Comparing harvest management alternatives for Eastern Wild Turkeys in Alabama

James B. Grand[1]
Amy L. Silvano[2]
Steven W. Barnett[2]
Carolyn E. Moore[3]
Brianna D. Stewart[3]

[1] U.S. Geological Survey, Alabama Cooperative Fish and Wildlife Research Unit

[2] Wildlife and Freshwater Fisheries Division, Alabama Department of Conservation and Natural Resources

[3] Auburn University, Alabama Cooperative Fish and Wildlife Research Unit

Cooperator Science Series # 137-2021

About the Cooperator Science Series:

The Cooperator Science Series was initiated in 2013. Its purpose is to facilitate the archiving and retrieval of research project reports resulting primarily from investigations supported by the U.S. Fish and Wildlife Service (FWS), particularly the Wildlife and Sport Fish Restoration Program. The online format was selected to provide immediate access to science reports for FWS, state and tribal management agencies, the conservation community, and the public at large.

All reports in this series have been subjected to a peer review process consistent with the agencies and entities conducting the research. For U.S. Geological Survey authors, the peer review process (http://www.usgs.gov/usgs-manual/500/502-3.html) also includes review by a bureau approving official prior to dissemination. Authors and/or agencies/institutions providing these reports are solely responsible for their content. The FWS does not provide editorial or technical review of these reports. Comments and other correspondence on reports in this series should be directed to the report authors or agencies/institutions. In most cases, reports published in this series are preliminary to publication, in the current or revised format, in peer reviewed scientific literature. Results and interpretation of data contained within reports may be revised following further peer review or availability of additional data and/or analyses prior to publication in the scientific literature.

The Cooperator Science Series is supported and maintained by the FWS, National Conservation Training Center at Shepherdstown, WV. The series is sequentially numbered with the publication year appended for reference and started with Report No. 101-2013. Various other numbering systems have been used by the FWS for similar, but now discontinued report series. Starting with No. 101 for the current series is intended to avoid any confusion with earlier report numbers.

Contractual References:

This document was developed in conjunction with the Oklahoma Cooperative Fish and Wildlife Research Unit and was partially supported by the U.S. Fish and Wildlife Service, Southwestern Native Aquatic Resources and Recovery Center. Previously published documents that partially fulfilled any portion of this contract are referenced within, when applicable. (USGS IPDS #: IP- 077758).

Recommended citation:

Grand, J. B., A. L. Silvano, S. W. Barnett, C. E. Moore and B. D. Stewart. 2021. Comparing harvest management alternatives for Eastern Wild Turkeys in Alabama. U.S. Department of Interior, Fish and Wildlife Service, Cooperator Science Series FWS/CSS-137-2021, Washington, D.C.

For additional copies or information, contact:

James B. Grand
U.S. Geological Survey
Cooperative Fish and Wildlife Research Unit Program
Phone: (334) 200-8458
E-mail: barry_grand@usgs.gov

Comparing harvest management alternatives for Eastern Wild Turkeys in Alabama

James B. Grand, U.S. Geological Survey, Alabama Cooperative Fish and Wildlife Research Unit

Amy L. Silvano, Wildlife and Freshwater Fisheries Division, Alabama Department of Conservation and Natural Resources

Steven W. Barnett, Wildlife and Freshwater Fisheries Division, Alabama Department of Conservation and Natural Resources

Carolyn E. Moore, Auburn University, Alabama Cooperative Fish and Wildlife Research Unit

Briana D. Stewart, Auburn University, Alabama Cooperative Fish and Wildlife Research Unit

Abstract

Eastern wild turkey (*Meleagris gallopavo silvestris*; hereafter turkey) is an important game species that is pursued by thousands of Alabama hunters each spring. Biologists in Alabama and other parts of the southeastern United States believe that turkey populations have been declining for at least two decades. Managers in many state agencies and organizations believe that liberal spring bag limits and the timing of hunting seasons are contributing to this decline. We used an expert-driven approach to develop models of turkey populations that predicted the outcomes of spring harvest management alternatives. The models were based on recent research and expert judgement regarding the effects of spring hunting regulations on turkey vital rates. We then used the relationship between the expected spring density of adult males and expected harvest elicited from experts to compare the values of the alternatives over a 30-year period. Our model suggests that if later opening dates result in increased turkey productivity and increased harvest, the result will be larger turkey populations, increased harvest, and greater value to stakeholders. In 84% of deterministic projections from 27,951 different initial populations, the highest valued alternative was to open seasons later, reduce bag limits, and shorten the season. This alternative also was best in 48% of projections that included parametric uncertainty. These results were used to produce a decision-support tool, that could be used to guide decisions about spring hunting regulations for turkeys in Alabama, and updated using the results of monitoring programs. Further research is needed to more precisely estimate the causes and effects of spring hunting seasons on turkey vital rates.

Introduction

Eastern wild turkey (*Meleagris gallopavo silvestris*; hereafter turkey) is an important game species in Alabama. Each year, tens of thousands of Alabama hunters pursue male turkeys during the spring hunting season which opens on 15 March and closes 30 April throughout most of the state (Barnett and Barnett 2008). Biologists in Alabama, like many in the southeastern United States. believe that turkey populations are declining based on declining harvests and anecdotal information (Byrne et al. 2012, ADCNR 2015, Eriksen et al. 2016). The consensus among biologists and managers in many state agencies and non-governmental organizations is that liberal spring bag limits and hunting seasons that begin before most nests are initiated are contributing to this decline (Isabelle 2018). However, few attempts have been published that directly address this hypothesis; therefore, management agencies are forced to make decisions based on expert judgement and rely on limited information to evaluate the results.

Spring hunting seasons that begin in mid-March precede peak nest initiation periods in Mississippi, Alabama, and Georgia where peak nest initiation occurs 20-30 April (Pylant 1977, Everett et al. 1980, Speake et al. 1985, Miller et al. 1997, Whitaker et al. 2005). During this period, females only spend a small portion of each day on the nest (Williams and Peoples 1974) leaving them vulnerable to incidental hunting mortality (Kimmel and Kurzejeski 1985, Williams and Austin 1988, Davis et al. 1995, Miller et al. 1997, Norman et al. 2001a). However, once incubation begins, females rarely leave the vicinity of the nest (Martin et al. 2015). Lohr et al. (2020) found that female turkeys left the nest an average of 1.6 times per day and traveled an average of 357.6 m during incubation recesses. Harvest of males during the spring season is thought to be additive to natural mortality (Moore et al. 1993) and reducing harvest increases survival (Chamberlain et. al 2012), which may influence population size and structure in subsequent years (Kurzejeski and Vangilder 1992, Vangilder and Kurzejeski 1995).

We used a decision analytic approach to evaluate spring harvest management alternatives, based on a model of turkey populations in Alabama we developed from a combination of published estimates and expert judgement. Decision analytic approaches are often employed when there is great uncertainty (Gregory et al. 2012, Conroy and Peterson 2013) because they can be used to integrate quantitative data and expert judgement along with realistic estimates of uncertainty to help inform decision-making. Problems were first disassembled into component parts, and then reassembled into system models that could be used to predict the outcome of management actions. The value of outcomes were based on consultations with stakeholders from the Alabama Department of Conservation and Natural Resources, (ADCNR), National Wild Turkey Federation, Alabama Wildlife Federation, and the hunting public.

Our objectives were to: 1) develop a model for Alabama turkey populations that emulates current conditions and can be used to predict population dynamics and harvest based on published estimates and expert judgement under a wide variety of population states; 2) predict the effect of multiple harvest management alternatives on turkey populations and harvest also under a wide variety of population conditions; and 3) evaluate the outcomes of the various harvest management alternatives based on values elicited from stakeholders.

Methods

Population model

We developed an age- and sex-structured turkey population model that was density-dependent. The post-breeding matrix model included four classes of turkeys: young of the year 0.5y (*p*), females $\geq$0.5y (*f*), males 1.5y (m_j), males >1.5y (m_a) (eq. 1, Fig. 1).

$$\begin{bmatrix} p_{t+1} \\ f_{t+1} \\ m_{j\ t+1} \\ m_{a\ t+1} \end{bmatrix} = \begin{bmatrix} 0 & pph & 0 & 0 \\ 0.5s_f & s_f & 0 & 0 \\ 0.5s_{jm} & 0 & 0 & 0 \\ 0 & 0 & s_{am} & s_{am} \end{bmatrix} \begin{bmatrix} p_t \\ f_t \\ m_{j\ t} \\ m_{a\ t} \end{bmatrix}$$

We used four classes because ADCNR plans to monitor turkey populations in late summer while poults are still distinguishable from adults. At that time, ages of females $\geq$1.0y are indistinguishable, but 1.5y males can be distinguished from older males based on secondary sexual characteristics and are harvested less frequently than older males. In our model, productivity (i.e., *pph* – number of poults recruited to the fall population per female) was dependent on the density of females to avoid unrealistic predictions of exponential growth in increasing populations (eq. 2, Fig. 2):

$$pph = \frac{\propto}{(1 + e^{-\beta(f_t - x_0)})}$$

where α is the maximum *pph* expected when populations are small and hunting pressure is absent, β is the strength of the density-dependent effect (i.e., the inverse log of the per female change in *pph*, and x_0 is the inflection point (i.e., *f* at which the effect of β begins to decline) such that *pph* asymptotically approaches 0 as N_f becomes large. This function does not explicitly require any assumptions regarding carrying capacity, and makes *pph* a function of the density of females in the previous fall (f_t):

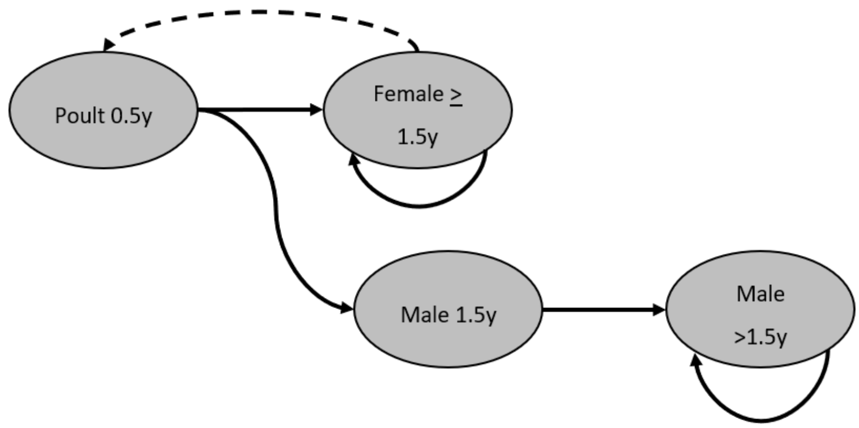

Figure 1 Graphical, 4-class model of turkey population. Individual classes represented as nodes include 0.5 year-old poults, 1.5 year old and older females, 1.5 year old males, and greater than 1.5 year old males. Solid lines represent survival rates of poults to females at least 1.5 years old, poults to 1.5 year-old males, females 1.5 years old and older, 1.5 year-old males to older males, and males older than 1.5 year old males. Dashed line represents recruitment and connect from females 1.5 year old and older back to poults.

Estimates from recent research were used in conjunction with expert elicitation to parameterize the state-space model under current harvest management regulations (Status quo; Table 1). We used survival rates of males and females and harvest rates for males that were estimated from radio-marked turkeys on three study areas in Alabama (Zenas 2018) (Table 1). We used estimates of *pph* based on estimates from opportunistic uncorrected counts from across the state, because estimates from camera surveys (Gonnerman 2017) were judged by experts to be too low. Based on discussions with ADCNR experts, the relationship between *pph* and f_t is nearly linear, with a value of approximately 1.70 at the current f_t under Status quo conditions of 15 females/mi^2. We estimated α = 2.66, β = -0.1652, x_0 = 5.8182 by fitting eq. 2 with elicited estimates of *pph* at female densities that were higher and lower than current conditions.

Harvest management alternatives

In this analysis, we compare eight harvest management alternatives for spring turkey season including Status quo, highly restricted season (Restricted), closed season (Closed); and five alternatives that included combinations of reduced bag limit (RB), later opening date (OL), and shortened season (SS). Our panel of experts found it difficult to estimate the vital rates that would result from each alternative; thus, vital rates (recruitment, annual survival, and harvest) relative to the Status quo were elicited during workshops held at Auburn University (Table 2). Experts reviewed recent estimates of vital rates from Alabama and surrounding states and were asked to enumerate their individual beliefs of the relative effect of the management actions on each rate. The group then reviewed and discussed their individual beliefs, updated them, and the mean estimate was used (Hemming et al. 2020). After the effects of individual actions (i.e. reducing bag limits and changing seasons) were determined by consensus, the combined effects of actions were estimated using a similar method.

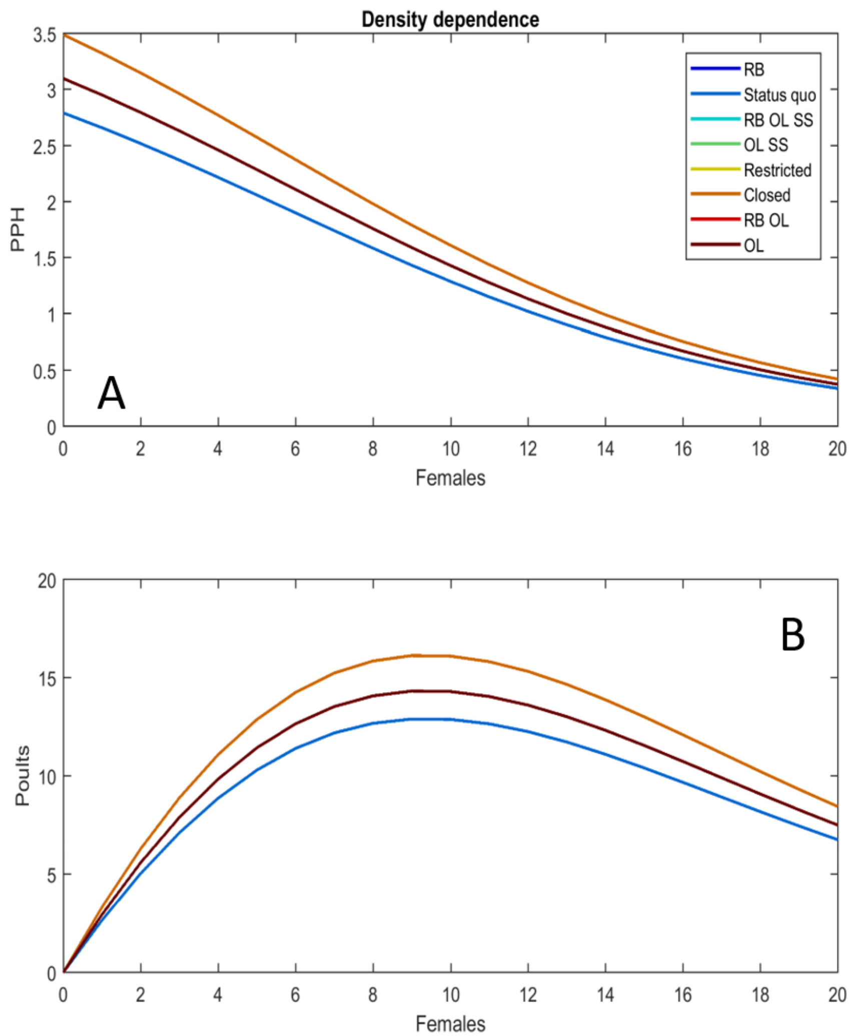

Figure 2 Relationship based on expert judgement between female density (f, n/mi2) and poults recruited to the fall population per female (pph) (A) and fall poult density (p, n/mi2) (B) in Alabama.

Table 1. Expected vital rates under eight alternatives for spring turkey seasons in Alabama using published estimates and relative effects of alternatives elicited from experts. Harvest was considered to be 50% compensatory. Maximum expected recruitment rates correspond to values of α in a density-dependent productivity function (see text). Expected vital rates for each alternative were determined by multiplying relative effects (Table 2) by the corresponding rates under Status quo in this table.

Alternative	Maximum Recruitment (*pph*)	Juvenile Female Survival	Adult Female Survival	Juvenile Male Survival	Juvenile Male Harvest	Adult Male Survival	Adult Male Harvest
RB[1]	2.66	0.57	0.48	0.54	0.10	0.46	0.30
Status quo[2]	2.66	0.57	0.48	0.54	0.10	0.44	0.33
RB OL SS[1,3,4]	2.95	0.57	0.48	0.55	0.08	0.48	0.30
OL[3]	2.95	0.57	0.48	0.55	0.08	0.48	0.30
OL SS[3,5]	2.95	0.57	0.48	0.55	0.09	0.46	0.30
RB OL[1,3]	2.95	0.57	0.48	0.54	0.10	0.46	0.30
Restricted[5]	3.32	0.57	0.48	0.57	0.04	0.54	0.14
Closed[6]	3.32	0.57	0.48	0.59	0.00	0.61	0.00

[1]RB – Reduced bag limit from 5 males per hunter per season (Status quo) to 3 males per hunter per season.
[2]Status quo – bag limit 5 males per hunter per season, 45-day season, Season 15 March – 30 April.
[3]OL – Open season later (10 days).
[4]SS – Shortened season by opening later and retaining 30 April closing date.
[5]Restricted – Open season later, reduced bag limit, and reduced season to 10 days in length.
[6]Closed – Closed hunting season.

Table 2. Effects of regulation changes on productivity, survival, and harvest rates relative to Status quo (current management) developed by expert judgement for eastern wild turkeys in Alabama. Vital rates for alternative population models were parameterized by multiplying the corresponding vital rate for the Status quo (Table 1) by the relative effect.

Alternative	Poult Recruitment	Juvenile Female Survival	Adult Female Survival	Juvenile Male Survival	Juvenile Male Harvest	Adult Male Survival	Adult Male Harvest
Status quo[1]	1.00	1.0	1.0	1.0	1.0	1.0	1.0
Reduced bag[2]	1.00	1.0	1.0	1.01	0.91	1.03	0.91
Open season later[3]	1.11	1.0	1.0	1.00	1.00	1.00	1.00
Shortened season[4]	1.00	1.0	1.0	1.01	0.90	1.04	0.90
Restricted[5]	1.25	1.0	1.0	1.05	0.41	1.22	0.41
Closed[6]	1.25	1.0	1.0	1.09	0.00	1.37	0.00

[1]Status quo – bag limit 5 males per hunter per season, 45-day season, Season 15 March – 30 April.
[2]Reduced bag limit from 5 males per hunter per season (Status quo) to 3 males per hunter per season.
[3]Open season later (10 days).
[4]Shortened season by opening later and retaining 30 April closing date.
[5]Restricted – Open season later, reduced bag limit, and reduced season to 10 days in length.
[6]Closed – Closed hunting season.

Effects of alternatives on survival and harvest

We defined harvest rate as the percentage of males in a given age class that were shot by hunters during the spring hunting season. We used estimates of survival and harvest from Zenas (2018) for the annual survival and harvest rates under status quo (current) regulations. We assumed that 50% of harvest was additive to natural mortality. Thus we estimated annual survival of adult males under the closed season alternative was 0.61 (0.44 + 0.33*0.5; Table 1). Similarly, Zenas (2018) estimated the annual survival rate of juvenile males in Alabama was 0.54 under status quo. Experts reviewed data elicited by ADCNR from hunters in 2015-2016 (ADCNR 2015, 2016), and estimated that reducing the bag limit from 5 males to 3 males per season would reduce the overall harvest rate by 9%, because 9% of hunters reported harvesting more than 3 turkeys. Although hunters reported a large portion of the harvest during the first week of the season, they assumed that opening the season later would only shift the timing of the harvest and have no impact on the portion of turkeys harvested. Hunters also reported little harvest during the last week of the season, thus experts assumed that holding the end date constant and moving the opening date later (i.e., shortening the season) would have no effect on harvest. In Alabama it is illegal to harvest female turkeys, so experts assumed that changes to the spring hunting season would have no effect on survival rates of females.

Little published data is available for Alabama on the timing of nesting by females or the effects of hunting on nesting at the population level. The few observations that are available suggest that most female turkeys in Alabama initiate nests in April just after the start of the spring hunting season (Everett et al. 1980). Turkeys are known to abandon nests frequently when disturbed, but this is not always the case (Everett et al. 1980, Williams et al. 1980, Vangilder et al. 1987). Thus, estimates of the effects of later opening dates and closed seasons on turkey recruitment rates are based solely on expert judgement.

Because there are few records of turkeys incubating nests prior to 25 March and nest predation operates independently of hunting disturbance, expert consensus was that α would increase by 11%, if the opening date of the spring hunting season is moved 10-days later from 15 March to 25 March, and by 25%, if the spring hunting season is closed (Table 2). This was implemented in the model by modifying the value of α and assuming that there is no effect on β or x_0. Thus, α = 2.95 and α = 3.32 for alternatives with hunting seasons with later opening dates and hunting seasons that are closed, respectively. We estimated the current population density by assuming the density of breeding females was 15 per mi^2 and increasing the estimated population density until the population trend met the expectations of our team of experts (i.e., declining at approximately 1%/year, $\lambda = 0.99$).

Consequences

We created deterministic models of turkey populations under each management alternative. The models were projected for 30 years from initial states with every possible combination (n = 27,951) of 0 to 20 p and 0 to 10 f, m_j, and m_a (eq. 1). We then determined the expected population size and structure each year as though the management alternative was maintained over the 30-year period. We also added random normal variation (CV = 0.2) to each parameter in the model and produced 1,000 simulations for each alternative beginning from each of the initial states. Survival rates were transformed to odd ratios (OR = s/(1-s)) before adding normal variation and then transformed back to the logit scale (s = OR/(1+OR)) for stochastic projections. Stochasticity was emulated for *pph* by adding random normal variation to α with CV=0.2.

Value of Outcomes

We initially consulted with stakeholders on the ADCNR Turkey Management Committee (TMC) to determine the fundamental objectives for harvest management decisions. From these discussions, we determined that the management objectives for turkey harvest in Alabama were to maximize the number of adult males (gobblers) available at the beginning of the hunting season, while simultaneously maximizing their harvest. We then asked them to score potential management outcomes, 0-100, at values of 0, 1, 5, and 10 adult males/mi^2 and adult males harvested/mi^2 to assess tradeoffs between the objectives. TMC and other ADCNR biologists then conducted a series of meetings across the state with additional stakeholders who self-identified as avid turkey hunters. Stakeholders were also asked to score outcomes. We averaged the scores across TMC and all stakeholders. We later extrapolated values up to 15 adult males/mi^2 and 15 adult males harvested/mi^2 and re-scaled the values 0-100, because our model projected populations that exceeded 10 adult males/mi^2. We used the griddata() function in Matlab v9.2 (R2017a) (Mathworks, Inc., Natick, MA) to assign predicted values to all possible outcomes from each alternative for turkey harvest management over a 30-year period from deterministic and stochastic models.

Results

Seventy-two stakeholders including TMC members scored the potential outcomes. Mean values were lowest when harvest and density of males was 0 and increased monotonically as the number of gobbling males and harvest increased (Figure 3). As indicated by indifference curves (contours on the value function surface), value increased at a greater rate in response to increases in harvest than to increases in gobbler density although the rates of increase diminished as harvest increased. For example, the value of harvesting 10 males/mi^2 when there are 10 gobbling males/mi^2 is the same as harvesting approximately 5 males/mi^2 when there are 15 gobbling males/mi^2.

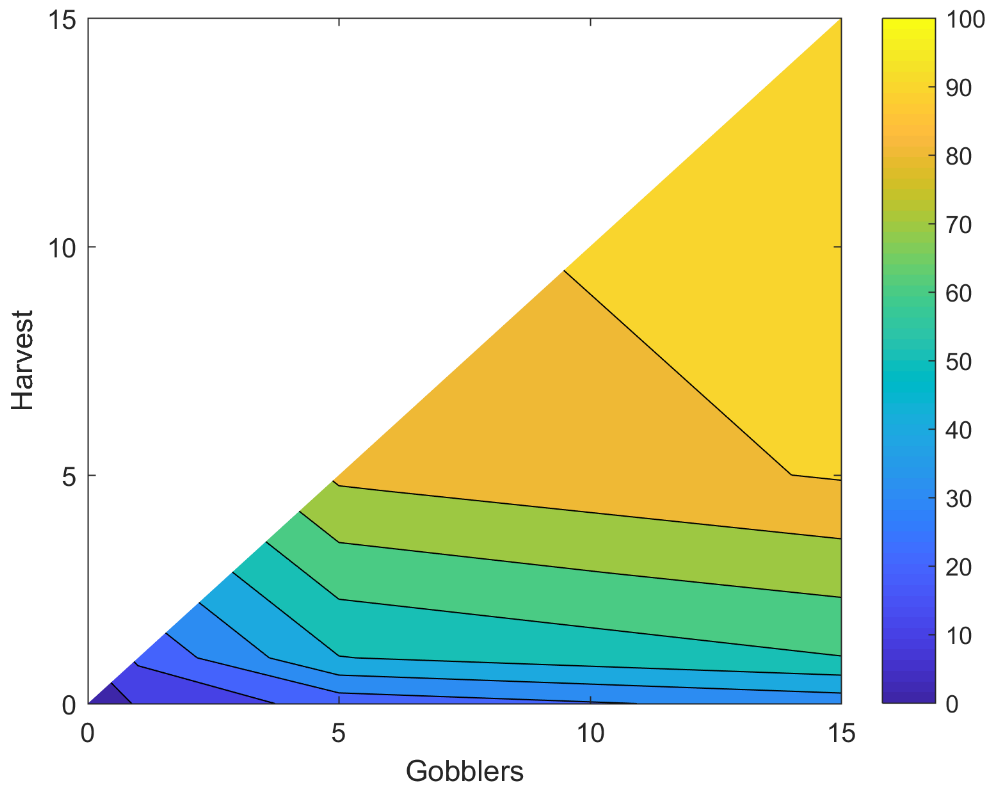

Figure 3. Shaded contour plot of interpolated values for outcomes from wild turkey harvest management elicited from 72 stakeholders invited to 5 meetings held at multiple locations in Alabama. Each contour represents a 10% change in value to stakeholders. Outcomes along each contour indicate the tradeoff in value between harvest and gobbler density.

Because there were only 3 levels of α and the other parameters were held constant in the model of density-dependent production, our estimates of the relationship between *pph* and *f* and the relationship between *p* and *f* for the eight alternatives fall into 3 distinct groups (Figure 2). The highest levels of *pph* and *p* for a given level of *f* were expected to occur when seasons were Closed or Restricted. The next highest levels were expected when seasons opened later (OL), and the lowest levels of productivity are expected when seasons do not open later (i.e., Status quo and RB). The greatest p is expected to occur at approximately $f = 9$.

Population size and structure

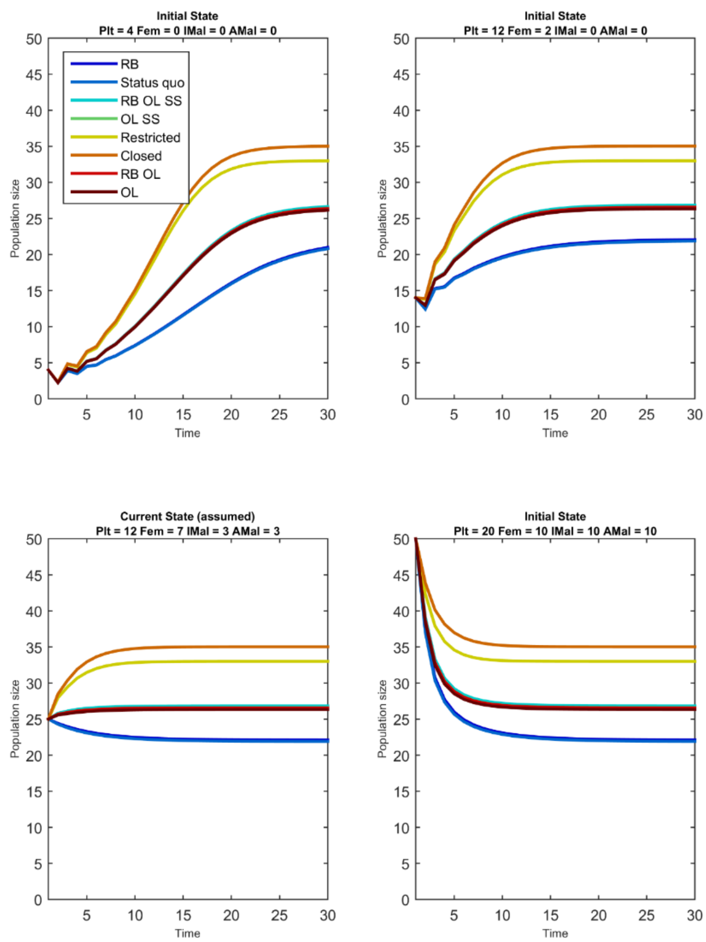

Figure 4. Projections of Alabama turkey populations from 4 different initial population states under Status quo and 8 different harvest management alternatives using 4-stage density dependent model. Population stages include poult (Plt), females $\geq$1.5y (Fem), males 1.5y (IMal), and males >1.5y (Amal). Alternatives include combinations of the following regulations: RB (Reduced bag limit), Status quo (current regulations) , OL (Open season later), SS (Shorten season), Restricted (OL, RB, 10-day season)– Open season later, reduced bag limit, and reduced season to 10 days in length), and Closed (no hunting). Note that some projections are hidden.

The projections for every alternative reached a near equilibrium state (NES) regardless of the initial state (Figure 4, Table S3). The length of time required to reach NES depended upon the initial population state, but every projection reached NES before the end of the 30-year projection. The number of time steps (years) required for the projection to reach NES decreased as the distance between the initial state and the equilibrium state decreased.

Projections under Restricted and Closed seasons resulted in the highest equilibrium populations (>34 turkeys/mi^2). Projections under alternatives that allowed hunting, but did not include OL including Status quo, resulted in the lowest expected equilibrium populations (<25 turkeys/mi^2). Projections that included OL and moderate harvest restrictions resulted in intermediate population sizes (28-29 turkeys/mi^2).

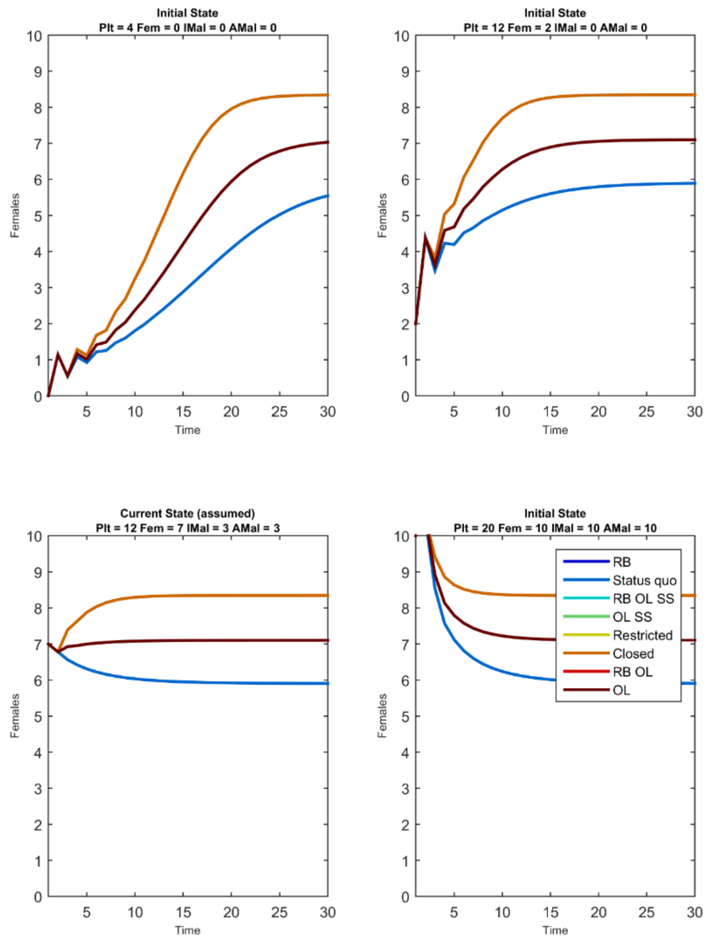

Figure 5 Expected density (N/mi^2)of females ($\geq$ 1.5y) in fall populations of eastern wild turkeys from 4 different initial states under Status quo and 8 different harvest management alternatives in Alabama. Population stages include poult (Plt), females $\geq$1.5y (Fem), males 1.5y (IMal), and males >1.5y (Amal). Alternatives include combinations of the following regulations: RB (Reduced bag limit), Status quo (current regulations) , OL (Open season later), SS (Shorten season), Restricted (OL, RB, 10-day season)– Open season later, reduced bag limit, and reduced season to 10 days in length), and Closed (no hunting). Some projections are hidden.

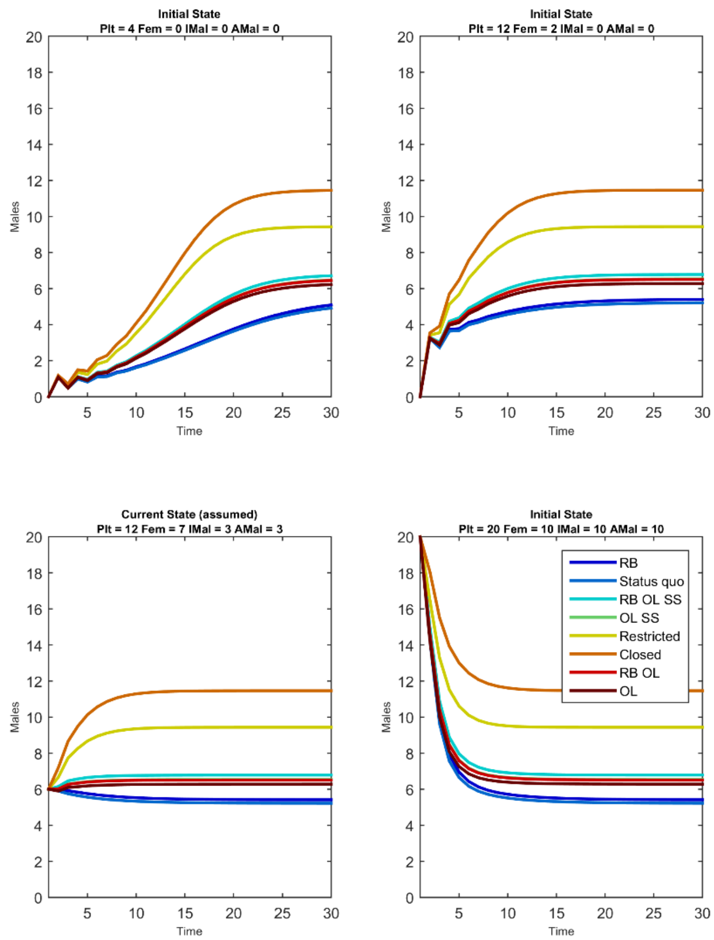

Figure 6 Expected density (N/mi^2)of males (> 1.5y) in fall populations of eastern wild turkeys from 4 different initial states under Status quo and 8 different harvest management alternatives in Alabama. Population stages include poult (Plt), females $\geq$1.5y (Fem), males 1.5y (IMal), and males >1.5y (Amal). Some projections are hidden. Alternatives include combinations of the following regulations: RB (Reduced bag limit), Status quo (current regulations) , OL (Open season later), SS (Shorten season), Restricted (OL, RB, 10-day season)– Open season later, reduced bag limit, and reduced season to 10 days in length), and Closed (no hunting). Some projections are hidden.

Although experts agreed that female survival would be unaffected by the spring harvest alternatives, the mean number of females was greatest under Restrictive and Closed alternatives (8.3 f/mi^2), moderate under alternatives that included OL (7.1 f/mi^2), and lowest under RB and Status quo alternatives (5.9 f/mi^2) (Fig. 5, Table S3). The expected mean number of males >1.5 years-old varied from 2.4 m_a/mi^2 – 7.0 m_a/mi^2 under the 8 different alternatives (Table S3; Fig. 6). The lowest expected densities of males came with alternatives RB and Status quo. Expected harvest of m_a (> 1.5 y) was lowest for Closed and Restricted seasons, and they were highest under OL and RB OL SS (Table 3, Table S3, Fig. 7). With each scenario, the number of poults recruited to the fall population reached an equilibrium value of 1.82 poults per female ≥1.5y (Figure S1).

Table 3. Mean expected long-run (30-year) value, spring density of adult males (>1.5) and harvest of adult males in Alabama under 8 spring harvest regulation alternatives. Values are based on tradeoffs between number of adult males in population (n/mi^2) and harvest of adult males (n/mi^2) as elicited from stakeholders.

Alternative	Male Density	Harvest	Value
RB[1]	2.48	0.38	43.99
Status quo[2]	2.32	0.39	43.80
RB OL SS[1,3,4]	3.22	0.47	51.55
OL[3]	3.00	0.44	50.39
OL SS[3,5]	2.98	1.40	50.39
RB OL[1,3]	2.78	1.49	50.26
Restricted[5]	5.10	0.33	48.29
Closed[6]	6.97	0.00	26.83

[1]RB – Reduced bag limit from 5 males per hunter per season (Status quo) to 3 males per hunter per season.
[2]Status quo – bag limit 5 males per hunter per season, 45-day season, Season 15 March – 30 April.
[3]OL – Open season later (10 days).
[4]SS – Shorten season by opening later and retaining 30 April closing date.
[5]Restricted – Open season later, reduced bag limit, and reduced season to 10 days in length.
[6]Closed – Closed hunting season.

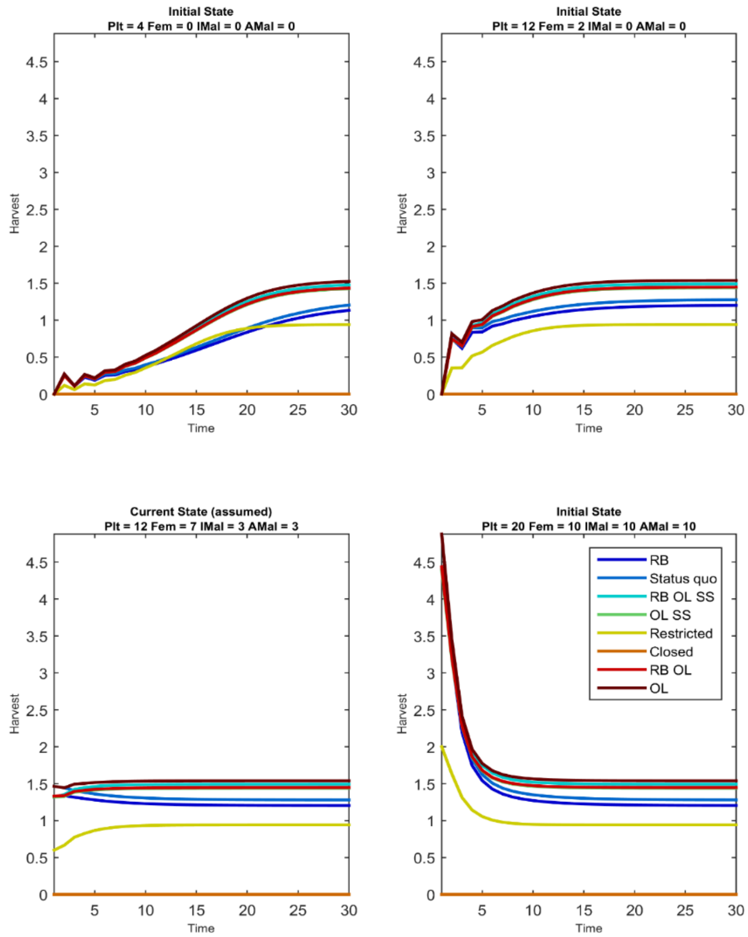

Figure 7. Expected spring harvest (N/mi^2)of adult males (> 1.5y) from Alabama turkey populations under long-run implementation of 9 different harvest management alternatives. Population stages include poult (Plt), females ≥1.5y (Fem), males 1.5y (IMal), and males >1.5y (Amal). Alternatives include combinations of the following regulations: RB (Reduced bag limit), Status quo (current regulations) , OL (Open season later), SS (Shorten season), Restricted (OL, RB, 10-day season)– Open season later, reduced bag limit, and reduced season to 10 days in length), and Closed (no hunting). Some projections are hidden.

Decision tools

The value of expected outcomes is based on the tradeoff between mean spring harvest and mean number of adult (density) males in the spring population (Figure 3). Mean values of outcomes over 30 years across all population states based on interpolations from elicited values (Table 3) ranged from 26.8-51.6. The highest valued alternative was RB OL SS despite the lower expected harvest in comparison to OL SS, RB OL, and OL. In comparison to these three alternatives, the expected density of males was higher for RB OL SS. The best alternative was Closed season when there were 0 females and 0 poults in the population (Figure 8). When the density of females was low ($\leq$2), a Restricted season was often most highly valued alternative, as might occur in areas where populations have only recently been re-established. However, unless the density of females or poults was relatively high, the most highly valued alternative was RB OL SS. RB OL SS produced the greatest long-run value (i.e., best decision) in 84% (n = 27,951) of deterministic trials (Figures 8 and 9a; Table S1). When the density of females or poults was high, OL provided the greatest values. When uncertainty in vital rates was introduced, RB OL SS was the best decision in 48% of stochastic trials across all initial states, and Restricted seasons were best in 26% of trials (Figure 9b). Status quo was usually ranked 6th (52%) or 7th (39%) best (Figure 9, Table S2), and Closed season was the worst alternative in 95% of stochastic trials.

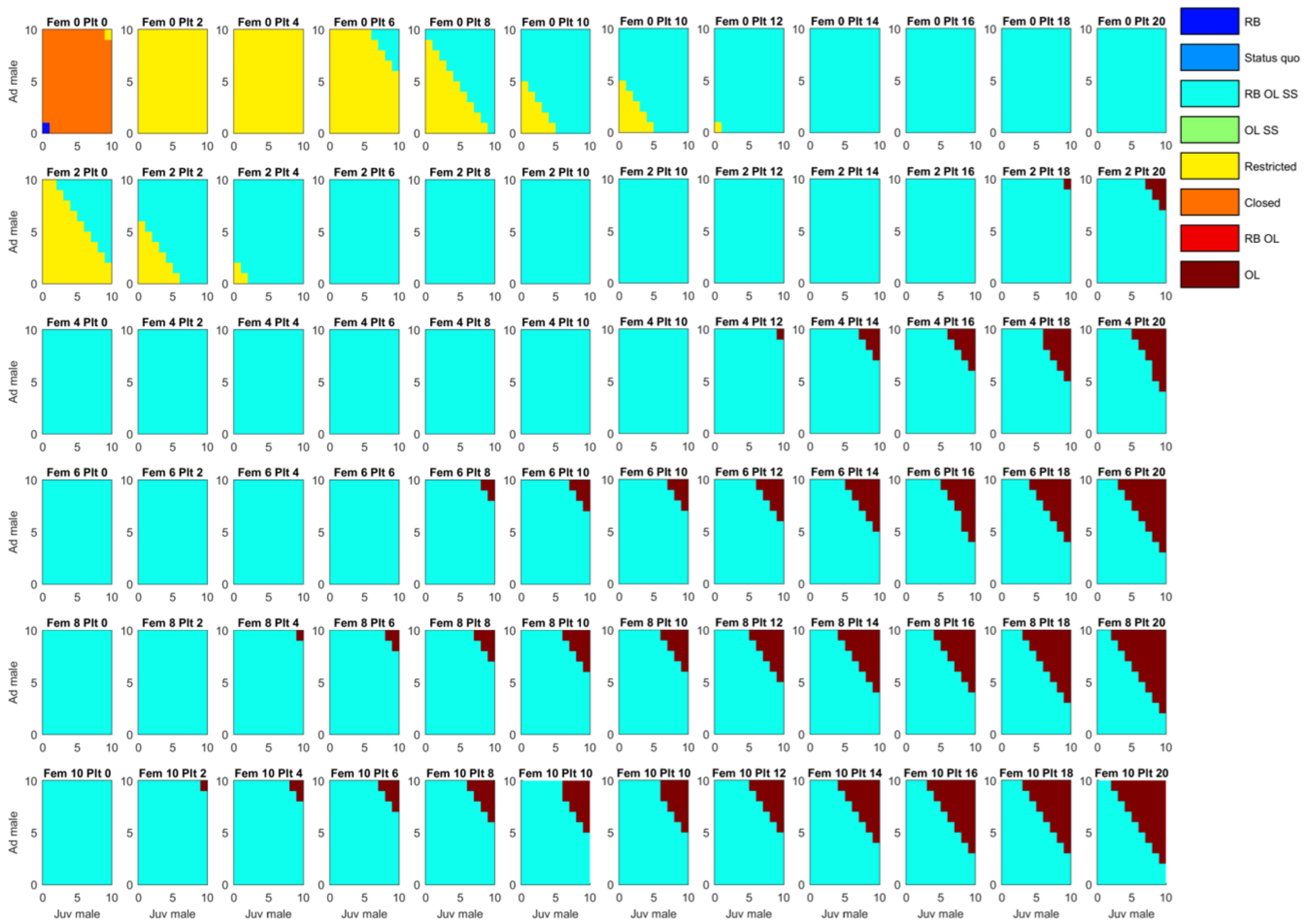

Figure 8. Optimal harvest decisions based on population state (i.e., number of poults 0.5y (Plt), females ≥1.5y (Fem), males 1.5y (Juv male), and males >1.5y (Ad male)) for populations with 0-10 poults and 0-10 females. Each tile represents decisions for 121 population states. Alternatives include combinations of the following regulations: RB (Reduced bag limit), Status quo (current regulations) , OL (Open season later), SS (Shorten season), Restricted (OL, RB, 10-day season)– Open season later, reduced bag limit, and reduced season to 10 days in length), and Closed (no hunting).

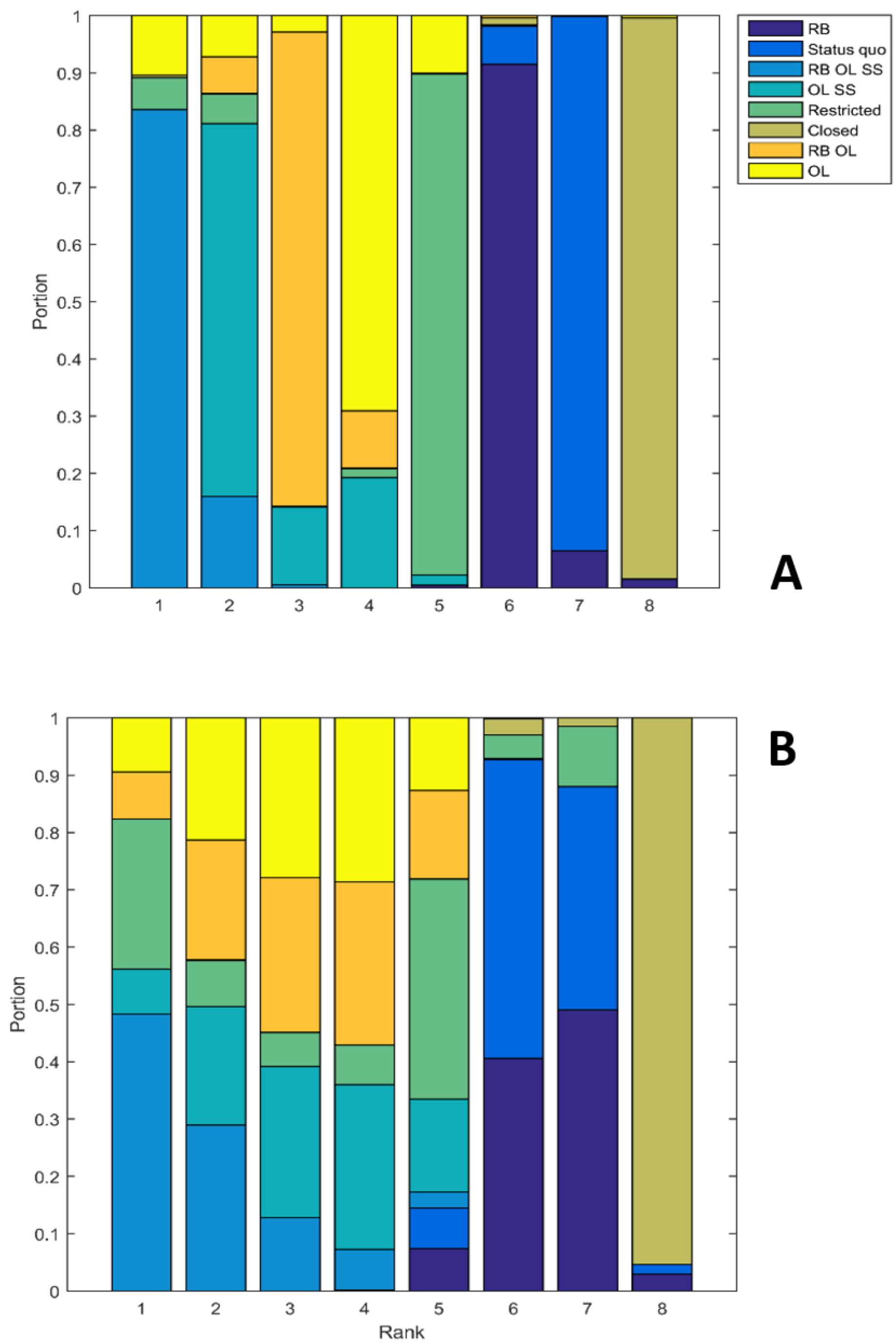

Figure 9 Proportion of projections and ranks of each alternative without (A, Table S1) and with parametric uncertainty (B, Table S2). Alternative RB OL SS was the optimal decision for 84% of initial states without parametric uncertainty and 48% of trials in projections with parametric uncertainty. Alternatives include combinations of the following regulations: RB (Reduced bag limit), Status quo (current regulations) , OL (Open season later), SS (Shorten season), Restricted (OL, RB, 10-day season)– Open season later, reduced bag limit, and reduced season to 10 days in length), and Closed (no hunting).

Discussion

Our results suggest that alternatives that include later opening dates for spring turkey seasons and result in increased productivity of turkey populations are likely to provide the most value to stakeholders. Those alternatives are expected to provide a larger population, more gobbling turkeys during spring hunting seasons, and greater harvest than alternatives that maintain Status quo or RB only. The alternatives Closed and Restricted are expected to provide the largest turkey populations and the most gobbling turkeys each spring, but the severely reduced or eliminated harvest will result in low value to stakeholders.

We determined the value of alternatives to stakeholders based on elicited relationships. The values we elicited placed approximately twice as much emphasis on high harvest as high gobbler density (Figure 3). The only initial states for which RB OL SS did not provide the greatest expected value for stakeholders were those with very small f (0-2). Those populations were expected to grow very slowly and result in low harvest for a longer period of time than larger populations. Thus, in populations with very few females and very few poults, there was little value from harvest over the 30-year period.

The experts we worked with concur with many other turkey biologists that spring seasons with later opening dates will result in more productive turkey populations (Isabelle et al. 2018). There is speculation that removal of male turkeys early in the nesting season limits productivity, but there is no published information to suggest that this is the case, and it is likely that turkey populations in most areas of Alabama are not male-limited. Long-term trends for populations that are not limited by the availability of males and not at equilibrium levels are most sensitive to female survival and productivity (Caswell 2006). Additionally, previous research demonstrated that adult female survival was an important driver of turkey populations (Vangilder and Kurzejeski 1995, Alpizar-Jara et al. 2001). While there is considerable evidence that illegal or inadvertent female harvest has occurred in Alabama (Wright and Speake 1975), recent research by Zenas (2018) found no evidence of female harvest during spring, which corroborates observations in other southeastern states (Everett et al. 1980, Palmer et al. 1993, Miller et al. 1998, Wilson et al. 2005). Thus, it follows that if spring hunting affects the trend of turkey populations in Alabama, the effect will be due to changes in productivity.

Population growth and equilibria

Because turkey populations are currently thought to be declining in Alabama and other southeastern states (Isabelle et al. 2018), and female survival rates are assumed to be unaffected by harvest regulations, we expect the population to continue to decline until an equilibrium is established under alternatives that do not affect productivity (i.e., RB and Status quo). Furthermore, the rate at which populations are expected to equilibrate and their eventual equilibrium levels are affected by the strength of the density-dependent relationship, the maximum *pph* expected under each alternative, and the difference between current population size and equilibrium population size. If estimates of female survival change, then the *pph* required to reach equilibrium will also vary in an inverse fashion. Our models suggest that increasing productivity or female survival will be required to increase the rate of growth and size of turkey populations in Alabama.

Even though female survival was held constant in our models, and only three levels of productivity were considered, equilibrium populations were different and greater than populations at Status quo under every alternative. This was the result of interactions between productivity and male survival rates. While greater productivity resulted in a greater number of females and poults in the fall population, the number of males in the fall population was inversely affected by harvest rates and the concomitant survival rates. Additionally, once a population reached equilibrium, alternatives for which male survival was greater also had a greater percentage of males.

We assumed that 50% of male harvest was additive to natural mortality, thus the differences in male survival among alternatives corresponded to 50% of the differences in harvest rates. The result was that for alternatives with similar levels of productivity, populations with lower harvest rates were expected to be larger at equilibrium. Moore et al. (2008) suggested that harvest mortality of adult gobblers was entirely additive to natural mortality, but found little effect of a 25% harvest rate on hunted populations in Georgia. If our assumption was wrong, and more than 50% of hunting mortality of turkeys in Alabama is additive, the differences in equilibrium populations among alternatives will be greater, equilibrium populations will be smaller, expected harvest will be smaller, and the relative value of alternatives will be more widely separated.

The experts we consulted believed that turkey productivity was density-dependent, and that current populations were below equilibrium values. Thus, our analysis predicted higher value on alternatives that resulted in increased productivity, larger populations, and larger harvests. McGhee and Berkson (2007a, 2007b) and McGhee et al. (2008) concluded that there was only a weak correlation between population size and productivity of turkeys and inferred that turkey populations experienced non-linear density-dependence based on autocorrelation of harvest indices. They also suggested that both density-dependent and density-independent processes increased the likelihood of overharvest. If their conclusions are correct, turkey populations in Alabama are unlikely to respond and reach equilibria as we predicted.

However, productivity is also affected by predation which can be affected by habitat quality and the availability of preferred nesting and brood-rearing sites (Badyaev 1995, Godfrey and Norman 1999). Accordingly, at a given population size, loss of habitat or declining habitat quality functionally increases female density and could lower productivity. Thus, current declines in turkey populations could be correlated with predation rates or loss of habitat or declining habitat quality. Additional research should address the effects of predation rates and habitat degradation on trends in turkey populations.

Management implications

Regulatory decisions based on this heuristic decision tool should be satisficing, but may not be optimal, because we did not consider whether periodic changes to management would provide greater value over time, and we did not consider decisions that would change with fluctuations in turkey populations. For example, we did not evaluate policies of limiting harvest for an initial period to allow the turkey population to reach equilibrium quickly, and then switching to a more liberal harvest regulation. Instead, we examined the long run value of each alternative regardless of initial state. This approach is similar to Management Strategy Evaluation (Smith 1994), which is commonly used in marine fisheries management, and has been shown to achieve results comparable to optimal approaches such as Stochastic Dynamic Programing. Therefore, we suggest that periodically modifying regulations based on monitoring could result in different and potentially greater long-run values. Monitoring data will also be useful for updating model parameters using Bayesian methods.

Our results suggest that alternatives for managing wild turkey harvest in Alabama that include opening hunting seasons later than Status quo will provide greater value to stakeholders. However, recent research suggests that a 9-day delay in opening dates in some parts of Alabama did not affect turkey occupancy or production, and hunting pressure may have had a greater effect on productivity than the delayed opening date (Stewart 2019). However, Stewart (2019) also suggests that 1) occupancy may not be sensitive to small changes in productivity and survival in turkey populations; 2) delays in opening dates greater than 9 days may be required to positively influence turkey productivity; and 3) there may be lags in population responses to changes in opening dates that obfuscate results. It should be noted that we based our estimates of the effect of later opening dates on expert judgement, not empirical estimates, and the only vital rate that was affected by later opening dates was productivity. Thus, it follows that alternatives other than harvest strategies that also affect productivity could have similar effects on populations. For example, factors such as predation rates and weather, may alter female survival and productivity (Kurzejeski et al. 1987, Miller et al. 1998, Healy and Nenno 1985, Peoples et al. 1995, Roberts and Porter 1998). We believe that further research addressing the relationship between the timing and magnitude of spring turkey harvest and the productivity and survival of female turkeys will prove invaluable.

Decision tools such as ours can be used to inform and guide the development and selection of management alternatives. In combination with monitoring and management experiments, they can also be used to reduce epistemic uncertainty in natural systems (Nichols et al 2007). We suggest that regardless of which harvest alternatives are implemented, implementing a rigorous monitoring program directed at reducing uncertainty can be used to improve the management of turkey populations.

Acknowledgements

This research was funded by grants from Federal Aid for Wildlife through ADCNR (Grant AL-W-35-62, 63, 64, 65) and contributions from the Alabama and National Chapters of the National Wild Turkey Federation. We are thankful for the input and support from the members of the Alabama Turkey Management Committee: S. Barnett, B. Bobo, J. Brock, M. Brock, C. Conring, J. Easterwood, K. Gauldin, J. Glover, J. Makemson, K. Marable, R. Metzler, A. Pritchett, A. Silvano. Earlier versions of this manuscript benefited greatly from suggestions by M.C. Runge and B.A. Collier. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. The Alabama Cooperative Fish and Wildlife Research Unit is sponsored jointly by the U.S. Geological Survey, Alabama Department of Conservation and Natural Resources, Auburn University, the Wildlife Management Institute, and the U.S. Fish and Wildlife Service.

Literature Cited

Alabama Department of Conservation and Natural Resources 2015. Full Fans and Sharp Spurs: Wild Turkey Report 2015. Alabama Department of Conservation and Natural Resources. Montgomery, Alabama, USA.

_________ 2016. Alabama Hunting Survey: 2015-2016. Alabama Department of Conservation and Natural Resources. Montgomery, Alabama, USA.

Alpizar-Jara, R. , E. N. Brooks, K. H. Pollock, D. E. Steffen, J. C. Pack, and G. W. Norman. 2001. An eastern wild turkey population dynamics model for Virginia and West Virginia. The Journal of Wildlife Management 65:415–424.

Badyaev, A. V. (1995). Nesting habitat and nesting success of eastern wild turkeys in the Arkansas Ozark Highlands. The Condor, 97(1), 221-232.

Barnett, S. W. , and V. S. Barnett. 2008. The wild turkey in Alabama. Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Montgomery, AL.

Byrne, M. E. , M. J. Chamberlain, and B. A. Collier. 2012. Southeast Regional Wild Turkey Reproductive Decline Study. Athens, GA.

Caswell, H. (2006). Matrix population models. Encyclopedia of Environmetrics, 3.

Chamberlain, M. J. , Grisham, B. A. , Norris, J. L. , Stafford III, N. J. , Kimmel, F. G. , and Olinde, M. W. 2012. Effects of variable spring harvest regimes on annual survival and recovery rates of male wild turkeys in southeast Louisiana. The Journal of Wildlife Management, 76(5), 907-910.

Conroy, M. J., & Peterson, J. T. 2013. Decision making in natural resource management: a structured, adaptive approach. John Wiley & Sons.

Davis, J. R. , H. R. Barnhill, D. C. Guynn, Jr. , R. E. Larkin, and W. M. Baughman. 1995. Wild turkey nesting ecology in the Lower Coastal Plain of South Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:454–465.

Eriksen, R. E. , T. W. Hughes, T. A. Brown, M. D. Akridge, K. B. Scott, and C. S. Penner. 2016. Status and distribution of wild turkeys in the United States: 2014 Status. Proceedings of the National Wild Turkey Symposium 11:7-18.

Godfrey, C. L. , and G. W. Norman. (1999). Effect of habitat and movement on wild turkey poult survival. In Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies (Vol. 53, pp. 330-339).

Everett, D. , D. Speake, and W. Maddox. 1980. Natality and mortality of a north Alabama wild turkey population. Proceedings of the National Wild Turkey Symposium 4:117–126.

Gonnerman, M. B. 2017. Estimating Use, Density, and Productivity of Eastern Wild Turkey in Alabama. *M*. S. Thesis. Auburn University, Alabama.

Gregory, R. , L. Failing, M. Harstone, G. Long, T. McDaniels, and D. Ohlson. (2012). Structured decision making: a practical guide to environmental management choices. John Wiley and Sons.

Godfrey, C. L. , and G. W. Norman. (1999). Effect of habitat and movement on wild turkey poult survival. In Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies (Vol. 53, pp. 330-339).

Healy, W. M. , and E. S. Nenno. 1985. Effect of weather on wild turkey poult survival. Proceedings of the National Wild Turkey Symposium 5:91-101.

Hemming, V., N. Armstrong, M.A. Burgman, and A.M. Hanea. 2020. Improving expert forecasts in reliability: application and evidence for structured elicitation protocols. Quality and Reliability Engineering International, 36:623-641.

Isabelle, J. L. , A. B. Butler, C. Ruth, D. K. Lowrey. 2018. Considerations for timing of spring wild turkey hunting seasons in the southeastern United States. Journal of the Southeastern Association of Fish and Wildlife Agencies 5:106-113.

Kimmel, V. L. and E. W. Kurzejeski. 1985. Illegal hen kill—a major turkey mortality factor. Proceedings of the National Wild Turkey Symposium 5:55–66.

Kurzejeski, E. W. , L. D. Vangilder, and L. B. Lewis. (1987). Survival of wild turkey hens in north Missouri. The Journal of Wildlife Management, 188-193.

Lohr, A. K., Martin, J. A., Wann, G. T., Cohen, B. S., Collier, B. A., & Chamberlain, M. J. 2020. Behavioral strategies during incubation influence nest and female survival of Wild Turkeys. Ecology and Evolution, 10:11752-11765.

McGhee, J. D. , and J. Berkson. 2007a. Correlation of eastern wild turkey poult: hen ratios with population indices to detect reproductive density dependence. Virginia Journal of Science, 58(3), 3.

McGhee, J. D. , and J. M. Berkson. 2007b. Estimation of a nonlinear density-dependence parameter for wild turkey. The Journal of Wildlife Management, 71(3), 706-712.

McGhee, J. D. , J. Berkson, D. E. Steffen, and G. W. Norman. 2008. Density-dependent harvest modeling for the eastern wild turkey. The Journal of Wildlife Management, 72(1), 196-203.

Martin, J. A. , W. E. Palmer, S. M. Juhan, and J. P. Carroll. 2015. Incubation and predation ecology of wild turkey nests: a cautionary case study regarding video camera surveillance. Proceedings of the National Wild Turkey 11:295–301.

Miller, D. A. , G. A. Hurst, and B. D. Leopold. 1997. Chronology of wild turkey nesting, gobbling, and hunting in Mississippi. The Journal of Wildlife Management 61(3):840-845.

__________. , L. W. Burger, B. D. Leopold, and G. A. Hurst. 1998. Survival and cause-specific mortality of wild turkey hens in central Mississippi. The Journal of Wildlife Management, 306-313.

Moore, W. F. , J. C. Kilgo, D. C. Guynn Jr, and J. R. Davis. 1993. Is spring wild turkey gobbler harvest additive or compensatory? In Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 62:77-81).

Nichols, J. D. , Runge, M. C. , Johnson, F. A. , & Williams, B. K. 2007. Adaptive harvest management of North American waterfowl populations: a brief history and future prospects. Journal of Ornithology, 148(2), 343-349.

Norman, G. W. , D. E. Steffen, C. I. Taylor, J. C. Pack, K. H. Pollock, and K. Tsai. 2001. Reproductive chronology, spring hunting, and illegal kill of female wild turkeys. Proceedings of the National Wild Turkey Symposium 8:269–280.

Palmer, W. E. , G. A. Hurst, J. E. Stys, D. R. Smith, and J. D. Burk. 1993. Survival rates of wild turkey hens in loblolly pine plantations in Mississippi. The Journal of Wildlife Management 57:783–789.

Peoples, J. C. , Sisson, D. C. , and Speake, D. W. 1995. Mortality of wild turkey poults in coastal plain pine forests. In Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 49:448-453.

Pylant, D. B. 1977. A study of mortality and nest desertion in eastern wild turkeys. Dissertation. Auburn University, Auburn, Alabama.

Roberts, S. D. , and W. F. Porter. 1998. Influence of temperature and precipitation on survival of wild turkey poults. The Journal of Wildlife Management, 1499-1505.

Smith, A. D. M. 1994. Management strategy evaluation: the light on the hill. Population dynamics for fisheries management, 249-253.

Speake, D. W. , R. Metzler, and J. McGlincy. 1985. Mortality of wild turkey poults in northern Alabama. The Journal of Wildlife Management 49(2):472-474.

Stewart, B. D. 2019. Occupancy Rates of Eastern Wild Turkeys: Estimating effects of experimental harvest regulations and automating image analysis. *M*. S. Thesis. Auburn University, Alabama.

Vangilder, L. D. , E. W. Kurzejeski, V. L. Kimmel-Truitt, and J. B. Lewis. 1987. Reproductive parameters of wild turkey hens in north Missouri. The Journal of wildlife management 51:535-540.

_____________, and E. W. Kurzejeski. 1995. Population ecology of the eastern wild turkey in northern Missouri. Wildlife Monographs 130.

Whitaker, D. M. , J. C. Pack, G. W. Norman, D. F. Stauffer, and S. D. Klopfer. 2005. A range-wide meta-analysis of wild turkey nesting phenology and spring season opening dates. National Wild Turkey Symposium 9:351–360.

Williams, L. E. , Jr. and D. H. Austin. 1988. Studies of the wild turkey in Florida. Florida Game and Fresh Water Fish Commission Technical Bulletin 10.

Williams, L. E. , and T. E. Peoples. 1974. Movement of wild turkey hens in relation to their nests. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 28:602–622.

Zenas, S. J. 2018. Factors Influencing Post-Capture Survival and Survival of Eastern Wild Turkeys in Alabama. *M.* S. Thesis. Auburn University, Alabama.

Supplemental Figures

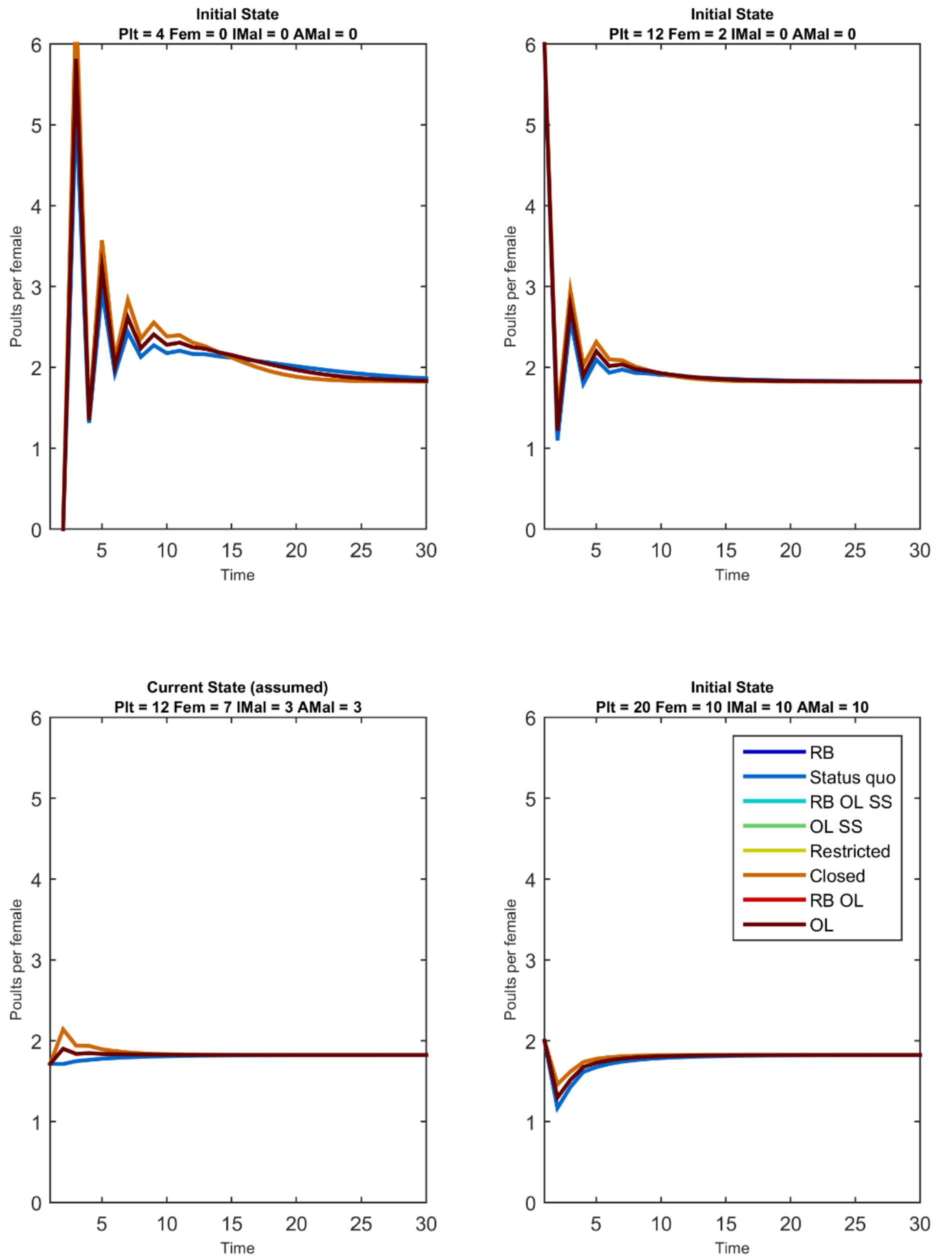

Figure S1. Expected annual productivity (poults per female) in fall populations of eastern wild turkeys from 4 different initial states under Status quo and 8 different harvest management alternatives in Alabama. Note that estimates for some alternative are hidden.

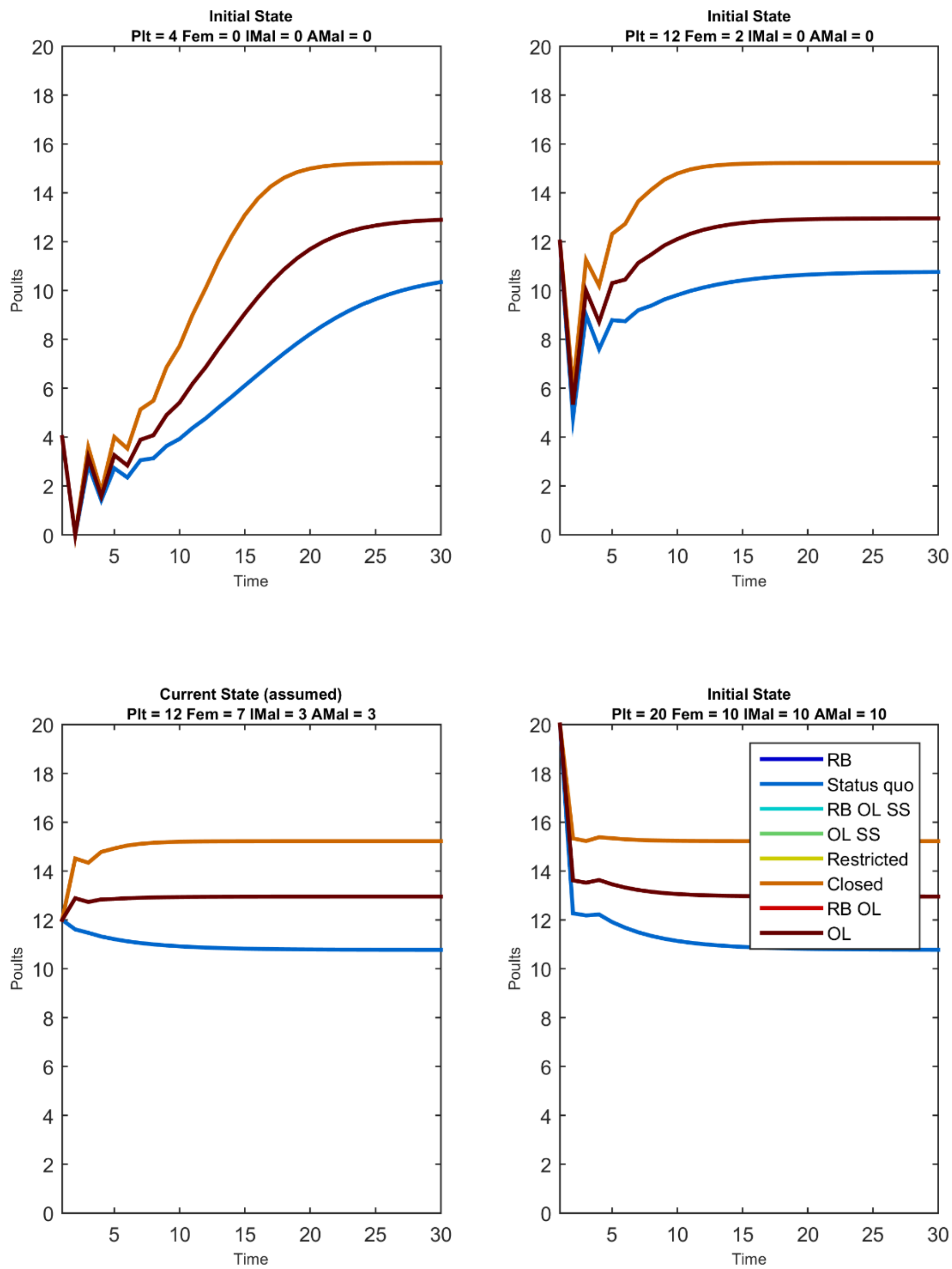

Figure S2. Expected density (N/mi^2) of poults (0.5y) in fall populations of eastern wild turkeys from 4 different initial states under Status quo and 8 different harvest management alternatives in Alabama.

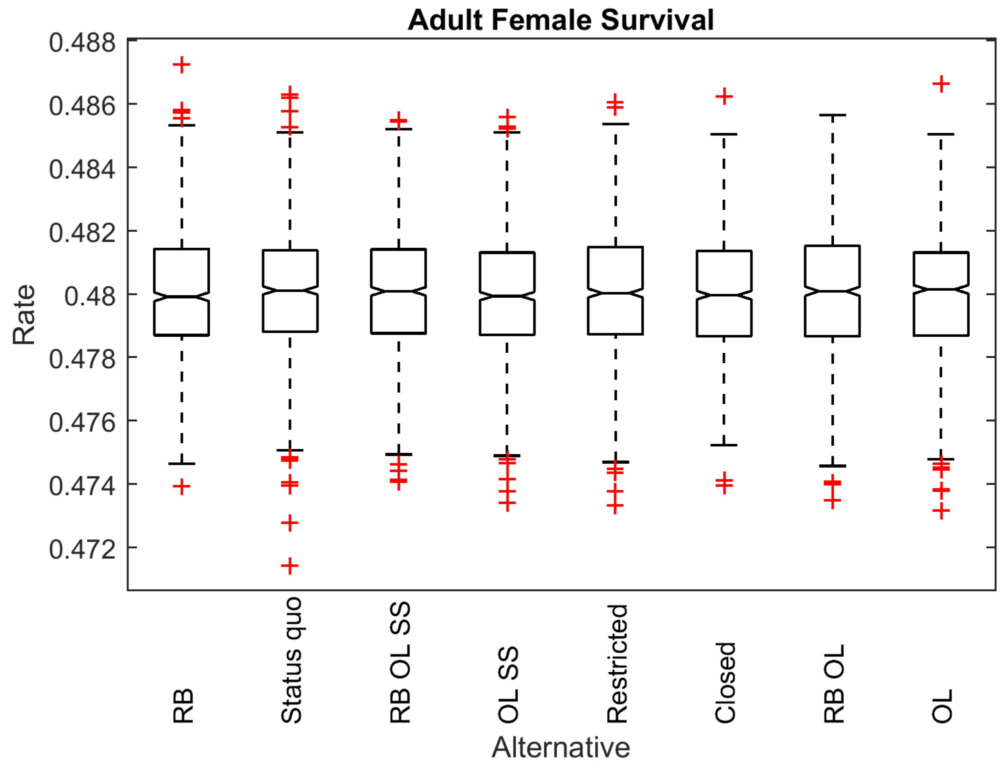

Figure S3. Boxplots of annual survival rates of adult females used to examine the effect of parametric uncertainty on preferred alternatives for harvest management of eastern wild turkey harvest in Alabama. Notches indicate the median, boxes indicate the 25th-75th percentiles, whiskers indicate the extent of values not considered outliers, and outliers are indicated with red + (some outliers may be obscured). Whisker length (*w*) is 99.3 percent coverage. Outliers were defined as values great than $q_3 + w \times (q_3 - q_1)$ or less than $q_1 - w \times (q_3 - q_1)$, where *w* is the maximum whisker length, and q_1 and q_3 are the 25th and 75th percentiles of the sample values, respectively. Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed).

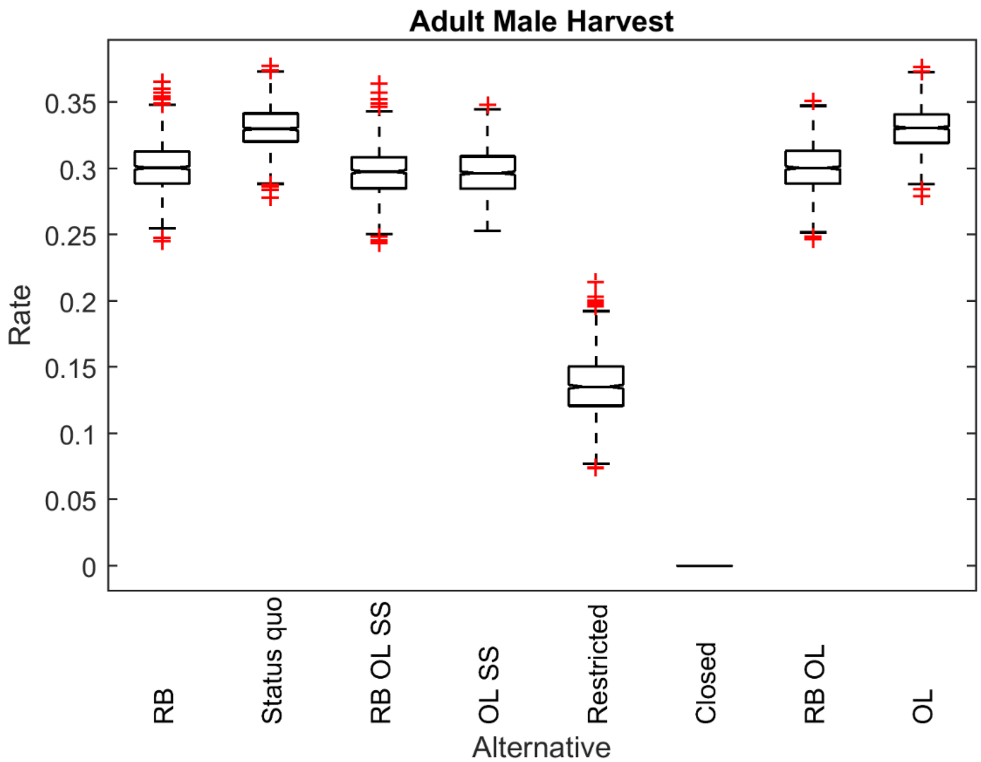

Figure S4. Boxplots of annual harvest rates of adult males used to examine the effect of parametric uncertainty on preferred alternatives for harvest management of eastern wild turkey harvest in Alabama. Notches indicate the median, boxes indicate the 25th-75th percentiles, whiskers indicate the extent of values not considered outliers, and outliers are indicated with red + (some outliers may be obscured). Whisker length (w) is 99.3 percent coverage. Outliers were defined as values great than $q_3 + w \times (q_3 - q_1)$ or less than $q_1 - w \times (q_3 - q_1)$, where w is the maximum whisker length, and q_1 and q_3 are the 25th and 75th percentiles of the sample values, respectively. Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed).

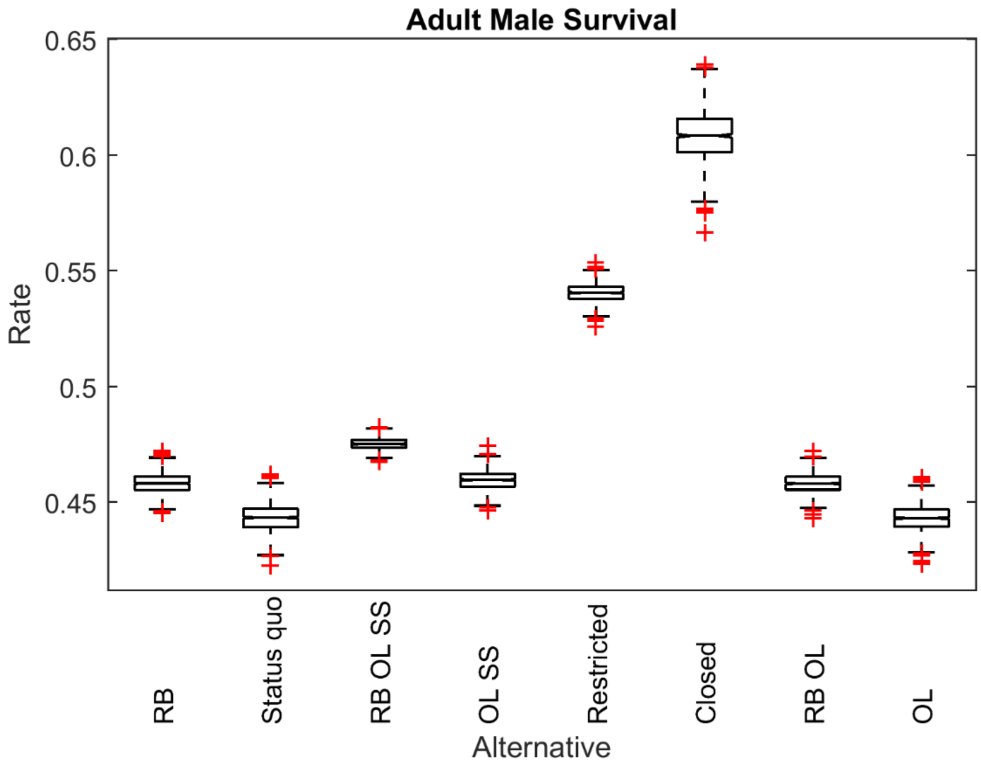

Figure S5. Boxplots of annual survival rates of adult males used to examine the effect of parametric uncertainty on preferred alternatives for harvest management of eastern wild turkey harvest in Alabama. Notches indicate the median, boxes indicate the 25th-75th percentiles, whiskers indicate the extent of values not considered outliers, and outliers are indicated with red + (some outliers may be obscured). Whisker length (*w*) is 99.3 percent coverage. Outliers were defined as values great than $q_3 + w \times (q_3 - q_1)$ or less than $q_1 - w \times (q_3 - q_1)$, where w is the maximum whisker length, and q_1 and q_3 are the 25th and 75th percentiles of the sample values, respectively. Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed).

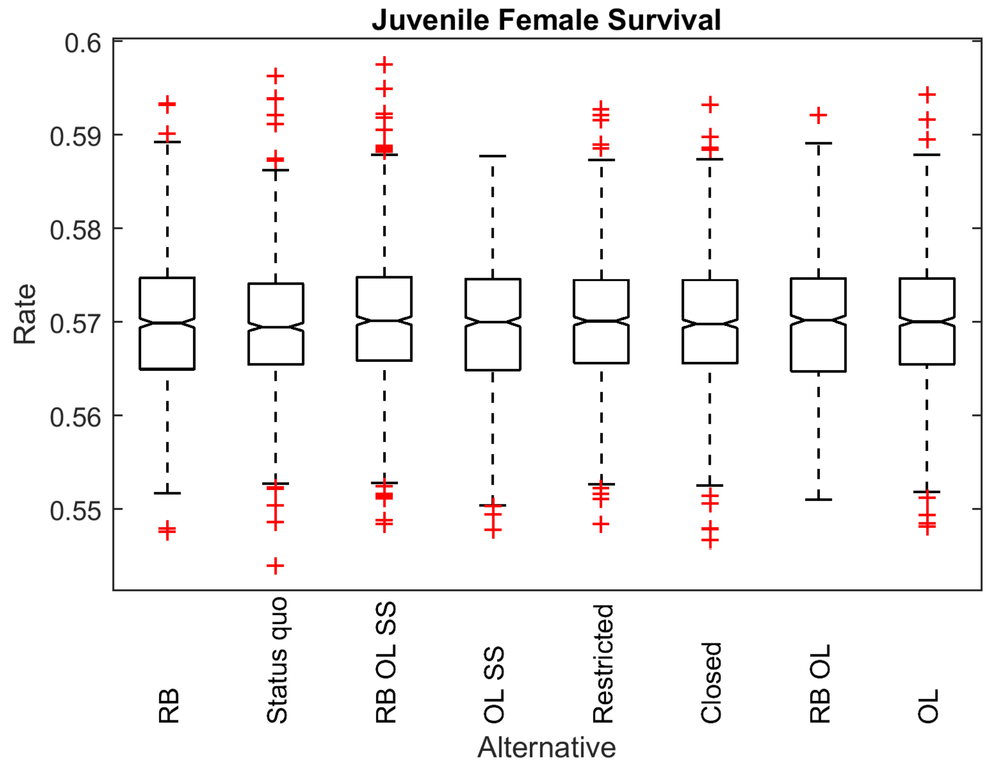

Figure S6. Boxplots of annual survival rates of juvenile females used to examine the effect of parametric uncertainty on preferred alternatives for harvest management of eastern wild turkey harvest in Alabama. Notches indicate the median, boxes indicate the 25th-75th percentiles, whiskers indicate the extent of values not considered outliers, and outliers are indicated with red + (some outliers may be obscured). Whisker length (w) is 99.3 percent coverage. Outliers were defined as values great than $q_3 + w \times (q_3 - q_1)$ or less than $q_1 - w \times (q_3 - q_1)$, where w is the maximum whisker length, and q_1 and q_3 are the 25th and 75th percentiles of the sample values, respectively. Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed).

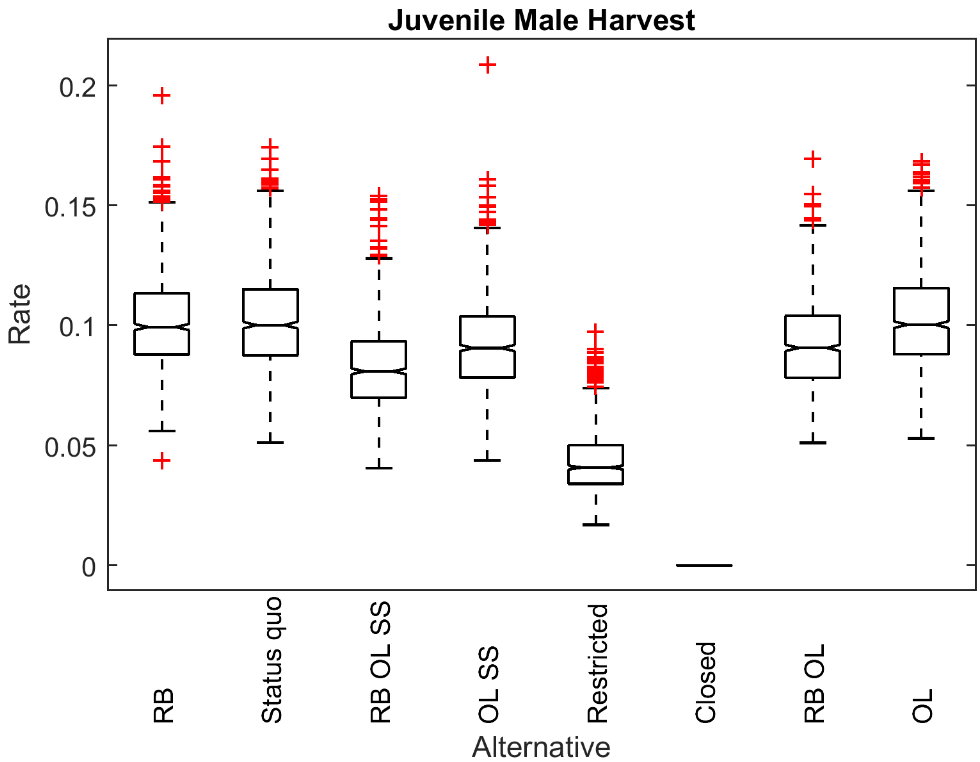

Figure S7. Boxplots of annual harvest rates of juvenile males used to examine the effect of parametric uncertainty on preferred alternatives for harvest management of eastern wild turkey harvest in Alabama. Notches indicate the median, boxes indicate the 25th-75th percentiles, whiskers indicate the extent of values not considered outliers, and outliers are indicated with red + (some outliers may be obscured). Whisker length (*w*) is 99.3 percent coverage. Outliers were defined as values great than $q_3 + w \times (q_3 - q_1)$ or less than $q_1 - w \times (q_3 - q_1)$, where *w* is the maximum whisker length, and q_1 and q_3 are the 25th and 75th percentiles of the sample values, respectively. Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed).

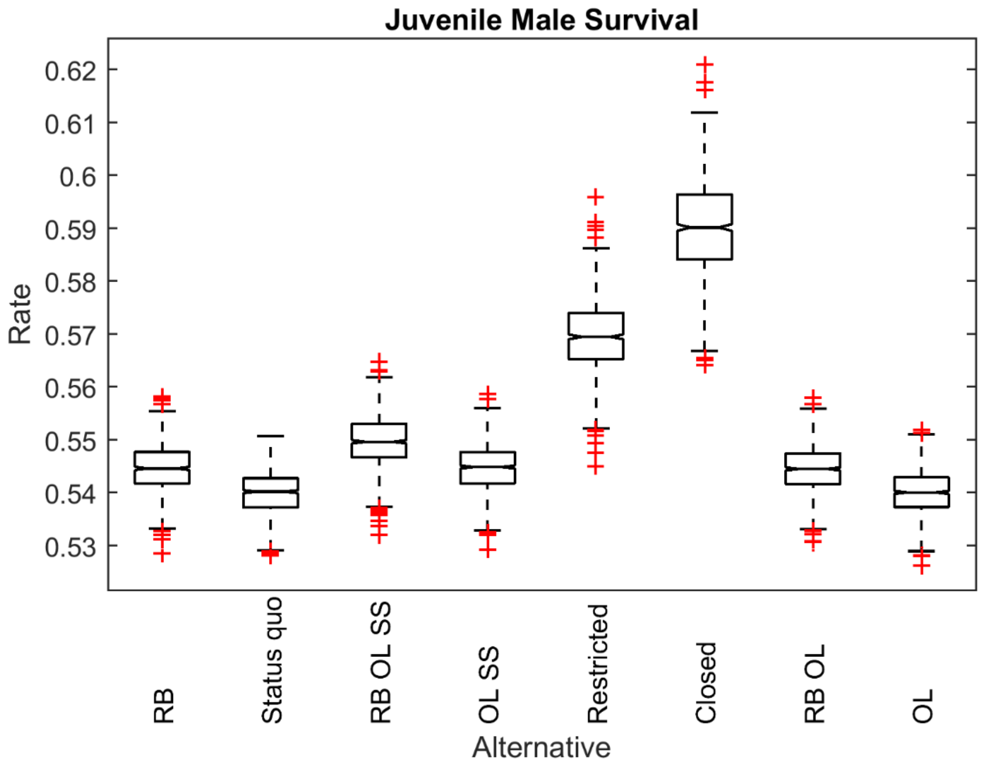

Figure S8. Boxplots of annual survival rates of juvenile males used to examine the effect of parametric uncertainty on preferred alternatives for harvest management of eastern wild turkey harvest in Alabama. Notches indicate the median, boxes indicate the 25th-75th percentiles, whiskers indicate the extent of values not considered outliers, and outliers are indicated with red + (some outliers may be obscured). Whisker length (w) is 99.3 percent coverage. Outliers were defined as values great than $q_3 + w \times (q_3 - q_1)$ or less than $q_1 - w \times (q_3 - q_1)$, where w is the maximum whisker length, and q_1 and q_3 are the 25th and 75th percentiles of the sample values, respectively. Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed).

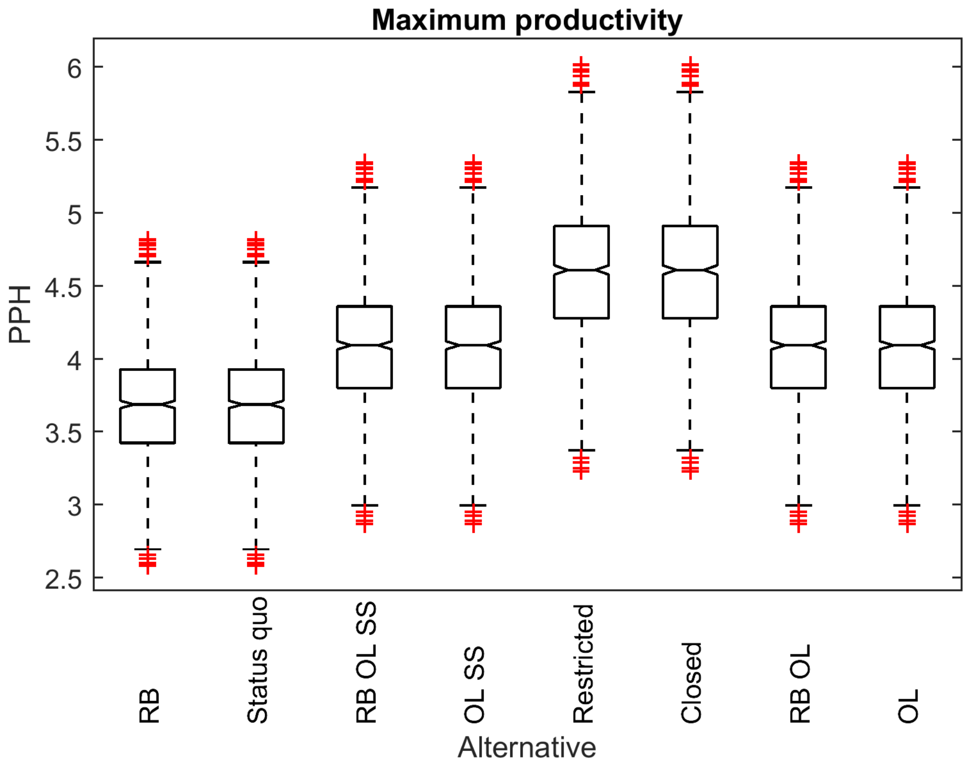

Figure S9. Boxplots of productivity (*PPH*, number of offspring per female in the fall population) used to examine the effect of parametric uncertainty on preferred alternatives for harvest management of eastern wild turkey harvest in Alabama. Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed). Notches indicate the median, boxes indicate the 25th-75th percentiles, whiskers indicate the extent of values not considered outliers, and outliers are indicated with red + (some outliers may be obscured). Whisker length (w) is 99.3 percent coverage. Outliers were defined as values great than $q_3 + w \times (q_3 - q_1)$ or less than $q_1 - w \times (q_3 - q_1)$, where w is the maximum whisker length, and q_1 and q_3 are the 25th and 75th percentiles of the sample values, respectively.

Supplemental Tables

Table S1. The effect of initial population state (n = 27,951) on the ranked value of harvest management alternatives for eastern wild turkeys in Alabama. Column headings are the ranks of alternatives. Ranks were determined for each alternative using 30 year projections of deterministic values for productivity, harvest, and survival parameters. Table values are the proportion of projections in which an alternative received a given rank. Thus, the first column of values is the portion of projections in which a given alternative was ranked first (best). For example, in 0.84 of projections RB OL SS was the top-ranked alternative.

Alternative[2]	1[1]	2	3	4	5	6	7	8
RB	0.00	0.00	0.00	0.00	0.00	0.92	0.06	0.02
Status quo	0.00	0.00	0.00	0.00	0.00	0.07	0.93	0.00
RB OL SS	0.84	0.16	0.01	0.00	0.00	0.00	0.00	0.00
OL SS	0.00	0.65	0.14	0.19	0.02	0.00	0.00	0.00
Restricted	0.06	0.05	0.00	0.02	0.88	0.00	0.00	0.00
Closed	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.98
RB OL	0.00	0.06	0.83	0.10	0.00	0.00	0.00	0.00
OL	0.10	0.07	0.03	0.69	0.10	0.00	0.00	0.00

[1]Ranked value of alternative in each trial (n = 27,951). Rank 1 indicates the preferred alternative.
[2]Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed).

Table S2. The effect of parametric uncertainty on the ranked value of harvest management alternatives for eastern wild turkeys in Alabama. Column headings are the ranks of alternatives. Ranks were determined for each alternative on trials (n = 1,000) including random values of productivity, harvest, and survival parameters and 27,951 initial population states. Table values are the proportion of projections in which an alternative received a given rank. Thus, the first column of values is the portion of projections in which a given alternative was ranked first (best). For example, in 0.48 of projections RB OL SS was the top-ranked alternative.

Alternative[2]	1[1]	2	3	4	5	6	7	8
RB	0.00	0.00	0.00	0.00	0.07	0.41	0.49	0.03
Status quo	0.00	0.00	0.00	0.00	0.07	0.52	0.39	0.02
RB OL SS	0.48	0.29	0.13	0.07	0.03	0.00	0.00	0.00
OL SS	0.08	0.21	0.26	0.29	0.16	0.00	0.00	0.00
Restricted	0.26	0.08	0.06	0.07	0.38	0.04	0.10	0.00
Closed	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.95
RB OL	0.08	0.21	0.27	0.28	0.15	0.00	0.00	0.00
OL	0.09	0.21	0.28	0.29	0.13	0.00	0.00	0.00

[1]Ranked value of alternative in each trial (n = 19,965,000). Rank 1 indicates the preferred alternative.
[2]Alternatives include combinations of reducing the seasonal bag limit from 5 males to 3 males (RB), opening the season later (OL), shortening the season length (SS), as well as a restricted 10-day season in combination RB and OL, and Closed season (no hunting allowed).

Table S3. Near equilibrium densities (n/mi^2) and expected value for projections of eastern wild turkey populations in Alabama under 8 harvest regulation alternatives. Column headings are the 8 alternatives. Mean value was determined from elicited stakeholder values averaged over a 30-year projection. Mean values were highest for alternatives RB OL SS, OL SS, and RB OL.

Parameter	RB[1]	Status quo[2]	RB OL SS[1,3,4]	OL SS[3,4]	Restricted[5]	Closed	RB OL[1,3]	OL[3]
Poults (p)	10.8	10.8	13.0	13.0	15.2	15.2	13.0	13.0
Females (f)	5.9	5.9	7.1	7.1	8.3	8.3	7.1	7.1
Juvenile (m_j) males	2.9	2.9	3.6	3.5	4.3	4.5	3.5	3.5
Adult males (m_a)	2.5	2.3	3.2	3.0	5.1	7.0	3.0	2.8
Total	22.1	21.9	26.8	26.6	33.0	35.0	26.6	26.3
Adult males in spring	4.0	3.9	5.0	4.8	7.0	8.4	4.8	4.7
Adult male Harvest	1.2	1.3	1.5	1.4	0.9	0.0	1.4	1.5
Mean value	44.5	44.1	53.7	52.1	50.1	27.4	52.1	51.6

[1]Reduced bag limit from 5 males per hunter per season (Status quo) to 3 males per hunter per season.
[2]Status quo – bag limit 5 males per hunter per season, 45-day season, Season 15 March – 30 April.
[3]Open season later (10 days).
[4]Shortened season by opening later and retaining 30 April closing date.
[5]Restricted – Open season later, reduced bag limit, and reduced season to 10 days.
[6]Closed – Closed hunting season.