An Introduction to Michigan's Bear SCAA Models

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Introduction

The Michigan Department of Natural Resources (DNR) manages the black bear population of Michigan primarily through manipulating hunter harvest by adjusting the quota of hunting licenses. Estimates of the bear population allow the DNR to evaluate the effects of past management decisions, assess the status of the population relative to the DNR's goals, and set license quotas to achieve those goals. The DNR uses a technique called statistical catch-at-age analysis (SCAA) to monitor the bear populations of the Upper Peninsula (UP) and northern Lower Peninsula (NLP).

How the Models Work

The DNR uses two separate SCAA models, one each for the UP and NLP bear populations. The models are structurally similar but are customized for each bear population. Like other statistical models, the SCAA models use *data*, information gathered during the bear registration process and the annual bear hunter mail surveys, in a mathematical framework to estimate unknown characteristics, called *parameters*, of the bear population. The data and parameters can be used in mathematical equations to generate *calculated values* that describe other aspects of the population.

All models are, by necessity, simplifications of real life. We cannot build equations to describe the infinite interactions inherent in wildlife biology, nor could we gather sufficient data to support those equations. Instead, we collect data to represent as much of the variability in the population as possible and use advanced statistical techniques to generate parameter estimates that align with those data as closely as possible. In other words, the data represent reality, the models describe the processes that led to that reality, and the statistical techniques let us quantify those processes. In the case of the SCAA models, we represent reality with the number and composition (sex and age) of bears harvested each year and with independent estimates of the population. (Historically, the independent population estimates have been derived from the hair snare survey in the NLP and the tetracycline survey in the UP. The DNR discontinued the tetracycline survey following the 2014 survey and has initiated a research project to develop a replacement.) Essentially, the models try to answer the question, "What must the population have been to result in the harvest we observed?"

The SCAA models have three primary components that work together to estimate the bear population. The first component is the *Population Sub-Model* which describes how bears are removed from, added to, or age through the population. The actual Population Sub-Model breaks the population down into different sex and age categories, but the diagram in Figure 1 shows a simplified version of the sub-model and how it calculates the changes in the bear population over time. The models begin in 1992 because that is the first year for which all the data are available.

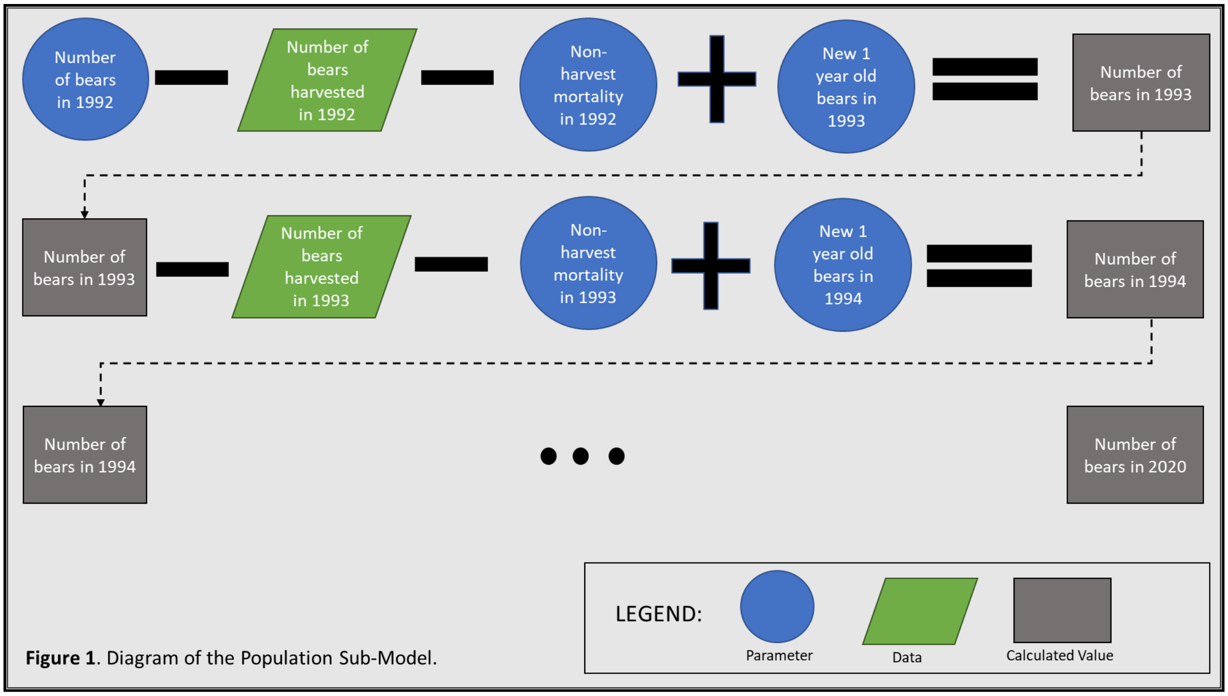

Figure 1. Diagram of the Population Sub-Model.

The *Observation Sub-Model* assumes that we should be able to calculate the number of bears harvested each year if we know the number of bears in the population (from the Population Sub-Model), the number of hunters pursuing bears, and the relationship between the number of hunters and the susceptibility of bears to harvest. If you compare Figure 1 to Figure 2, you'll notice that the number of harvested bears shows up twice: once as data, in the Population Sub-Model, and once as a calculated value, in the Observation Sub-Model. You might be wondering why we would want to calculate something we already know. We do this so we can verify that the population estimate is consistent with the harvest we observed.

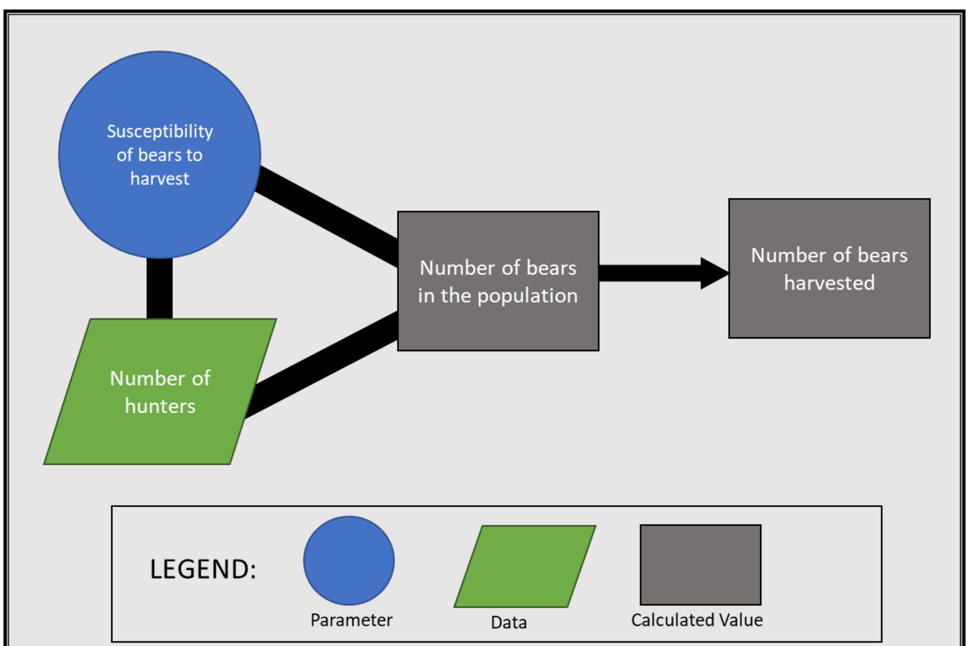

Figure 2. Diagram of the Observation Sub-Model.

The final component of the SCAA models, the *Objective Function*, ties together the two sub-models. In the sub-models, the parameters represent unknown values. The Objective Function gives us a way to generate estimates of the parameters that are most consistent with the data. For a particular set of parameter estimates, we can compute all the calculated values in the sub-models. We then use the Objective Function to compare the calculated values to the data and measure the difference between them. By minimizing the differences, we can use the Objective Function to find the set of parameter estimates that most closely aligns with the data. This happens in an iterative process:

1) Generate a set of parameter estimates.
2) Plug the data and the parameter estimates into the Population Sub-Model and the Observation Sub-Model.
3) Compare the calculated population to the independent population estimates and calculate the difference between them. Compare the calculated harvest to the known harvest and calculate the difference between them. The comparisons are depicted in Figure 3.
4) Use the differences between the calculated values and the data (known harvest and independent population estimates) to calculate the Objective Function value, as depicted in Figure 4.
5) Repeat Steps 1-4 with new sets of parameter estimates until you find the set that has the smallest Objective Function value possible. This ensures that you have found the parameter estimates that provide the best fit of the model to the data.

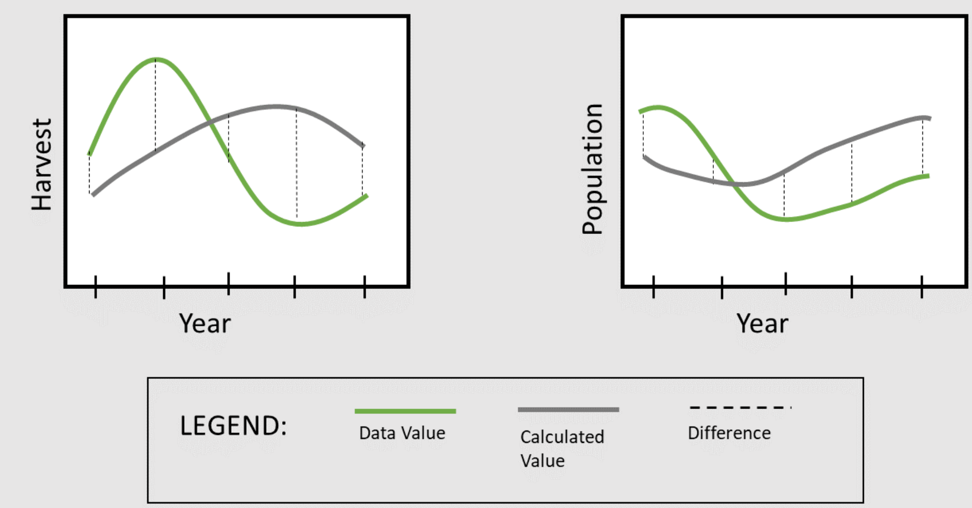

Figure 3. Comparing the calculated values (from the sub-models) to the data values (from harvest registration and independent population estimates).

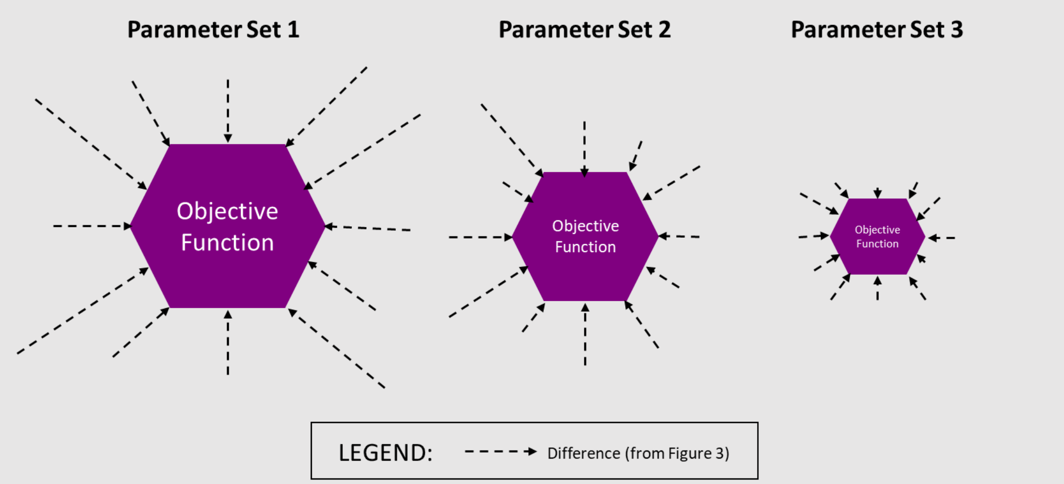

Figure 4. For each set of parameter estimates, the differences between the calculated values (from the sub-models) and the data values (from the harvest registration and independent population estimates) are used to calculate the Objective Function value. The larger the differences, the larger the Objective Function value. The parameter set that has the smallest Objective Function value, Set 3 in this example, allows the sub-models to most closely match the data.

Implications

Just like weather forecasts change over time as the meteorologists gather more data on precipitation, temperature, and windspeed, the SCAA model results change over time as we gather more data on the bear population and harvest. Every year, hundreds of Michigan hunters harvest and register bears and thousands respond to the annual bear mail survey. Every five years (approximately), the DNR conducts a new field survey of the bear population to generate an independent population estimate. Each harvested bear, each survey response, and each independent estimate provides us with new information on the bear population that we incorporate into the SCAA models. In the Population Sub-Model diagram (Figure 1), you can see that the model estimates the initial 1992 bear population as a parameter and then calculates all the annual populations that follow by removing bears from and adding bears to that 1992 population. This means that every time we add new data into a model, the model generates a more refined estimate of the 1992 population (and all the other parameters), which leads to more refined estimates of the population for every year that follows (Figure 5). To draw conclusion about changes in the bear population over time, we can only compare results from the same run of the model. Comparing results from the 2015 model run to the 2020 model run, for example, would be inappropriate because the 2015 model run would be missing 5 years of information and would be based on a different initial population than the 2020 model run.

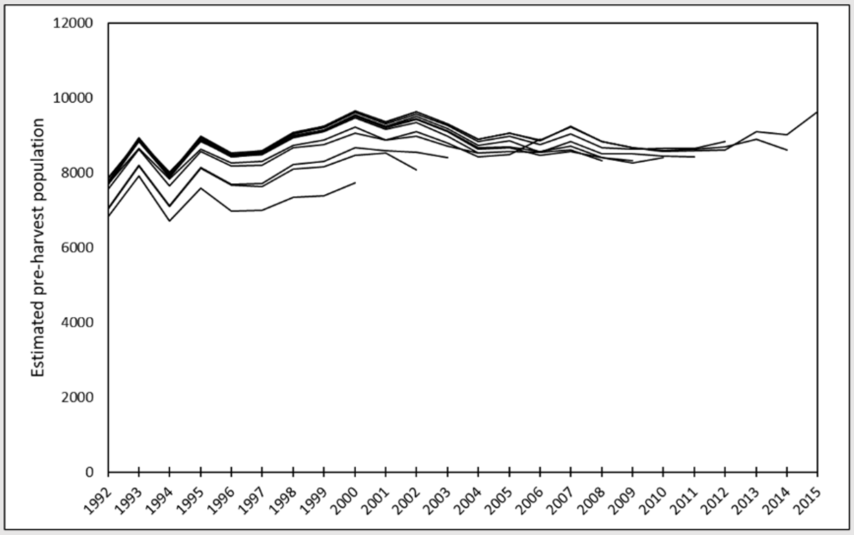

Figure 5. An example of refining population estimates as more years of data become available.

A natural extension of the SCAA models is a projection of future populations. We can apply the parameter estimates derived in the SCAA models to a Projection Model that models future changes in the bear population based on different potential harvest scenarios (Figure 6).

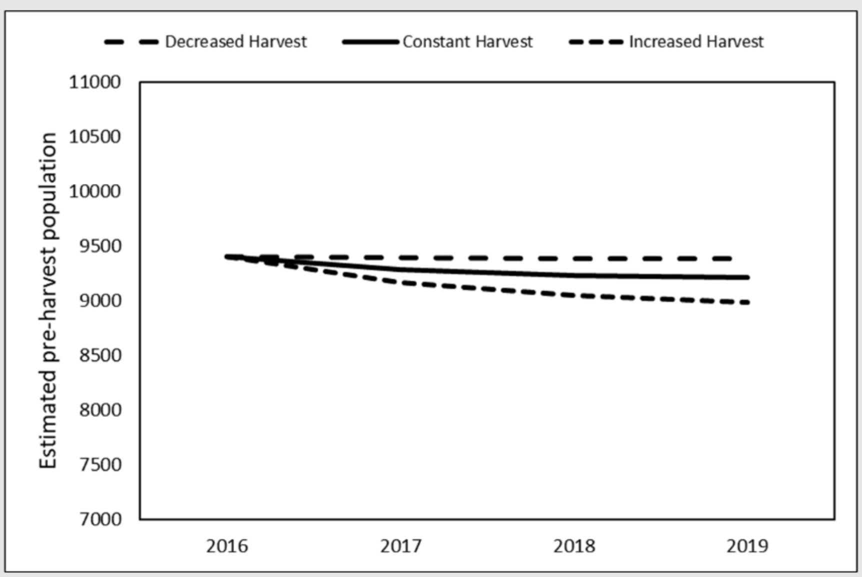

Figure 6. An example of projecting future populations under different harvest scenarios.

Conclusion

The DNR's bear SCAA models play an integral role in the bear management program. They provide the DNR with a science-based method to monitor the bear populations and predict the effects of future harvests. The parameter estimates, including population abundance, are biologically realistic and are estimated from data that represents almost 30 years in the history of Michigan bears. Continuing efforts to collect the harvest data and independent population estimates and to conduct periodic evaluations of model behavior will allow the DNR to continue to use the SCAA models and will ensure the results are realistic and reliable.