring wild turkey population(s).

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A persistent shortcoming of wild turkey management programs is the inability of managers to monitor population levels with proven accuracy, precision, and statistical power at a reasonable cost. Turkeys are difficult to survey because they are very mobile and secretive and they occupy large, often isolated areas that make observations difficult (Lewis 1967, Williams and Austin 1988). Numerous approaches can be used to survey turkey populations on individual study areas. Among these techniques are the personal interview (Mosby and Handley 1943, Leopold and Dalke 1943), roadside survey (Shaw 1973), census of flocks concentrated in winter (Lewis 1963, Thomas et al. 1966, Weinrich et al. 1985) and winter roosts (Cook 1973, Smith 1975), subjective biologist estimation (Powell 1967), gobble count (Scott and Boeker

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1972, Porter and Ludwig 1980, Lint et al. 1995), and direct and automated bait site count (Bartush et al. 1985, Hayden 1985, Cobb et al. 1996).

The variety of survey techniques used reflects the lack of a single methodology for reliably estimating or monitoring turkey population levels. In many southeastern states, turkey movements are not dictated by severe weather; therefore, techniques based on flock concentrations may be inappropriate. Index techniques often yield poor (or unknown) levels of accuracy, precision, and/or statistical power (see e.g., Diefenbach et al. 1994, Kalso 1995). However, many wildlife management agencies still use index data in their selection of population management alternatives. Increasing effects in many areas of habitat loss and other population damping agents make reliable knowledge of population numbers essential to successful management in the future. The "population surplus" in some game species with which managers have worked for many years is declining. Future demands on resources will require managers to act on anticipated population changes, instead of being reactive to such changes. Effects of habitat changes and population management techniques can only be evaluated using a monitoring technique that reliably reflects population changes. As demands placed on the turkey resource increase and demographic management becomes more important, more accuracy and precision in monitoring population levels will be required than is possible using index data.

Cobb et al. (1996) suggested infrared cameras and sensors (TrailMaster® Infrared Trail Monitors, Goodson & Associates, Inc., Lenexa, Kan.) show promise as a technique for monitoring wild turkey populations, but additional research was needed. Automated camera systems have been used for many years to monitor wildlife (Gysel and Davis 1956, Pearson 1959, Dodge and Snyder 1960, Osterberg 1962, Pharris and Goetz 1980, Wunz 1990, Carthew and Slater 1991, Bull et al. 1992, Jones and Raphael 1993, Mace et al. 1994, Kristan et al. 1996, Proudfoot 1996, Jacobson et al. 1997, Koerth et al. 1997). Use of the TrailMaster® system was described by Kucera and Barrett (1993, 1995), Sadighi et al. (1995), Rice (1995), Cobb et al. (1996), and Brooks (1996). The assumptions inherent to the use of infrared cameras and sensors have not, however, been evaluated.

The ideal monitoring technique would allow data collection from a large proportion of a total population, calibration to population status, and use by research or management personnel with minimal cost and manpower requirements. For monitoring turkey populations, Cobb et al. (1996) suggested the approach used in their pilot study should be replicated to validate turkey survey techniques using cameras and infrared sensors. Cameras and infrared sensors could be used to compare sample (i.e., survey) data to population data obtained from tagging studies conducted over several years in different habitats.

At least 7 primary assumptions associated with using cameras and infrared sensors to monitor turkey populations can be grouped into those pertaining to baiting and those associated with sampling design. To date, none of these assumptions have been tested. Our objective is to outline an experimental design appropriate for determining which theoretical assumptions are practically valid when using TrailMaster® camera systems to monitor wild turkey population(s). We believe testing these assumptions should be a priority for additional research on the use of camera and infrared sensors for monitoring wild turkey population(s).

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Assumptions

Baiting Assumptions

1. *Individuals whose home ranges overlap bait sites have the same probability of being observed at a(any) site in any habitat type.*—We believe that this assumption is rarely true. Bait sites placed in different habitats likely attract turkeys differently at least because of differing production of natural foods among habitats. The validity of this assumption is related to the coarseness of habitat classifications. As the resolution in habitat classification decreases, so should the consistency in natural food availability. If the primary assumption is invalid, 2 alternative assumptions are possible: a) The probability of an individual being observed at sites in each habitat type can be quantified, and/or b) Individuals have the same probability of being observed at any site within each habitat type.

2. *Individuals are counted at only one site during each survey replicate.*—The validity of this assumption hinges on adequate spacing between bait sites and consistency of movement distances within sampling periods among years. If the primary assumption is invalid, 3 alternative assumptions are possible: a) If individuals are counted >1 time during a survey replicate, rate of multiple counting can be quantified; and/or b) If individuals are counted >1 time during a survey replicate, the rate of multiple counting is constant within the temporal limits of a single survey; and/or c) If individuals are counted >1 time during a survey replicate, the rate of multiple counting is constant among years.

3. *Individuals in any age and sex class have the same probability of being observed at a site.*—We believe this assumption is rarely true because of variation in nutritional requirements between age and sex classes and because of seasonal flocking tendencies. If the primary assumption is invalid, 2 alternative assumptions are possible: a) The probability of an individual in any age or sex class being observed at a site can be quantified, and/or b) Individuals in each age and sex class have the same probability of being observed at a site.

4. *Individuals have the same probability of being observed at a site within the temporal limits of a single survey.*—Cobb et al. (1996) found no temporal differences in mean number of turkeys observed in a 14-day sampling period. However, they did not test for equal temporal observability for individual birds because no birds were marked. We believe that as long as sampling periods are relatively short (i.e., ≤30 days) and do not overlap, distinct changes in activity or habitat use patterns (e.g., initiation of nesting or fall shifts to areas with significant hard mast production), observability should remain constant within an annual survey.

5. *Observability of turkeys whose home ranges overlap bait sites is equal at a site among years.*—Within seasons with distinct activity and habitat use patterns (e.g., prenesting, poult rearing, fall/winter), we believe individual observability should remain relatively consistent as long as habitats are not modified. This assumption is most impacted, however, by annual fluctuations in natural foods. If prebaiting is temporally sufficient to attract birds whose home ranges include bait sites, significance of annual variation in food production should be mitigated.

Sampling Assumption

6. *All individuals in a flock have the same probability of being observed when on a site.*—Once turkeys are on a site, equal observability hinges on having a camera field of view that completely covers the baited area between the infrared transmitter and receiver. It also requires having the site a sufficient distance from cover so that all birds in a flock are within the camera field of view before any birds are on the bait and activate the infrared system. Additionally, where large flocks are common, the receiver can be programmed so that multiple photographs are taken of the same flock.

7. *Individuals are identifiable to age and sex class.*—The ability to correctly identify individuals to age and sex classes depends upon the orientation of the camera and the quality of the photographs. Cobb et al. (1996) reported few instances where birds were classified as unknown and determined that slides were superior to color prints for age and sex identification.

Experimental Design

We believe that a long-term approach over a large area should be used to test the 7 assumptions discussed above. We suggest choosing study sites ≥2,000 ha in area with stable ownership to minimize changing land use and other possible impacts on the study population. Ideally, a study should be conducted over multiple years in different physiographic regions to sample turkey populations with differing environmental influences. Interstate, cooperative research projects likely would yield the best results (see e.g., Weinstein et al. 1996).

The first emphasis should be on trapping and individually tagging a large proportion of the study population. Patagial tags, leg bands, and radio transmitters should be used. The evaluation of assumptions 1, 3, 4, and 5 require intensive radio telemetry and tagging data; for assumptions 2, 6, and 7, only tagging data are required.

The study we propose follows a mark-resight approach. The data needed to test the assumptions only can be acquired if a large proportion of the birds photographed (i.e., resighted) are tagged. As high of a percentage as possible of the study population (subjectively based on perceived density relative to area size) should be double-marked with patagial tags and uniquely identifiable combinations of colored leg bands. The exact number of birds (or percentage of the population) that should be marked will vary depending on population density and resight probabilities (Otis et al. 1978, White et al. 1982, Pollock et al. 1990). Based upon our experience (Kalso

1995, Cobb et al. 1996, Fla. Game and Fresh Water Fish Comm., unpubl. data), however, we suggest tagging 50%–75% of the population.

Patagial tags should be colored, numbered cattle ear tags (Knowlton et al. 1964). Four clearly distinguishable colors of leg bands should be used with 2 bands being placed on each leg of all marked birds. With no limitations on which color combinations can be placed on each leg, 256 birds could be banded. Even in areas with moderate-high turkey populations (i.e., 6–8 birds/km^2), this approach should be adequate for most studies. The importance of tagging a large proportion of the study population cannot be overemphasized. Trapping should commence long before monitoring, continue until an adequate proportion of the population is tagged, and be repeated as needed to maintain the marked sample. If capture success is consistently low and ≥50% of the population cannot be captured and tagged, the study should not be conducted.

Intensive radio telemetry is an integral component of this project. Radio tracking should be conducted to focus on short-term (i.e., 30-minute) movement patterns and daily home ranges of individual birds. These data are not available in the literature, but an understanding of these variables is vital to addressing the assumptions. The number of birds that should be radio tagged will vary between location and available manpower for radio tracking, but we suggest radio marking as many birds as it is logistically possible to monitor. At the minimum, we suggest radio marking ≥28 birds including a proportion of males and females representative of the population sex ratio. For portions of the study that operate on a 14-day (Cobb et al. 1996) sampling scheme, 2 birds could be located each day.

Site Establishment

Camera sites used to test any of the assumptions should be prebaited with cracked corn (or other bait [e.g., whole corn] in areas where wild hogs [*Sus scrofa*] are not present) for ≥7 days (Cobb et al. 1996). The camera systems should already be in place when prebaiting begins so that disturbance to the site is minimized and turkeys become acclimated to camera presence. We suggest that each site initially be set following the description by Cobb et al. (1996). Additionally, bait should be placed in a narrow strip between the transmitter and receiver so that birds are concentrated once on site. Transmitter, receiver, and camera units should be placed away from densely vegetated areas where birds lingering behind those to first activate the system might not be seen in a photograph. When a site is discontinued, all remaining bait should be removed. Birds should be allowed 14 days to acclimate (Cobb et al. 1996) before prebaiting begins for sampling to test other assumptions.

Baiting Assumptions

Assumption 1.—Once tagging is completed, the study should proceed by addressing Assumption 1 separately and before the other assumptions because of differences in spacing used between individual camera sites to insure sampling in all habitats. Camera sites should be set up so it is possible to compare differences in observability between and among habitat types.

In testing Assumption 1, only radio-marked birds are of interest because daily home ranges and habitat use must be accurately estimated to determine observability. During a 14-day survey period, radio-marked turkeys should be diurnally monitored once every 30 minutes. Ideally, location data should be collected for each radio-marked bird for an entire day once during the 14-day sampling period. If it is not feasible to collect telemetry data on all radio-marked turkeys, a sub-sample from the radio-tagged population should be used. In either case, the particular birds to be located each day should be randomly drawn from the available sample until all birds have been located. If, as suggested, ≥28 birds are radio tagged, an average of at least 2 birds must be located on each day of the 14-day sampling period.

Percentages of each habitat type within the study area should be calculated. Camera sites should be placed randomly within each habitat type in the same proportion as is present in the study area. We suggest using ≥10 cameras per study area and ≥2 cameras per habitat. Home range sizes and observability at bait sites should be determined for each turkey monitored. Data from camera sites that fall outside of the daily home range of any individual turkey are not used in this analysis.

Whether an individual turkey will be observed at 1 site in 1 habitat on 1 day can be represented as 1 or 0 (i.e., the bird is either observed or not). For an individual bird, comparing these variable values at multiple sites in 1 habitat on 1 day is a comparison of the Boolean occurrence vector (Smith 1974) of 0s and 1s for each site. A statistical analysis on these data is not possible because you only have a $1 \times N$ vector, where N is the number of sites within a habitat. For an individual bird on 1 day, observability between habitats is also a vector of 0s and 1s for each habitat. Irrespective of proportional habitat use, the number of sites hit, or the number of photographs, if ≥1 photograph is taken in each habitat, observability = 1; alternatively, observability = 0.

Using telemetry and observation data, however, the probability that a turkey will be observed can be calculated on each day for each habitat per 30-minute period as: number of different 30-minute intervals in which a bird was photographed / number of 30-minute intervals the bird was in a particular habitat. The interval length simply matches the temporal frequency of radio locations. This probability is calculated for each bird in each habitat type. Differences in these probabilities between habitats can then be tested statistically as well as means and SDs calculated for all habitats by averaging probabilities for all individual birds within a habitat. Once field work related to testing this assumption is completed, all camera sites should be dismantled, all excess corn removed, and field work suspended for 14 days (Cobb et al. 1996).

Assumption 2.—To evaluate this assumption, the minimum spacing between sites so that birds are not multiply counted must be determined. We suggest that bait sites initially be spaced 1.6 km apart. After turkeys begin using the pre-baited sites, the camera systems should be activated and monitored for 14 days. After inspection of the photographs, sites should be moved closer if no birds are observed at >1 site in a survey replicate (i.e., 1 day) or farther apart if the same bird(s) is(are) photographed at >1 site. The distance sites should be moved depends upon the variability in movement of the most mobile turkey. Initially, we suggest moving sites in increments between 0.4 and 0.8 km. This approach should be repeated until the minimum distance at which no individual birds are observed at >1 site is determined.

Once site spacing so that birds are counted at only 1 site during a survey replicate is determined, long-term monitoring of sites to address remaining assumptions can commence. We suggest that monitoring to address most of the remaining assumptions be conducted for ≥2 years to overlap annual seasonal and biological cycles and elucidate variation between years.

Assumption 3.—Assumption 3 can be tested using radio telemetry and photographic data. Determining whether observability between age and sex classes is equal at 1 site is a matter of evaluating the Boolean occurrence vector of 0s and 1s for each site. The probability by habitat type of birds in each age and sex class being observed can, however, be defined as: number of different 30-minute intervals birds in a particular age or sex class were photographed / number of 30-minute intervals birds in a particular age and sex class were in a particular habitat. Differences in these probabilities between age and sex classes, and among habitats can be compared statistically. Means and SDs can be calculated by averaging probabilities for individual birds.

Assumptions 4 and 5.—Similarly, determining whether an individual bird has equal observability at a site for each day over the temporal limits of a survey is simply a matter of evaluating the 1 × 14 Boolean occurrence vector of 0s and 1s for that site. More interestingly, however, the probability for each habitat type that an individual bird will be observed per half hour period over the 14-day sampling period can be calculated as: number of different 30-minute intervals in the day a bird was photographed / number of 30-minute intervals in a particular habitat per day. Additionally, the daily probability that any bird will be photographed in a habitat over the 14-day sampling period can be calculated as: number of days photographs were taken / number of days birds were in a particular habitat. Both of these probabilities can be calculated for each bird in each habitat type. Differences in these probabilities can be tested statistically. Means and SDs can be calculated for all habitats by averaging probabilities for all individual birds for each day or 14-day sampling period, respectively. To evaluate assumption 5, probabilities calculated to test other assumptions should be statistically compared between or among years.

Sampling Assumptions

Assumption 6.—Whether all individuals within a flock have a similar probability of being observed once on a site is a concern because one individual in a flock can trip the infrared beam before all individuals in the flock are in the field of view of the camera. Consequently, only 1 photograph of a visitation may not include all the individuals present on the site. Cobb et al. (1996) reported an average length per visit of 8–9 minutes with the exception of 1 large, multibrood family flock that averaged just over 16 minutes. Testing assumption 6 equates to determining the appropriate camera delay and orientation relative to the transmitter and receiver so that no turkeys are missed (i.e., not photographed) once on site. Programming the delay between photographs to insure multiple photographs of each visitation should allay this concern. However, too many photographs per visit runs the risk of depleting film before all visitations can be recorded before the next film replacement. To determine the correct photographic interval, the camera delay should be set on a 1- to 2-minute cycle to insure numerous multiple photographs of each visit. Also, a roll of film containing the maximum number of exposures that the camera can accommodate should be used. By comparing the number of turkeys captured in each photograph, the minimum number of photographs of each visit required to capture all individuals photographed during that visit can be determined (i.e., assumption 6 is satisfied).

Assumption 7.—A reliable means of separating turkeys into age classes is by the configuration of the greater upper secondary wing coverts (Williams and Austin 1970, 1988). Other visual clues to sex and age are head feathering and coloration, breast plumage color and iridescence, and beard presence and length. In attempts to satisfy assumption 7, individuals with turkey expertise should classify turkeys by age and sex from pictures. While Cobb et al. (1996) found slides superior to photographs for this purpose, both should be used and examined by several experienced researchers to replicate the evaluation. Aside from observer experience, quality (clarity) of the picture and closeness and orientation of the subject influences identifiability most. Aligning the camera directly with the infrared beam should increase the likelihood of including all turkeys within the frame but risks reducing identifiability due to some birds being obstructed by others as they align themselves along the bait. To avoid this problem, Cobb et al. (1996) placed the camera on a separate pole offset from both the transmitter and receiver. Because a high proportion of the study population will be marked, accuracy of age and sex determination easily can be tested by having birds classified from the photographs by an observer unfamiliar with the marking system. If multiple observers are used, inter-observer variability should be quantified (Cobb et al. 1995).

On a sub-sample of sites, 2 cameras should be utilized at each site, simultaneously taking pictures. One should be offset at an obtuse angle to the infrared beam while the other would be more aligned with the beam. Comparison of the number of individuals detected and the ability to determine sex and age would reveal which setup provides the greatest degree of accuracy.

Timing of surveys can contribute greatly to the ability to identify turkeys, particularly by age. Surveys conducted in midsummer would maximize the difference between juvenile poults and adult turkeys, making them much easier to identify. However, depending on the habitat, they may be much harder to attract to bait than at some other time and it will be unlikely that the sex of young birds could be differentiated. Consequently, it is important to monitor the camera sites continuously for ≥1 year so that the time of the year when age and sex can best be determined is identified. Optimizing the orientation of the site and the timing of the survey maximizes the likelihood that assumption 7 is satisfied.

Conclusions

The assumptions we have presented are simply theoretical constraints under which we believe field work should be applied. Seldom do we expect that all assumptions will hold true. Using the approach we have described, however, will ensure consistency and maximize understanding of the relationship between data collected from photographs and the movements and dynamics of the turkey population under study. Additionally, once validation and/or calibration of the technique is achieved, future monitoring can be conducted with a high degree of accuracy at a reasonable cost. Obviously our approach is a time- and resource-intensive effort, at least in the short-term; but for long-term studies that focus on or include monitoring, the use of infrared camera systems and the testing of the inherent assumptions of the technique are worth the investment.

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