Annual Report: Modeling in Support of Adaptive Management of the Rocky Mountain National Park Elk Population

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We used a Bayesian state-space model to estimate the number of elk on low-elevation winter range in Rocky Mountain National Park during during winter 2011-2012. We developed population forecasts for 2012 and 2013 under different alternatives for culling during 2011. Here, we present the results from this work. We also discuss allocation of future sampling effort to support model estimates and management decisions.

Model estimates for 2011

Despite annual culling of adult females from winter range in Rocky Mountain National Park during 2008-2010, we observed a gradual upward trend in model estimates of elk numbers during 2008 to 2011, reversing nine consecutive years (2000 - 2008) of estimated declines (Figure 1). Declining harvest of adult females from Colorado Division of Wildlife Data Analysis Unit 9 during 2006-2010 is implicated in the increasing abundance of elk within the park (Figure 2). Assuming that harvest projections for 2011 accurately estimate realized harvest during 2011 and 2012, and assuming 0 culling in the park, the model forecasts that increases in abundance will continue through 2013, although we cannot rule out the possibility that the population will decline (Figure 3). There is greater uncertainty in these estimates, reflected in broader probability distributions, than we have seen in earlier years because there was no census during 2011. Thus, the 2011 estimate is based on the 2010 census, the 2011 ground classification data, and model estimates of population parameters and population size during 2010.

Model forecasts indicate that in the absence of any culling there is about a 27% chance that the population will be above the target range in 2012, increasing to 35% in 2013 (Table 1). Culling 0 females in 2011-2012 has the greatest probability of maintaining the population within the target range during the next two years, but it is important to note that all culling scenarios have similar probabilities of maintaining the population between 600 and 800 animals. The major differences among scenarios are seen in the probabilities that the population will be above or below the target range. As expected, increasing the number of animals culled increases the probability that the population will be below the target and reduces the probability that it will exceed it.

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Allocation of effort to census

This was the first year that the model's estimate was based on sex and age composition data alone, without census data. The absence of census this year was a result of our advice to park staff that it would be preferable to conduct at least three counts every other year than to perform one count every year. This advice was motivated by the need to properly estimate uncertainty in the census data. In the absence of multiple counts, it is impossible to estimate the sampling variance that results from the fact that elk move in and out of the park daily. As a result of these movements, there are different numbers of animals that are within the census area on any given day. Failing to include this uncertainty in estimates of the average population size will yield populations estimates that are excessively precise and that may be biased. Such estimates are likely to be misleading.

For example, the 2010 census obtained three counts with a mean = 634 and 95% credible interval = 482 - 753. This credible interval simultaneously reflects the uncertainty in the individual estimates (i.e., the estimation error from the sightability model) and the sampling error (i.e., the sampling error from differences among counts). The February 2010 count was 477 with a credible interval of 457 - 496. It is likely that this low and exceedingly precise estimate resulted from the snow on the ground when the count was conducted—there were not as many elk in the park and sightability was high. It was biased downward by the snow conditions and it was overly precise because it did not include any estimate of sampling variance.

It is clear that this count, if it were the only one made, would have produced misleading results on the Park population size. If uncertainties in the data are represented properly, then the model can, to some extent, compensate for biases like these because it "smooths" estimates over years using predictions of population size that are based on multi-year estimates of recruitment and survival. This smoothing is not possible, however, if there is virtually no uncertainty in the census estimate, as is the case in this example. When there is no uncertainty in the data then the census estimate becomes the model estimate, as it should. So, if 447 had been our only count in 2010, the model would have forecast an 82% chance that the population would be below the target range in 2011 and only a 2% chance that it would have been above the range. This almost surely would have caused a cessation in culling for winter 2010-2011. However, based on the three counts that were obtained in 2010, the forecast was only a 31% chance that the population would be below 600 animals, providing a basis for the decision to continue culling. The point is that it is just as important to properly quantify the uncertainty in our estimate of the mean population size as it is to estimate the mean itself. Failing to do so can lead to management choices that are just plain wrong.

For the immediate future, obtaining proper estimates of uncertainty due to sampling error requires multiple counts per year. Three years of multiple counts may allow relaxing this requirement because after multiple years with multiple counts, we will have a reliable estimate of the sampling error (i.e., $\sigma_{sampling}$). This estimate of $\sigma_{sampling}$ could then be combined with a single count or two counts during a winter to obtain a population estimate that includes both estimation uncertainty (from the sightability model) and sampling uncertainty resulting from daily animal movement in and out of the park. Our recommendation is to revisit the sampling regime after three sets of multiple census estimates have obtained. At that point, we can examine the precision of the estimate of sampling variance, and decide about the need for multiple annual counts in the future.

It is difficult to judge the value of sex and age classification from the ground during years when aerial census and classifications are not conducted. Classification data is important for estimating model parameters, particularly recruitment. However, we have a long time series of these data, so it may be that skipping years would not seriously degrade model estimates. That said, the classification could reveal changes in the structure of the population that might result in overly optimistic forecasts. We recommend keeping the ground classifications.

We also urge development of a simple regression model that would allow calibration of ground counts with sightability-corrected counts from the air. A proper model for the relationship between corrected aerial counts and ground counts would provide reasonable estimates, which associated uncertainties, during years that aerial counts are not made.

Until such a model can be developed and evaluated, we strongly urge the continuation of aerial census every other year. The consequences of reducing the counts can be seen in Figure 1. If counts are not done in winter 2011-2012, then the credible intervals for the current *forecast* for 2012 (Figure 1) will be approximately as wide as the *estimate* for 2012. The confidence limits for the 2013 forecast will be similar to those in Figure 1, but those for 2014 will be wider. Thus, in the absence of data during 2012, we will arrive at a point where the credible intervals on the forecast for 2014 span a guess made by any reasonably informed person. This is undesirable.

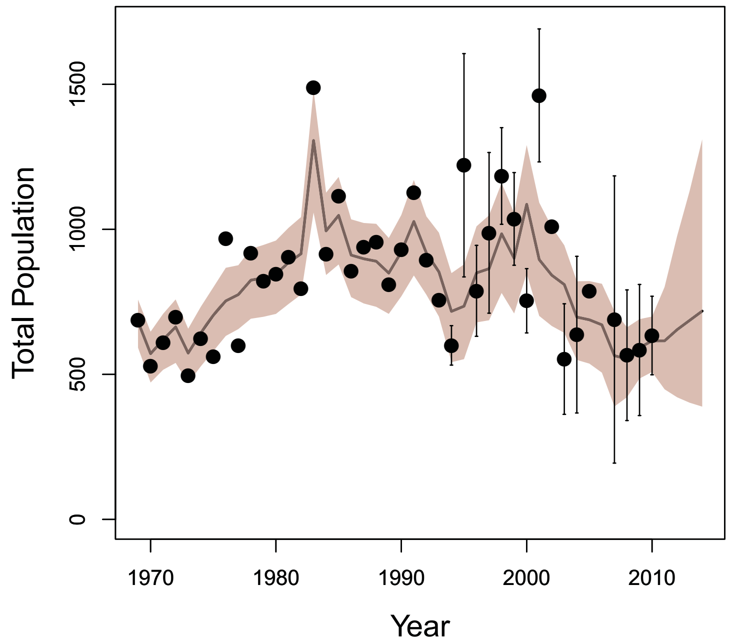

Figure 1: Census estimates (filled circles with ± 2 standard errors) and model estimates of the number of elk on winter range in Rocky Mountain National Park during 1969-2011 and forecasts for 2012, 2013 (solid line). Forecasts assume 0 culling and harvest projections for 2011. Shaded areas give 90% credible intervals on model estimates and forecasts.

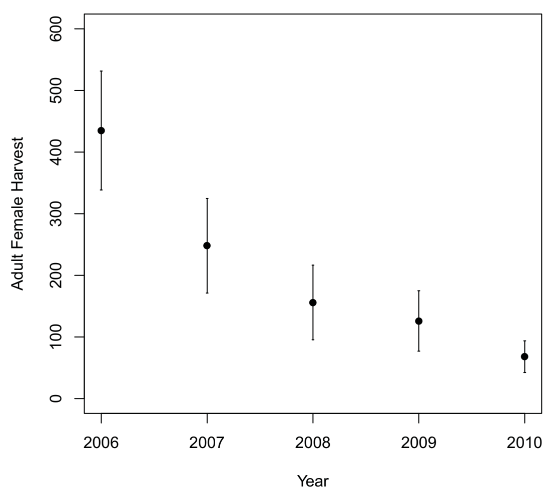

Figure 2: Number of yearling and older females harvested from Colorado Division of Wildlife Data Analysis Unit 9 during 2006-2010. Points are estimates of the mean harvest and vertical bars show ± 2 standard errors.

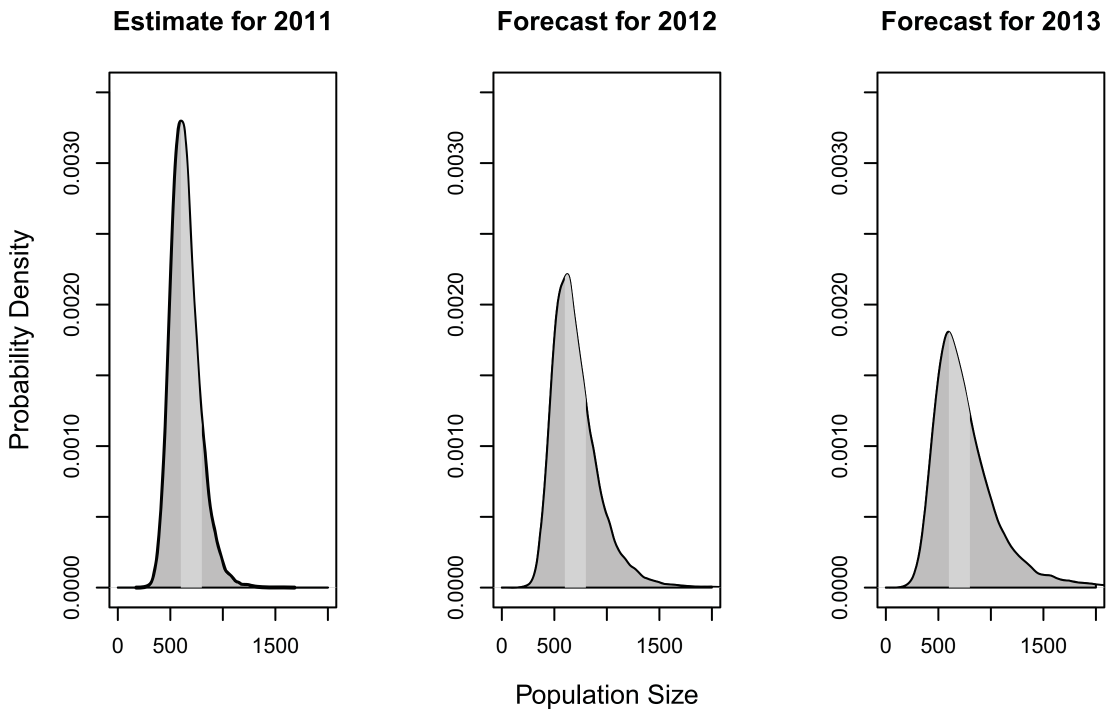

Figure 3: Posterior distributions of estimates of elk population size during 2011, 2012, and 2013. Forecasts assume 0 culling and harvest projected for 2011 in 2011 and 2012. Light grey areas show the target range for elk numbers, 600-800 animals. The total area under each curve = 1. The proportion of each distribution shown in dark grey gives the probability that the population is (or will be) outside the target range during a given year.

Table 1: Estimates of the elk population size on winter Range in Rocky Mountain National Park during 2011 and forecasts of the population size in 2012 and 2013 assuming 4 culling scenarios in 2011-2012. Culling scenarios are 0, 25, 50, and 75 adult females during December - early January.

Year	Median Population Size	95% CI		P(< 600)	P(>=600, <=800	P(>800)
2011	626	423	957	0.41	0.46	0.12
			Cull = 0			
2012	664	390	1268	0.36	0.37	0.27
2013	696	363	1629	0.34	0.31	0.35
			Cull = 25			
2012	639	367	1246	0.42	0.34	0.24
2013	664	336	1595	0.39	0.29	0.31
			Cull = 50			
2012	616	347	1200	0.47	0.33	0.2
2013	630	310	1511	0.45	0.28	0.27
			Cull = 75			
2012	581	317	1166	0.54	0.29	0.17
2013	588	280	1505	0.52	0.24	0.24