Maine Wild Turkey Project - Objective 1 Interim Report (May 2018)

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Disclaimer: The findings contained in this report represent preliminary results of ongoing research; they should be cited as unpublished data until they have undergone peer review and publication.

Summary: This report documents our initial efforts to address Objective 1 from the project titled "Population estimation, harvest management, and landscape-scale spatial ecology of wild turkeys in Maine". The goal of Objective 1 was to develop, evaluate, and refine approaches to estimate wild turkey abundance across large spatial scales using closed capture removal models and hunter harvest reporting data. During winter 2017-2018 we conducted preliminary analysis of Maine wild turkey harvest data, and conducted data simulations to evaluate the utility of closed capture removal models for estimating abundance and harvest rates. Simulations suggested that estimates were unbiased on average, but there was a wide range of variation among individual model runs. For a population of wild turkeys comprised of 2000 individuals, results suggesting an approximate margin of error for estimates of male abundance of +/- 25%, and for harvest of +/- 28%. Based on realized harvest of Maine birds and harvest rates reported elsewhere, we expect that most WMDs in Maine have spring male population sizes of fewer than 2000 adult males, making the above estimates reflective of what we could expect for removal model performance in general. Also in order to implement removal models at a large scale would require collecting hunter questionnaire data to quantify daily hunter effort throughout the season, which is presently not available. As an alternative, we recommend using harvest estimates based on band recovery (male) and radio-telemetry (female) data applied to Lincoln estimators, which

are increasingly being used to estimate population sizes for harvested gamebirds. This approach would dovetail nicely with our ongoing efforts to monitor wild turkey survival, movements, nesting, and disease ecology in the state, in that capture efforts would be complimentary, and takes advantage of the state's extensive harvest reporting database. However this would also likely require additional effort to generate a sufficient number of bandings and recoveries to produce useful harvest estimates.

Background: Information concerning wild turkey (*Meleagris gallopavo*; hereafter turkey) abundance throughout Maine is currently limited. With Objective 1 of the Maine Wild Turkey Does Project, we aimed to address this knowledge gap by assessing the use of hunter effort data and closed-capture removal models to estimate turkey population sizes and annual harvest rates statewide and within Wildlife Management Districts (WMDs). Removal or depletion sampling to estimate animal abundance has a well-developed theoretical foundation (Gould and Pollock 1997, Pollock et al. 2002, Dorazio and Jelks 2005), has been applied in a number of fish and wildlife management contexts (e.g., Dauphin et al. 2009, Haskell 2011), and has been proposed as an estimation method for wild turkey populations (Healy and Powell 1999). In concept, removal falls under the category of catch-per-unit effort sampling, where depletion of individuals from a closed population is used to estimate a detection function and adjust apparent counts of individuals to total abundance. Historically these methods have been applied largely as effort-corrected indices (Healy and Powell 1999), however, they can also be fit using more contemporary likelihood-based approaches that produce detection-corrected estimates probabilistic abundance. This is accomplished in practice using software such as Program MARK (White and Burnham 1999) or the R package unmarked (Fiske and Chandler 2015).

In Program MARK, removal models are implemented as a closed capture model, require that date of removal (harvest) is known, and assume that the number of individuals removed decline through time as the population is depleted. Reduction in removal rate is fit using a specified function that reflects a decrease in the capture probability, *p*, through time, where in the case of harvested individuals *p* reflects the maximum likelihood estimate of the proportion of individuals removed during each day of the season. The second detection component of a closed capture model, the recapture probability, *c*, is fixed to 0.0. Abundance, *N*, is also estimated as a component of the model likelihood, and successive estimates of N can be used to derive the population growth rate, λ. Typically population estimators based on catch-per-unit-effort require information on relative hunter effort. This is accomplished using hunter surveys to estimate daily hunter effort (Heely and Powell 1999) which are then applied as daily covariates on the detection function (Haskell 2011)

In order to be predictive, all models must meet assumptions that are implicit to the model structure. Furthermore, all quantitate methods are sensitive to sample sizes and other constraints associated with the data used to fit the model. In the case of wild turkeys, it is unclear what minimum sample size (number of harvested turkeys) is required to obtain reliable estimates, and the general accuracy of the harvest rate estimates derived from removal models should also be assessed. Latent variables such as unreported harvest, or unrecovered crippling loss, could also affect the accuracy of abundance and harvest estimates. As a closed capture model, these methods implicitly assume that no population losses occur outside of removals (i.e. no non-harvest mortality), and violation of this assumption becomes inherently more likely as hunting season length increases. Data simulation is particularly useful for evaluating such questions and for formalizing the consequences of violating model assumptions (Kery and Royale 2016). In the case of this report, simulation also allows us to evaluate whether this particular analysis method is well-suited to meeting objectives of wild turkey population monitoring in Maine.

This report summarizes our initial attempts to evaluate the utility of closed capture removal models to evaluate patterns in wild turkey abundance based on harvest data. Analysis for this objective were carried out in two stages. In stage one, we ran closed-capture removal models to estimate plausible WMD-specific harvest rates and abundances using existing spring turkey harvest data. Conducting this first phase required information on daily levels of hunter effort, which are not presently available, so we simulated plausible hunter effort values for each day of the hunting season strictly for the purpose of evaluating model utility and conducting simulations. Thus, estimates derived from the present analysis should not be viewed as representative of the true turkey population in Maine. In stage two, we developed a realistic model of springtime turkey harvest based on patterns we observed in the state-provided harvest records. Using simulated populations and realized harvest data with “known” structure, we again used closed-capture removal models to estimate harvest rates and abundances of each population, and used iteration to assess the accuracy of these estimated values in comparison to the “known” harvest rates and population sizes known for the simulated populations. The results from this portion of the study will be used to inform future decisions about analytical approaches to quantify turkey harvest and abundance in Maine.

Methods: We began stage one by obtaining records of turkey harvests that occurred in recent springs (2004-2016) from the Maine Department of Inland Fisheries and Wildlife’s (MDIFW) master registry of turkey harvests. We chose these records from among all available data for several reasons. First, we wanted to simplify our analysis by using records from only one harvest period, and we opted to use the spring season because spring harvest totals were typically ~2-3 times greater than fall totals. Second, we used years 2004 onward for consistency in season length; since 2004, the spring turkey hunting season in Maine has opened the Saturday closest to May 1st for Youth Day and to the general public the following Monday, with a season length of 31 days, excluding Sundays. Also, state hunting guidelines permitted the harvest of only bearded turkeys during spring seasons, therefore spring turkey harvests were almost entirely male. Any females harvested during spring seasons (i.e. bearded hens) were omitted from this analysis.

Because we wanted to use hunter effort as a covariate in our closed-capture population models, we investigated the utility of the hunter effort surveys conducted by MDIFW over recent spring turkey hunting seasons (2003-2005, 2007-2012). While these surveys would be informative for use in some applications (e.g. estimating total hunting effort by days and hours hunted, and subsequent success), these data did not specify hunter effort by day of the season, and thus could not be applied to the detection term (p; a daily probability) in the models. Therefore, we needed to simulate a model for hunter effort in our system, which we did by modifying the hunter effort model described by Haskell (2011) for white-tailed deer. While deer and turkey hunting clearly differ from each other, the primary goal of this aspect of the model was to describe how hunter effort changes through time within a particular season. We assumed that both deer and turkey hunters show similar general patterns in effort, with effort being greater on opening day and on weekends, and declining progressively throughout the season. Our simulated model for hunter effort did not vary among years and represented proportional time spent hunting by day of the season, with greatest proportional effort at the beginning of the season and proportional effort exponentially decreasing as the season progressed. However, we modified the negative exponential pattern in two ways: 1) we reduced proportional effort on day 1 of the hunting season to match the comparably few hunters that participate in Youth Day, and

2) we allowed greater proportional effort on Saturdays throughout the season. The values we ultimately used are depicted in Figure 1.

The goal of stage one was to estimate *p*, the removal rate, and *N*, abundance, for each WMD by year (2004-2016) by age (adult male and subadult male) group, using Huggins' closed-population capture-recapture models (Huggins 1991). We limited our analysis to include only WMD/year combinations with ≥200 harvested individuals to maintain a minimum sample size of harvested birds, and we generated removal histories for each of these groups that reflected the number of turkeys harvested each day of the hunting season. Prior to running models, we set *c*, the probability of removal given previous removal, to 0, because individual turkeys cannot be harvested more than once. We assessed the effect of hunter effort as a time-varying covariate, such that each day of the hunting season corresponded to a value of proportional effort from our simulated hunter effort data (Fig. 1), and we obtained estimates of daily harvest rates and population sizes from this model. This model was executed in R (R Core Development Team 2013) using the package 'RMark' (Laake 2013), which serves as an interface to Program MARK (White and Burnham 1999).

We began stage two of our analysis by creating simulated turkey populations using example code contained in Kéry and Royle (2015). We first designated the number of populations to simulate (M), which were analogous to the WMD/year/age groups from stage one. However unlike those groups, simulated populations were not explicitly related to any defined area, time frame, or individual characteristics. We specified λ, the mean expected abundance for each of the simulated populations, which we then used to generated abundance, *N*, as a numeric vector of M length containing "known" population sizes prior to harvest. To add some variability to *N* among groups, abundances were drawn as a random sample from a specified range of values (e.g. λ ± 20%). After creating simulated populations, we incorporated elements that determined when and how many turkeys were harvested from them (i.e. the harvest model). Here, we specified the number of days in the hunting season (J), which in our case was constant at 31 days. We also specified the level of daily hunter success (i.e. the daily probability a hunter would bag a bird, given they hunted that day), which we assumed to be constant at 0.015. We included our simulated hunter data to reflect daily differences in hunter effort, and we also introduced a random term here to reflect variability among populations (e.g. daily proportional effort ± 20%). We selected a mean probability of harvest (α) and specified effects sizes (β) of daily hunter success and hunter effort that were informed by temporal patterns observed in the state-provided harvest records. These values were used to calculate binomial probabilities of removal (p) for each population, by day, using the following model:

$$logit(Harvest_i) = \alpha + \beta_1 Effort_i + \beta_2 Success_i$$

which produced a daily binomial probability that a bird would be harvested and removed from the population on day i. This was in turn used to simulate daily harvests in each population. In practice this approach resulted in mean daily harvest rate of ~0.015, and an overall seasonal probability of harvest of ~0.39. These simulated removals provided us with a surrogate to wild turkey harvest data that reflected the total number of birds shot, recoverd, and reported by hunters during each day of the season for each population (WMD/year), with a known underlying rate of harvest and population abundance. We then derived estimates of harvest rates and abundance using closed-capture removal models and hunter effort as described for stage one, and we evaluated biases in these estimates by comparing them to the “known” values from the simulated data.

Finally, we used iterations of different scenarios to explore the influence of population size on harvest rate and abundance estimates produced by the removal models. We were particularly interested in seeing how various levels of λ (mean abundance per group) affected the accuracy and precision of the model estimates, because this would inform the minimum level of turkey harvested necessary to obtain useful population estimates. If too large a population size or level of harvest was required to generate precise estimates, removal models may not be useful for state monitoring objectives. We assumed 140 groups (WMD/year combinations), and ran 100 iterations of each of 10 levels of λ that ranged from a low abundance of 2000 males and a high abundance of 8750 males, in increments of 750. For each level of λ, we summarized the average error of estimated *N* and harvest rates across all iterations, and calculated the differences between these estimates and the known values for each iteration. Histograms were used to visualize the variability of model estimates.

Results and Interpretation: Mean estimates of abundance from simulations were unbiased on average, however there was a wide range of variation in the results of each individual iteration (Fig. 2). For example, under the smallest true mean abundance (λ=2000), bias in abundance estimates ranged from -500 to +1000 individuals. Thus if the true average annual abundance among WMD was 2000 male turkeys prior to the spring hunt, we would expect error in estimates from any given WMD of approximately +/- 500 individuals, or an ~25% margin of error. The magnitude of bias tended to be similar with increasing mean population size, however this also implies that proportional error decreased as abundance increased. For example, under a true mean abundance of 8000 males per WMD, the range of bias approximated +/- 1000 individuals, which equates to an ~12.5% margin of error at this population size.

Results were similar for estimates of harvest in that on average removal models produced estimates of harvest rates that were unbiased (Fig. 3). However in this case there was a more even distribution of positive and negative bias among iterations, with bias ranging from -0.10 to +0.10, or for a harvest rate of 0.35 we would expect approximately 28.5% margin of error.

For context to our results, the total spring harvest of turkeys in 2016 ranged from 7 to 612 males (jakes and toms combined), with a maximum of 390 adults (WMD) and 241 jakes in any given WMD. An approximate population size for Maine’s most heavily hunted WMDs can be obtained based on the Lincoln Estimator (Lincoln 1930, Alisauskas et al. 2014, Hagen et al. 2018), which derives abundance based on the ratio of the number of birds harvested (*k*) to the estimated individual harvest rate (*H*)

$$\hat{N} = {}^{k}/_{H}$$

While we lack reliable estimates of individual harvest rates for Maine turkeys at present, we can use recent estimates from NY and OH (Diefenbach et al. 2012) which have similar season lengths (33 days and 30 days, respectively, including youth seasons) to gauge an approximate harvest rate for the purpose of illustration. Mean harvest for adult males based on band recover data in those states was approximately 0.37, and for jakes was 0.22. Therefore the maximum WMD-specific abundance we might expect for Maine would be 1054 adult males and 1095 jakes. This is clearly a very rough approximation, but it illustrates that we should expect removal models to perform, at best, like the results depicted in panel A of Figures 2 and 3, with ≥25% margin of error in estimates of abundance and ≥28% margin of error in harvest.

While our results suggested that removal models are unbiased on average when fit to plausible wild turkey harvest data, individual iterations produced a wide range of bias. Whether these rates of potential error are acceptable depends on how estimates would be used and the degree of confidence desired for their application. Furthermore, greater information is needed in the form of daily hunter effort data, ideally stratified to sample across all WMDs, in order to apply removal models to generate harvest estimates. These data would likely be collected in the form of a hunter's journal (to record hours hunted for each day of the season) and would need to be updated periodically (e.g. every 5 years).

As an alternative method, we could use banding and radio-telemetry data to derive estimates of age- and sex-specific harvest rates, and then apply these rates to a Lincoln estimator to derive abundances. These approaches have been used increasingly to estimate abundances of gamebirds, including waterfowl (e.g. Alisauskas et al. 2014), grouse (Hagen et al. 2018) and wild turkeys (Diefenbach et al. 2012; although these authors do not refer to their method as a Lincoln Estimate). Maine is in a good position to use Lincoln estimates because mandatory reporting of harvested turkeys provides robust data for population estimation. Given that we are currently capturing, marking, and monitoring turkeys as part of our larger research effort, this approach is likely worth pursuing, but will require careful consideration of sample size targets for capture. During their study Diefenbach et al. (2012) banded >3200 male turkeys across three states and 4 years. Their lowest state-specific sample size was in Ohio, where they banded 663 males (pooled ages), and from these males obtained relatively precise harvest rate estimates for both jakes (0.17; 95% CI= 0.13 to 0.22) and toms (0.39; 95% CI= 0.34 to 0.44) which are considerably more precise than the estimates we obtained from removal model simulations.

During our pilot field season in 2017 we banded 39 male turkeys and as of 5 June we have received 5 reports of harvested males (jakes and toms combined) for an apparent harvest rate of 0.128 +/- 0.054 SE, which does not account for harvests that were reported at hunter check stations where we have not yet retrieved data. Our male captures during 2018 were largely incidental to targeting females. To increase sample size of banded males in subsequent years would require that we target males specifically and also increased capture effort so that we do not compromise female capture. We should also be able to derive harvest estimates from our radio-marked females, which can be applied to the Lincoln estimator similar to the band recovery estimates of spring harvest from males. Some additional simulations could assist in determining minimum sample sizes required to obtain useful harvest estimates from both males and females.

Two final considerations for implementing a Lincoln-based approach to population estimation are 1) that in order to be useful for spatially-explicit population modeling across the state, we need to estimate harvest rates that are unique (or at least potentially so) among WMDs, and 2) the harvest estimates should probably be periodically updated to capture changing trends in statewide harvest. Point 1 could be addressed using a model of harvest rates that predicts spatial variation in harvest as a function of underlying variables, such as land use and land cover data. Given predictive relationships, WMD-specific harvest rates could be estimated based on variability in spatial variables among WMDs. For example, Diefenbach et al. (2012) found that percent forest cover within 6.45 km of banding sites was negatively associated with harvest rate. To address point 2 would likely require periodic (e.g. every 3-5 years) short-term banding efforts to update and re-analyze band recovery and harvest rates and update the population model accordingly.

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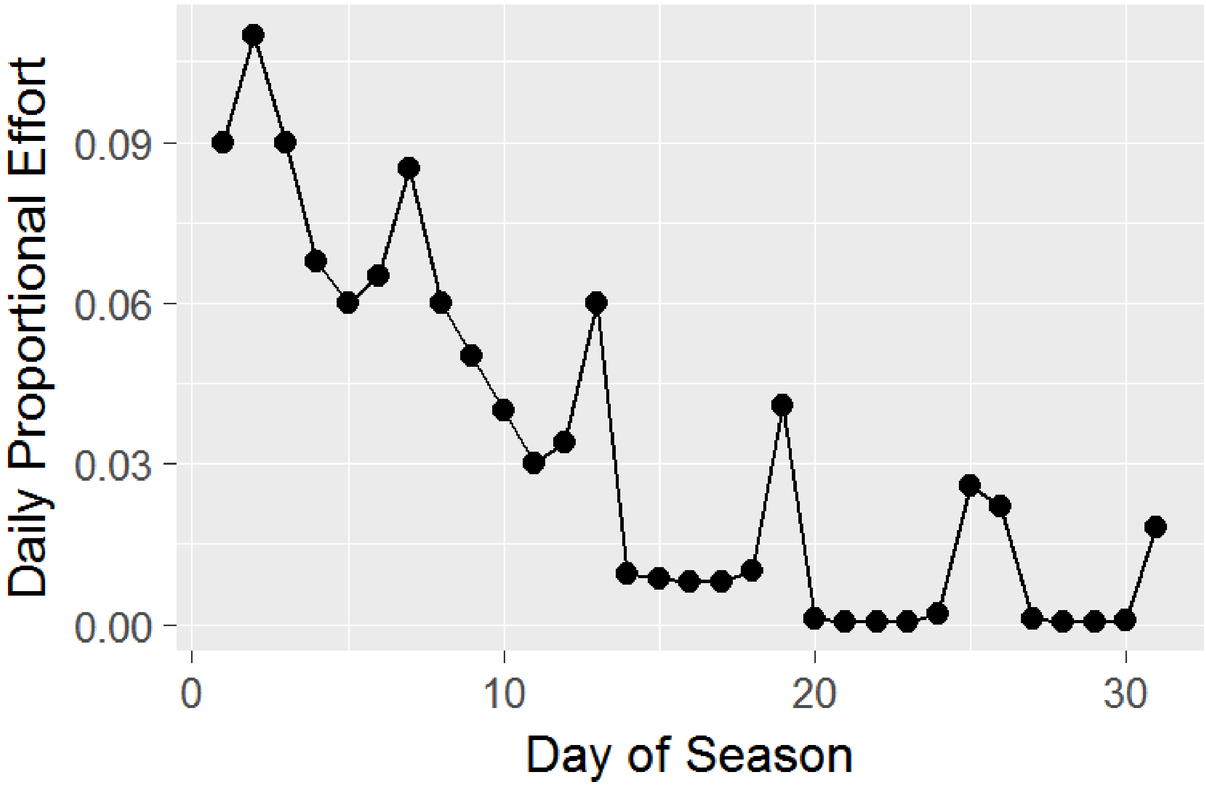

Figure 1. Assumed pattern in daily proportional effort (proportion of an average hunter's season spent hunting a given day) as a function of day of the season. Day 1 reflects Youth Day, the first peak is opening day, and each subsequent peak reflects a Saturday. Values sum to 1.0 across the entire season.

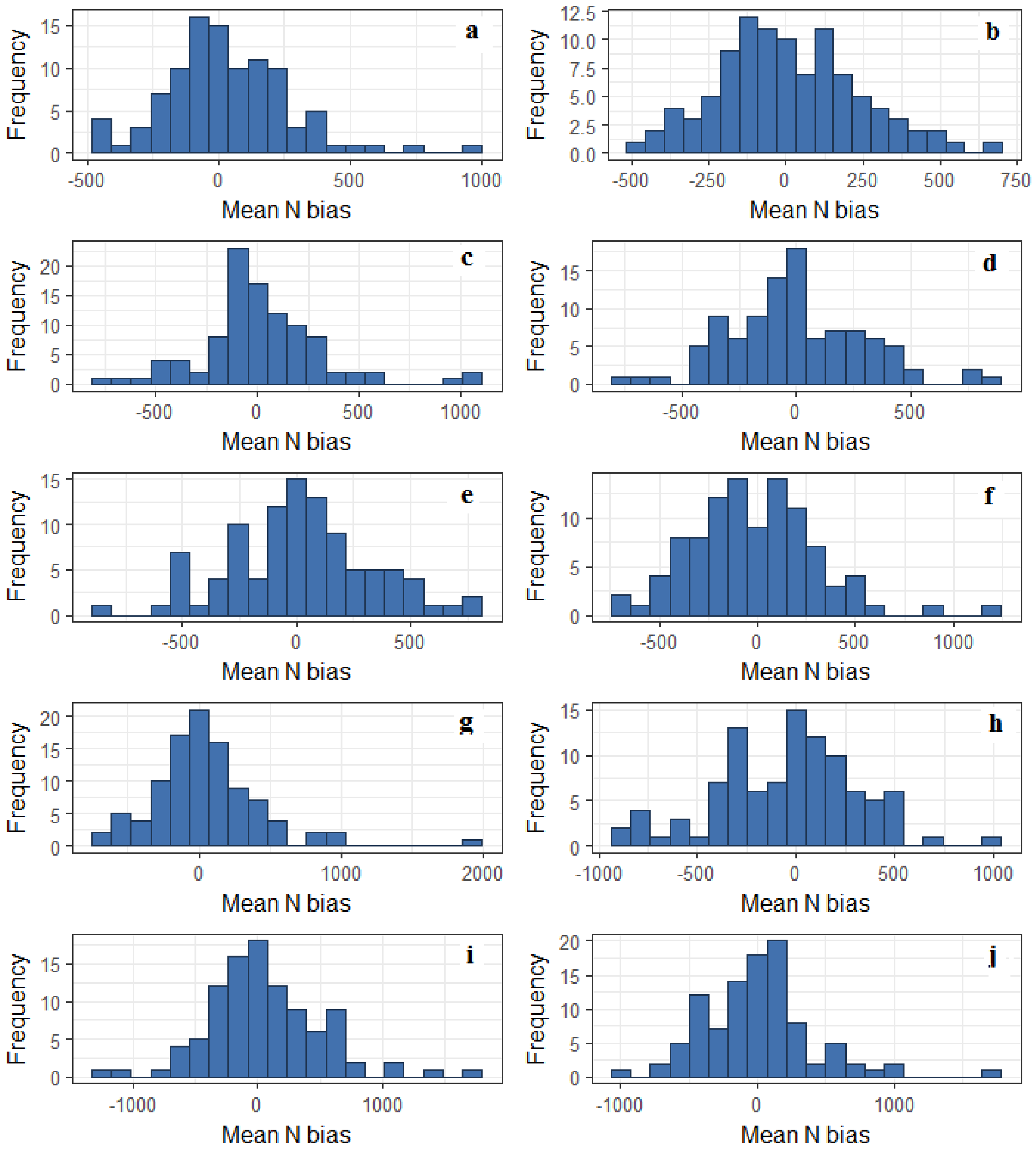

Figure 2. Histograms showing the distribution of biases in estimated *N*, abundance, from 100 iterations of 10 different spring turkey removal simulations with varying λ, mean expected abundances before removals. Levels of λ correspond to figure as follow: a) 2000, b) 2750, c) 3500, d) 4250, e) 5000, f) 5750, g) 6500, h) 7250, i) 8000, and j) 8750. Note that the scale of the x-axis changes among simulations.

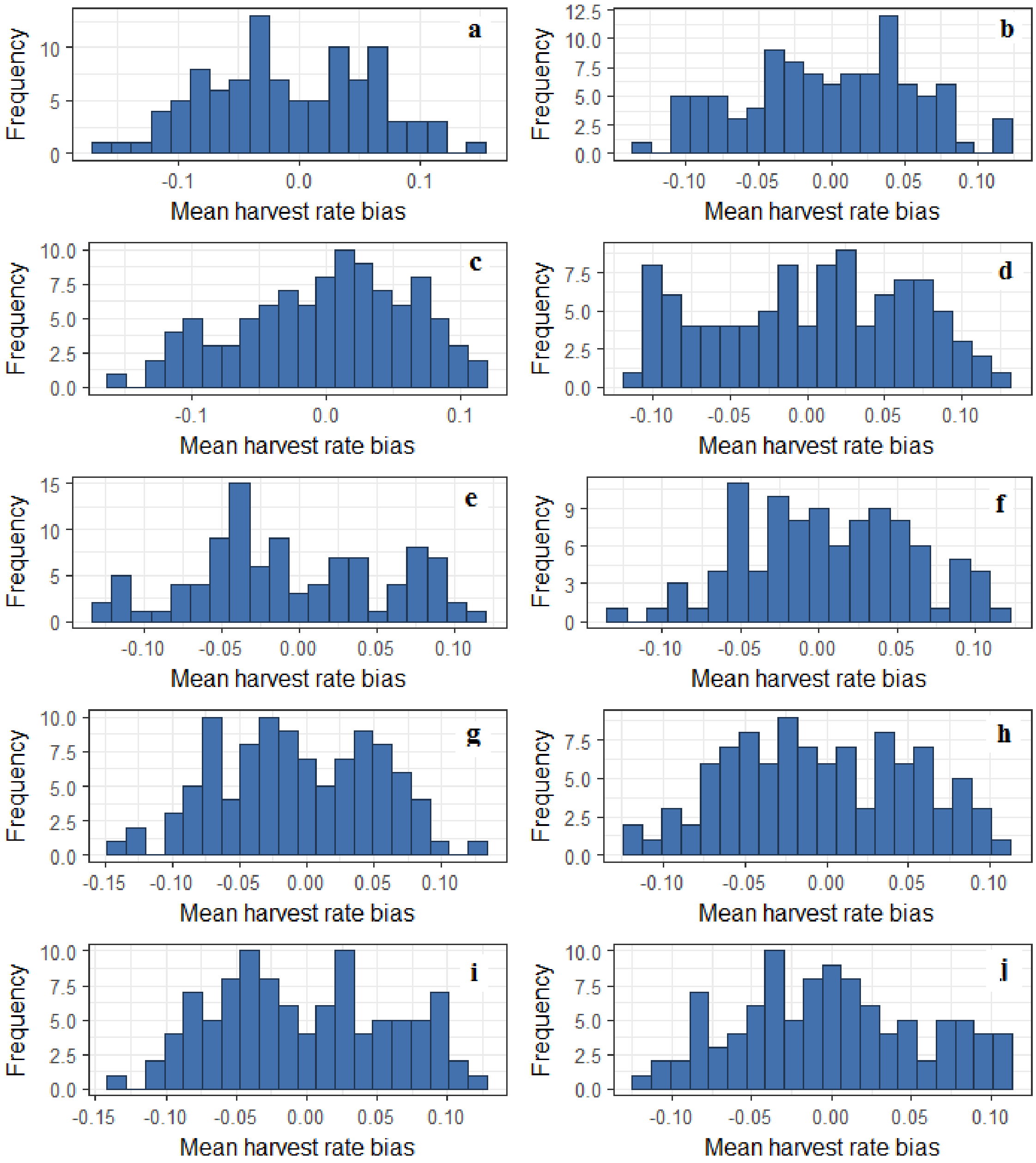

Figure 3. Histograms showing average biases in estimated harvest rates from 100 iterations of 10 different spring turkey removal simulations with varying λ, mean expected abundances, before removals. Levels of λ correspond to figure as follow: a) 2000, b) 2750, c) 3500, d) 4250, e) 5000, f) 5750, g) 6500, h) 7250, i) 8000, and j) 8750.