Bear Management Unit Population Model Report

Prepared by Florida Fish and Wildlife Conservation Commission

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Florida Fish and Wildlife Conservation Commission (FWC) used matrix population models to estimate population growth rates in four of Florida's bear management units (BMUs) and determine the extent to which different levels of harvest mortality reduce population growth. Matrix population models are a well-established method for using demographic information (i.e. survival and fecundity) to calculate population growth rates (Caswell 2001). Under this modeling framework, a projection matrix (**A**) of demographic parameters is multiplied by a vector of age or stage specific abundances from one time period ($\mathbf{n_t}$) to determine the abundance of each age or stage at the next time period as follows:

$$\mathbf{n_{t+1}} = \mathbf{A} \cdot \mathbf{n_t}$$

Asymptotic population growth rates can be determined using Eigen analysis by assuming that demographic rates remain constant through time and that the population is in stable age/stage distribution. This, however, is often an unrealistic assumption that can lead to inaccurate estimates of population growth, and this is especially true for long-lived species where short term (or transient) dynamics can be very different from asymptotic dynamics (Caswell 2001; Stott et al. 2011). Therefore, it is often useful to project the population over a relatively short time period and focus on understanding population growth in the near future. Such transient analyses require a vector of the initial age- or stage-specific population abundances. It is worth noting, however, that results (i.e. population trajectories) derived from transient analyses can be sensitive to initial values.

Demographic rates were drawn from parametric distributions to create female-only, post-breeding projection matrices. The asymptotic annual population growth rate was then calculated from the resulting matrix. This process was repeated 100,000 times for each BMU.

Short term (i.e. transient) population projections under different levels of constant harvest were simulated to determine likely population growth rates. FWC created female-only, post-breeding projection matrices consisting of four stages (or ages), cubs, first year sub-adults, second year sub-adults, and adults. The first three stages were considered ages and were all one year in length, which was the same length as the projection interval. However, the adult stage was not representative of age, as individuals remained in this stage for many years. Efforts to estimate abundance in each BMU will be made every ten years, and it will likely take a few more years to process these data and decide if a management change needs to be made. Therefore, FWC used twelve year projections as this is the likely time interval until the next management decision could be made based on when updated abundance estimates will be available. To initialize the population projections, the initial age/stage distribution was drawn from a mixture of normal distributions (Figure 1). A normal distribution was used to represent the initial proportional abundance of each age/stage with means of 0.25, 0.16, 0.13, and 0.46 for cubs, first year sub-adults, second year sub-adults and adults respectively. The standard deviation of each age/stage normal distribution was 0.1. Next, a draw from each age-specific distribution of proportional abundance was made, and the four values were normalized to sum to one. Next, the initial vector of age/stage abundances was calculated based on the most recent abundance estimate and the random starting age/stage distribution as

$$\frac{\mathbf{N_{2014/2015}} \cdot 0.58 - \mathrm{H_f}}{1 - \theta_{\mathrm{cub}}} \cdot \boldsymbol{\theta}$$

where $\mathbf{N_{2014/2015}}$ is the 2014/2015 abundance estimate which was multiplied by 0.58 to reduce it to females only (i.e. 58% of the population was assumed to be female), $\mathrm{H_f}$ was the number of females harvested in 2015, θ_{cub} was the randomly selected initial proportion of the population that was cubs, and $\boldsymbol{\theta}$ was the vector of the randomly selected initial age/stage distribution. Dividing the 2014/2015 abundance estimates by one minus the randomly selected proportion of cubs accounted for the fact that the abundance estimates only represented sub-adult or older individuals. Different levels of constant harvest were simulated as

$$\mathbf{n_{t+1}} = \mathbf{A_t} \cdot (\mathbf{n_t} - \mathbf{H})$$

where $\mathbf{A_t}$ was a randomly selected projection matrix for each time step (see below) and $\mathbf{H}$ was a vector of the number of females harvested in each stage each year. Various amounts of harvest were simulated to determine how population growth rates changed under different harvest levels, but the harvest was always equally divided between sub-adult and adult females. Based on the mean and range of demographic rates provided for each BMU, beta distributions were fit to survival parameters and log-normal distributions were fit to fecundity parameters. Then, cub survival, sub-adult survival (which was identical for both sub-adult ages), adult survival, and fecundity (only adults reproduce) were drawn from their respective distributions to create a matrix at each time step of the simulation. An annual population growth rate was calculated based on the starting and ending abundances for each simulation. For each BMU, six different harvest levels (including 0) were simulated and 10,000 12-year simulations were performed for each harvest level in each BMU.

The mean population growth rate was greater than one in all BMUs (Figure 2) and transient population projections indicate that some level of harvest will be sustainable in all BMUs. Transient population projections of the East Panhandle BMU resulted in a mean population growth rate of 1.078 (95% CI 1.044 – 1.111) when no harvest occurs (Figure 2) and an annual harvest of 51 females results in the closest mean population growth rate to 1 (mean = 1.00009, 95% CI = 0.9447 – 1.0452). Transient population projections of the North BMU resulted in a mean population growth rate of 1.154 (95% CI 1.124 – 1.186) when no harvest occurs (Figure 3) and an annual harvest of 44 females results in the closest mean population growth rate to 1 (mean = 0.9993, 95% CI = 0.8967 – 1.0684). However, simulations of the North BMU with 44 females harvested annually resulted in some population extinctions (Figure 3). Transient population projections of the Central BMU resulted in a mean population growth rate of 1.022 (95% CI 0.990 – 1.053) when no harvest occurs (Figure 4) and an annual harvest of 17 females results in the closest mean population growth rate to 1 (mean = 0.9988, 95% CI = 0.9643 – 1.031). Transient population projections of the South BMU resulted in a mean population growth rate of 1.122 (95% CI 1.099 – 1.144) when no harvest occurs (Figure 5) and an annual harvest of 78 females results in the closest mean population growth rate to 1 (mean = 0.9995, 95% CI = 0.9407 – 1.0445).

It is important to note that there is uncertainty surrounding estimates of population growth rates from these analyses. FWC has assumed that the use of parametric uncertainty is an adequate characterization of environmental stochasticity present in this system. Specifically, FWC created random matrices by drawing demographic rates from their respective parametric distributions at each time step of a given simulation. FWC does not know, however, how well this approach reflects the actual annual variation in demographic rates in these populations. For instance, if FWC has over- or under-represented environmental stochasticity, then the mean and variance of estimated population growth rates may be inaccurate. This means that while a given harvest level may result in a mean *simulated* population growth rate very close to one, the *realized* (i.e., actual) population growth rate could be

insufficient to stabilize the population and could even lead to population declines. Similarly, some demographic rates in these analyses were derived solely from expert opinion. Other demographic rates may have come from studies that were based on small sample size. Therefore, it is possible that the demographic rates used in these simulations may not truly approximate the demographic rates associated with these populations. Further studies confirming the demographic rates and their annual variability in each BMU would be needed to confirm the validity of the parameters used in these models.

The results of the transient population projections rely on several key assumptions. First is the assumption that harvest of females is equally balanced between sub-adults and adults. Adult survival has the biggest influence on population growth rates for black bears (Freedman et al. 2003) and for most long lived species (Heppell et al. 2000). Harvesting an equal number of sub-adult and adult females reduces the pressure on the adult age class. As such, if harvest were restricted to adult females, the results of these models would be an overestimate of sustainable harvest levels. Other general assumptions (which hold true for any matrix model) are that the choice of the number of age/stage classes is an adequate representation of the demography of the populations and that within each age/stage class there is not significant individual variation in demographic rates. Given these assumptions, the results of these analyses should not be viewed as a forecast of what will happen in each BMU; rather they should be viewed as a description of what would happen in each BMU if populations experienced the conditions FWC has simulated over the next 12 years.

Finally, it should be noted that the Central BMU is one of the largest in the state and has been relatively stable since 2002. In this BMU, the 2002 abundance estimate was 1025 and the 2014 estimate was 1193. These matrix models are density-independent and therefore assume exponential population growth. Under an exponential model the population growth rate must be sufficiently greater than one in order to sustain harvest. It is more likely that the Central BMU is experiencing some form of density-dependence and could sustain a higher level of harvest than reported here. As such, density-dependent models are currently being developed for the Central BMU.

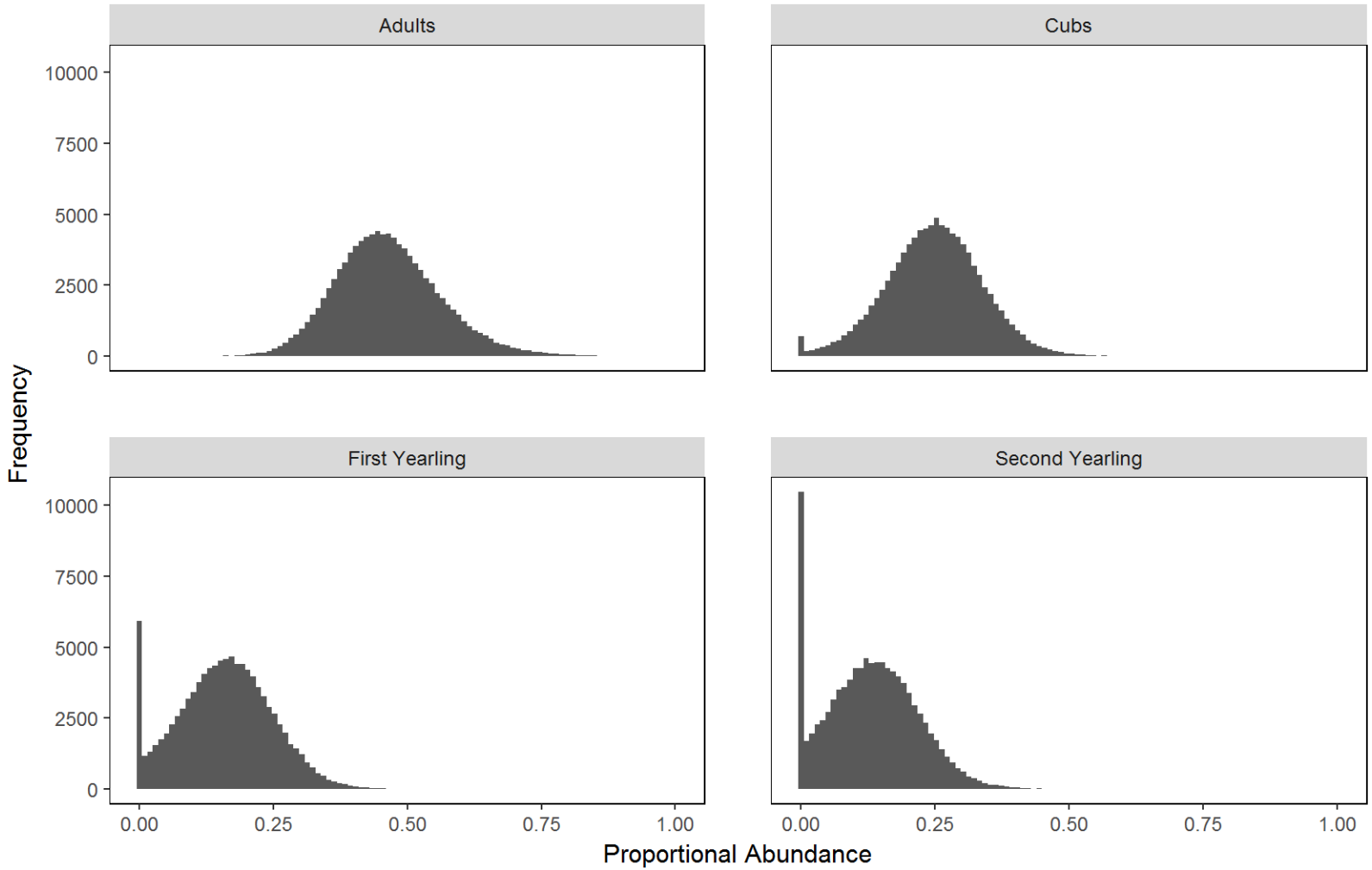

Figure 1. Distributions of initial stage-specific proportional abundances used to initialize each 12 year population simulation.

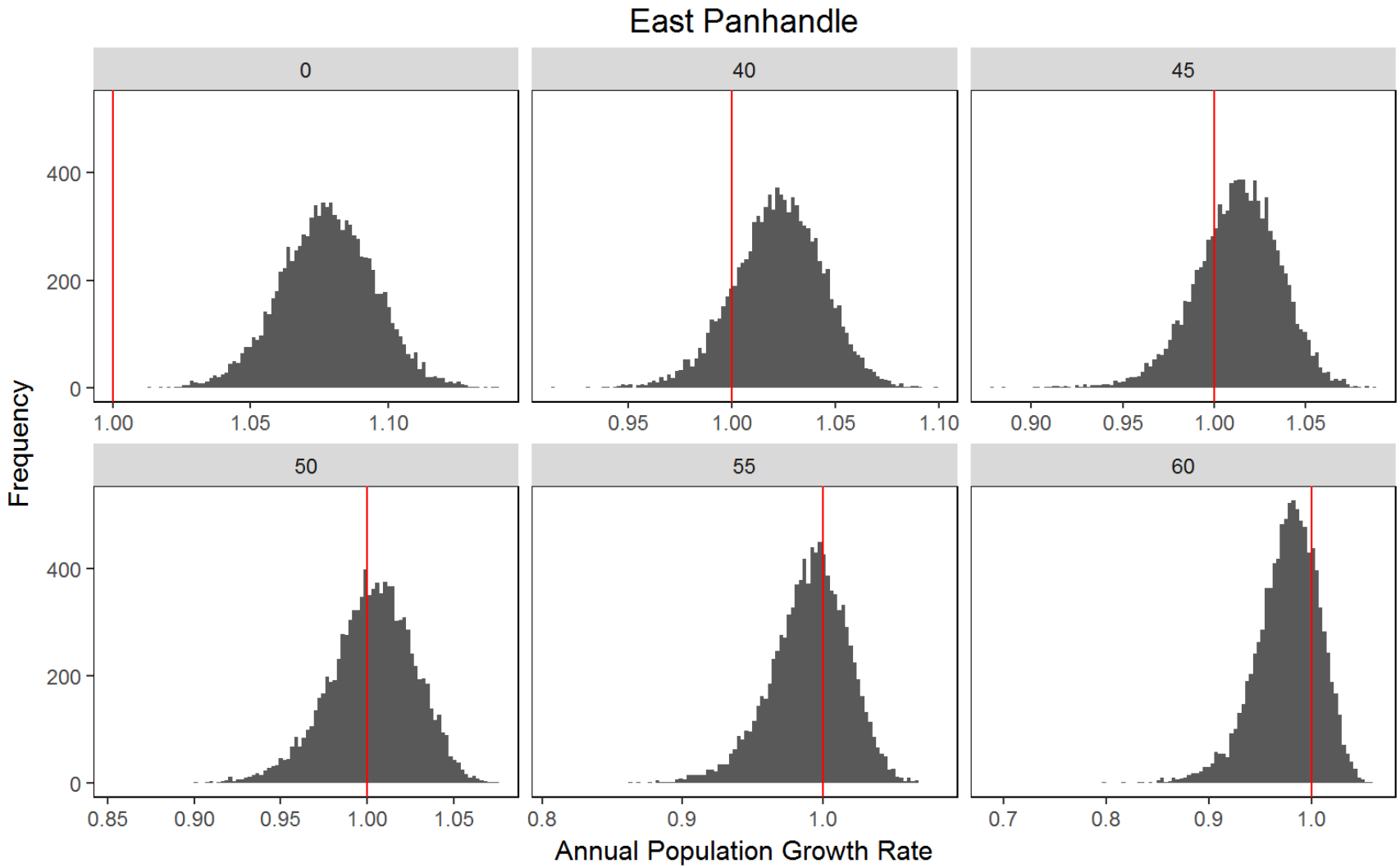

Figure 2. Annual population growth rates in the East Panhandle BMU under six different constant harvest levels. The red line indicates population growth of one, or a stable population.

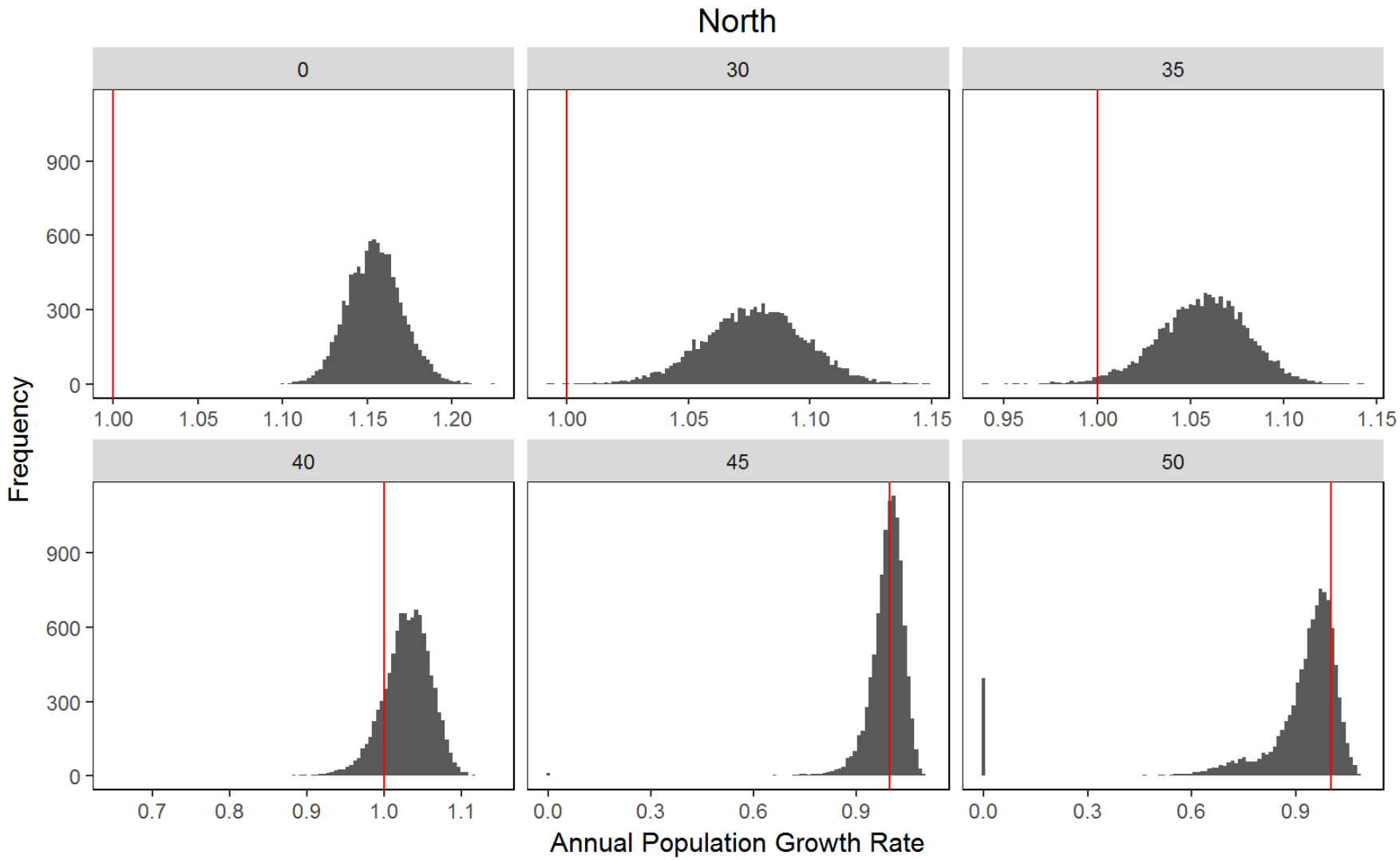

Figure 3. Annual population growth rates in the North BMU under six different constant harvest levels. The red line indicates population growth of one, or a stable population.

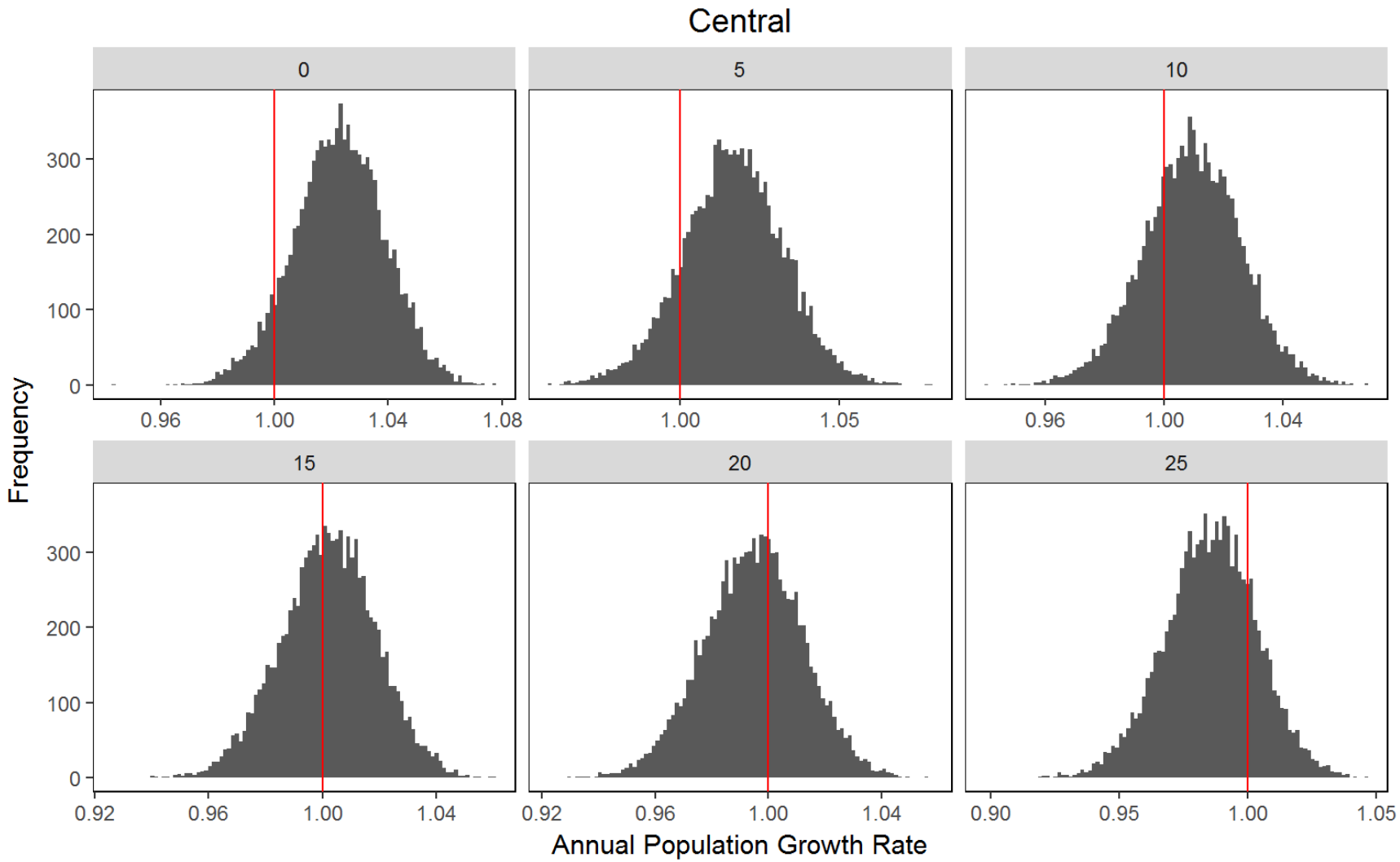

Figure 4. Annual population growth rates in the Central BMU under six different constant harvest levels. The red line indicates population growth of one, or a stable population.

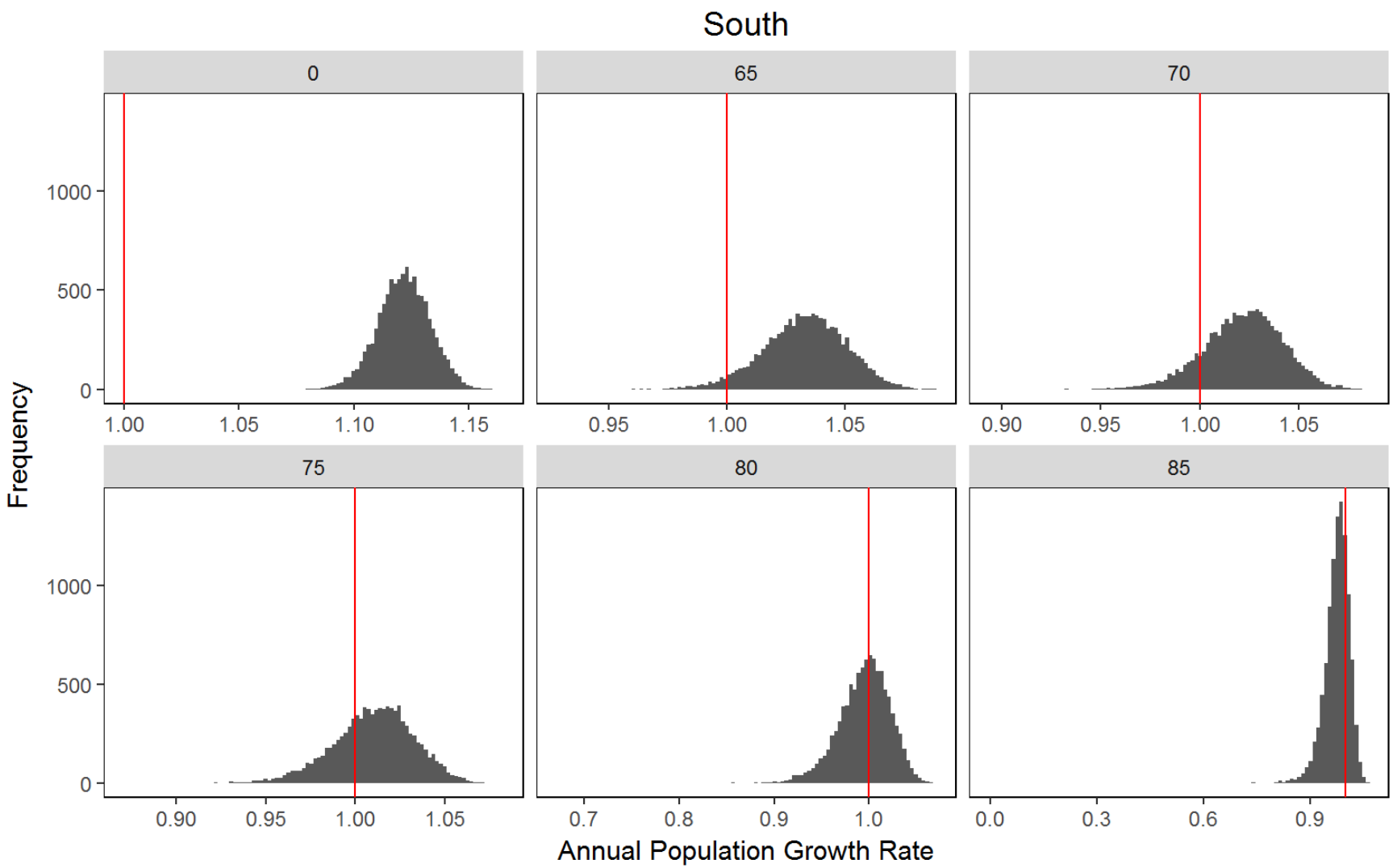

Figure 5. Annual population growth rates in the South BMU under six different constant harvest levels. The red line indicates population growth of one, or a stable population.

Literature Cited

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