

Green = public comment

Blue = peer review

Purple = both public comment and peer review

ISSUE 13: Issues regarding Chao2 (our method for estimating population) (Jennifer):

- Confusion about what the Chao2 estimator is
 - The definition of the "Chao2 estimator" in the Glossary is "a bias-corrected estimator of the total number of female grizzly bears with cubs-of-the-year, derived from the frequency of single sightings or double sightings of unique females with cubs-of-the-year as identified based on a rule set by Knight et al. (1995)." However, throughout the Proposed Rule the Chao2 estimator is referenced as producing an estimate of "overall grizzly bear abundance within the DMA"? This discrepancy should be resolved.
 - Explain the details of model averaging as used with the Chao2 estimator. Model averaging is a method used when alternative methods are evaluated using information-theoretic procedures. This is something that warrants careful attention because of problems that can exist with model averaging (Cade 2015). Or if the intent is to estimate abundance for each year between 2002 and 2014 and to average those estimates clarification needs to be made and the term "model-averaged Chao2 estimate" should be avoided.
- Lack of transparency regarding the Chao2 estimator
 - Is there published literature describing the Chao2 estimator in its entirety?
 - Has the Chao2 population estimator been subjected to peer review?
 - In general, there needs to be more transparency regarding the Chao2 estimator (i.e., What are the demographic inputs and how were they determined? What are the model assumptions? How were initial population size and the different sex-age distributions estimated? and How were natural mortalities estimated and incorporated? etc.)
- Outdated
 - Not the best available science for monitoring population trend
 - Currently use the Knight rule to distinguish unique females with cubs. Ordiz et al. 2007 proposed a different rule set for counts of FCOY in Europe. Knight rule is how we count unique females with cubs (how avoid counting same female twice).
- Unreliable/biased: Need to acknowledge the risk and bias associated with Chao2.
 - Proposed rule fails to account for bias associated with the method or disagreements in the scientific community about the population estimate of ~700 (Doak and Cutler 2014a, 2014b)
 - No accounting for factors that might influence sightings of FCOY (females with cubs of the year)
 - Total population size is strongly influenced by the multipliers used for dependent young, pre-reproductive independent females, and independent males, introducing more bias
 - The Chao2 estimate becomes increasingly negatively-biased with increasing density, so "the Chao2 estimates could level off while the population continues to increase,

- give a false sense of the population reaching carrying capacity (K). Likewise, once the population has exceeded the density threshold of FCOY that precludes further differentiation of distinct individuals, a decline also would not be detectable until dropping below this threshold.” (IBA)
- The Chao2 is only conservative if the population is indeed increasing. If the vital rates or mortalities are misestimated, the population could decline, undetected. (IBA)
 - Chao2 could become more unreliable with increased cub mortality because of more difficulty in distinguishing FCOY (i.e., litter sizes are changing). (IBA)
- Potential errors in usage
- The survival rate (and the multiplier) was increased for independent males in 2012 but survival rates actually decreased (Mattson)
 - Population composition (i.e., changes in sex ratio over time) (how we use sex ratios in population estimation)
 - What has been the trend in sex-age distribution from 2002-2014, the same time period that is used for the Chao2 estimate?
 - Shift to a more conservative 50:50 sex ratio or assume any probable mortality is an adult female.
 - To account for annual fluctuations in cub sex ratio, to be conservative alternative assignment of sex and assign female first.
- Acknowledge ways to manage this bias in the future
- Need to specify that population monitoring will continue indefinitely at the same intensity (neither more nor less) and distribution and under the same design given potential biases in the Chao2 method.

Proposed Rule language

Demographic Recovery Criterion 1

The model-averaged Chao2 method is currently the best available science to estimate the total population size in the GYE. The IGBST has been calculating population size on an annual basis using the model-averaged Chao2 (see glossary) estimate since 2002, and this method has been published in the peer-reviewed scientific literature. The model-averaged Chao2 method is the population estimate method that has the lowest amount of annual variation, and it is the most sensitive method to detect increasing or decreasing population trends over time. As the grizzly bear population has increased, model-averaged Chao2 estimates have become increasingly conservative (i.e., prone to underestimation). As a conservative approach to population estimation, the model-averaged Chao2 method will continue to be the method used to assess Criterion 1 (see U.S. Fish and Wildlife Service 2016, Appendix C, for the application protocol for annual population estimation using the Chao2 method) until a new population estimator is approved. If new methods become available, these will be considered for application in the GYE as long as they represent the best available science. However, until possible new methods are developed, the model-averaged Chao2 method will continue to be used. *Status:* This recovery criterion has been met since 2003 (see IGBST annual reports available at <http://www.nrmssc.usgs.gov/products/IGBST>).

Factor B

Accordingly, the agencies implementing the draft 2016 Conservation Strategy have decided that the population in the DMA will be managed around the long-term average population size for 2002–2014 of 674 (95% CI = 600–747)(using the model-averaged Chao2 estimate). The population inside the

DMA has stabilized itself at this population size through density-dependent regulation. The model-averaged Chao2 method will be used by the IGBST to annually estimate population size inside the DMA (in their entirety: Keating *et al.* 2002; Cherry *et al.* 2007), as this currently represents the best available science. To achieve a population in the DMA around the long-term average of 674, the total mortality limits for independent females will be set at 7.6 percent when the population is at 674, less than 7.6 percent when the population is lower, and more than 7.6 percent when the population is higher (as per table 1, above, and tables 2 and 3, below). A total mortality limit of 7.6 percent for independent females is the mortality level that the best available science shows results in population stability (IGBST 2012, entire). Annual estimates of population size in the DMA will be made each fall by the IGBST using the model-averaged Chao2 method. These annual estimates will normally vary as in any wild animal population. The annual model-averaged Chao2 population estimate for a given year within the DMA will be used to set the total mortality limits from all causes for the DMA for the following year as per table 1, above, and tables 2 and 3, below. Mortalities will be managed on a sliding scale within the DMA as follows (see table 1, above, for more information):

- Below 600: no discretionary mortality would be allowed unless necessary to address human safety issues.
- Between 600 and 673: total mortality limits would be less than 7.6 percent for independent females (>2 years old), 15 percent for independent males (>2 years old), and less than 7.6 percent for dependent young
- At 674: total mortality limits would be 7.6 percent for independent females, 15 percent for independent males, and 7.6 percent for dependent young.

- Between 675 and 747: total mortality limits would not exceed 9 percent for independent females, 20 percent for independent males, and 9 percent for dependent young.
- Greater than 747: total mortality limits would not exceed 10 percent for independent females, 22 percent for independent males, and 10 percent for dependent young.

Glossary

Chao2: The Chao2 estimator is a bias-corrected estimator of the total number of female grizzly bears with cubs-of-the-year, derived from the frequency of single sightings or double sightings of unique females with cubs-of-the-year as identified based on a rule set by Knight *et al.* (1995).

Draft Conservation Strategy language

Demographic Criteria for the Greater Yellowstone Ecosystem, all mortalities and all reports of unduplicated females with cubs-of-the-year (see Appendix C) will be monitored within the DMA (Figure 1). This will result in the management and monitoring of the grizzly bear population in the entire GYE DMA, as opposed to the system in the *1993 Recovery Plan*, which managed and monitored only the population inside the recovery zone and within 10 miles outside the recovery zone. This wider monitoring of mortalities and accounting for mortality limits is more stringent than the system under the *1993 Recovery Plan*. Conservation Strategy demographic standards are tied to the DMA, shown in Figure 1. The criteria and objectives in the existing *1993 Recovery Plan* have modified, as described below.

Conservation Strategy Population Standards

This Conservation Strategy and the state management plans set an objective of maintaining a recovered grizzly bear population in the Yellowstone area sufficient to meet management objectives inside and outside the PCA in biologically suitable and socially acceptable habitats. The demographic standards in this Conservation Strategy are designed to meet these goals.

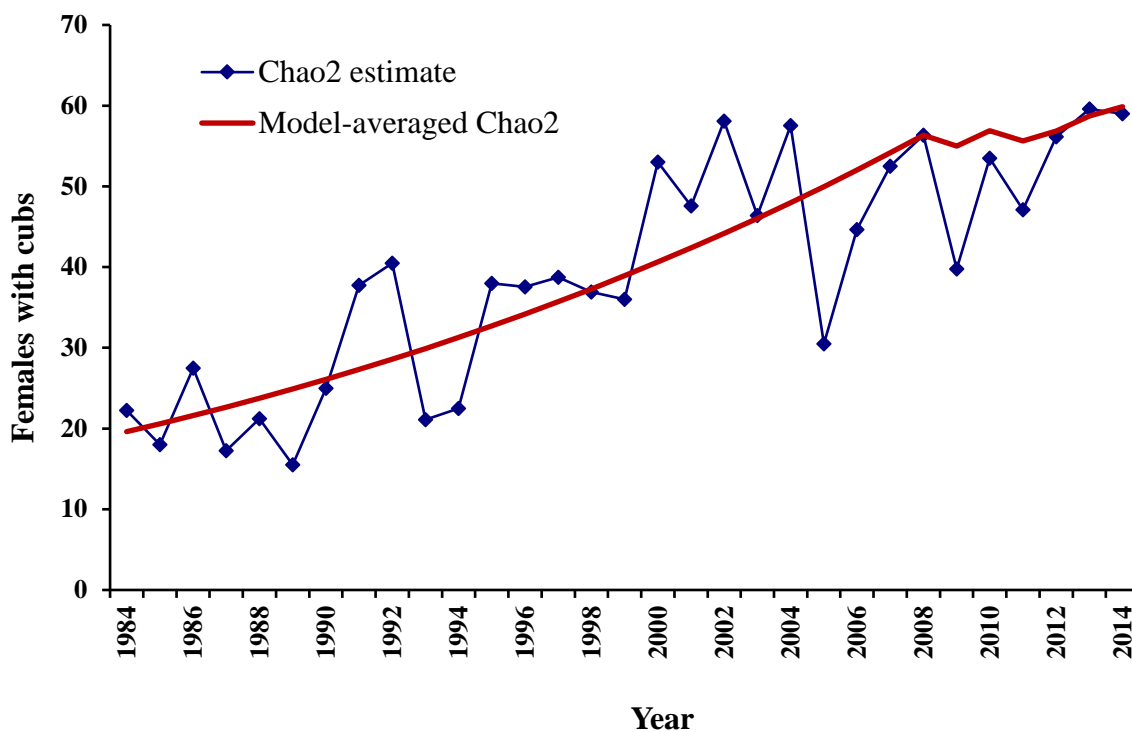
The GYE grizzly bear population exceeds 500 total bears as of 2006 (Appendix M). The intent of the Conservation Strategy is to allow grizzly bears to occupy all biologically suitable and socially acceptable habitats. It is the goal of the agencies of the YGCC implementing this Conservation Strategy to ensure a recovered population in accordance with the established Recovery Criteria. This Conservation Strategy requires continued monitoring of the standards in the 2016 Recovery Plan Supplement to the *1993 Recovery Plan* and some additional standards. These specific population standards, will be applied to the population within the DMA.

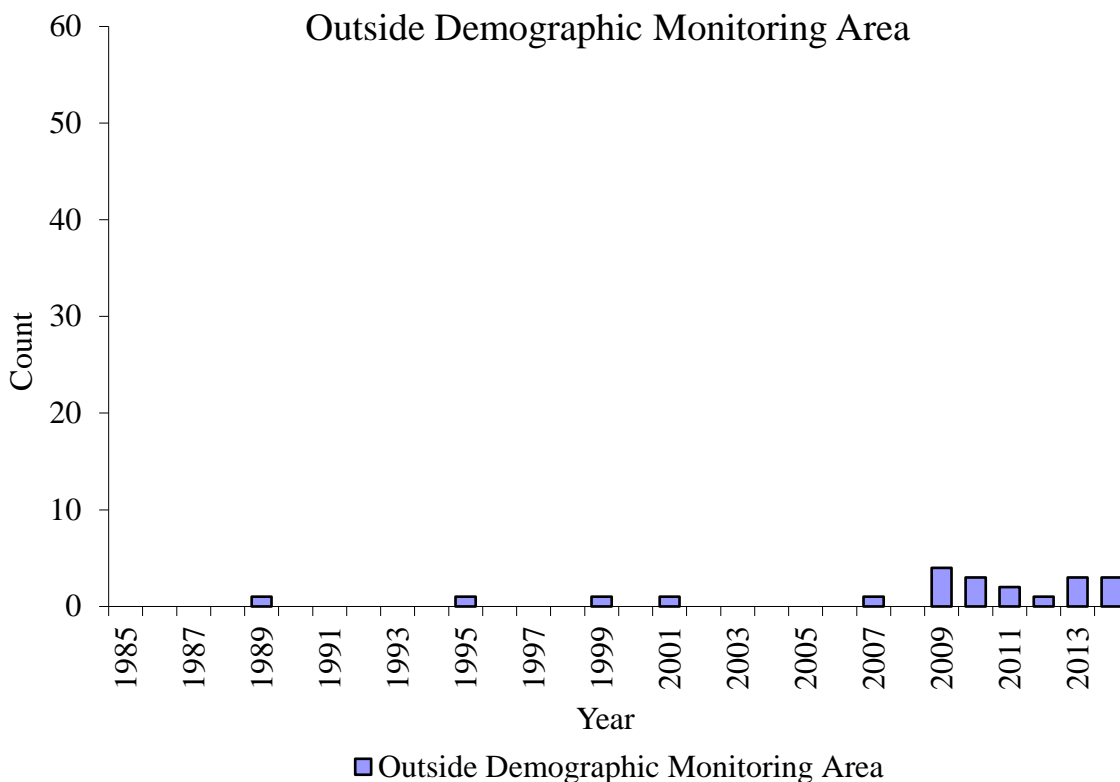
Unduplicated Females with Cubs-of-the-Year

Background

Females with cubs-of-the-year occupy all of the existing bear management units within the PCA as well as areas outside the PCA and DMA (Figure 3).

Figure 3. The Chao2 estimate and model-averaged Chao2 of unduplicated females with cubs-of-the-year inside the Demographic Monitoring Area, as per the Recovery Plan, 1984–2014. Estimates of grizzly bear population size in the Greater Yellowstone Ecosystem are based on the Chao2 estimator. Model-averaged Chao2 estimates were implemented starting in 2007. Estimates for 1984–2007 were model-averaged once, and were annually updated after 2007. Model-averaging is not retroactively applied to update entire time series each year. Starting in 2012, only observations from within the Demographic Monitoring Area (DMA) contribute to population estimates.





Monitoring Protocol

Monitoring unduplicated females with cubs-of-the-year will provide information to demonstrate adequate reproduction and to estimate *total* population size. *Total* population size will be estimated using the model-averaged Chao2 method, as described in Appendices B, C, L, and M using the sightings and resightings of unduplicated females with cubs-of-the-year from within the DMA shown in Figure 1. The IGBST has been calculating population size on an annual basis using the model- averaged Chao2 estimate since 2002. As the grizzly bear population has increased, model-averaged Chao2 estimates have become increasingly conservative (i.e., prone to underestimation). As a conservative approach to population estimation, the model-averaged Chao2 method will continue to be the method used to assess population status and the demographic criteria (see Appendix C for the application protocol for annual population estimation using the model-averaged Chao2 method). The IGBST will

continue to investigate new methods for population estimation as appropriate. If new methods become available, these will be considered for application in the GYE as long as they represent the best available science. However, until possible new methods are developed, the model-averaged Chao2 method will continue to be used. This is a departure from the way the population estimate was done per the *1993 Recovery Plan*. In the *1993 Recovery Plan*, a *minimum* population estimate was made based on the most recent three years of sightings of unduplicated females with cubs-of-the-year, using only unduplicated sights from the recovery zone and 10 miles outside the recovery zone. The revised and improved methodology used in this document allows an estimate of the *total* population using the model-averaged Chao2 method rather than the *minimum* population size. This allows the calculation of mortality limits based on the total population size for each age and sex class (i.e., independent females, independent males, and dependent young) within the DMA (Figure 1). This method allows mortality management and population monitoring of the grizzly bear population in the DMA, as opposed to the method used in the *Recovery Plan*, which focused mortality management and population monitoring on only a portion of the Yellowstone grizzly bear population inside the PCA (the former Recovery Zone) and within 10 miles of the outer boundary of the PCA. The number and distribution of females with cubs-of-the-year can also be used to demonstrate that a sufficient number of adult females are alive within the population to reproduce and offset existing levels of human-caused mortality.

The numbers of unduplicated sightings and resightings of females with cubs-of-the-year inside the DMA will be reported by the IGBST. Using these data, the IGBST will produce the model-averaged Chao2 estimate of the total number of independent females in the population inside the DMA, which will then be used to estimate the total population size in the DMA. This total population estimate will be used to apply the mortality limits as per Table 2 within the DMA for independent females (> 2 years old) and independent males (> 2 years old) from all causes as well as mortality limits for dependent young (\leq 2 years old) from human-caused mortality. For a more detailed description of this methodology, see Appendix C.

Sightings and resightings of females with cubs-of-the-year inside the DMA will be obtained from numerous sources, including radio tracking flights, confirmed sightings, and observation flights.

Observation flights are primarily designed to survey the DMA and the number of flights conducted is standardized to ensure equal effort in obtaining data. The IGBST will verify the reliability of all sightings. The IGBST will plot all sightings and summarize data for unduplicated females and numbers of cubs-of-the-year seen for the entire population. Methodology developed by Knight *et al.* (1995) will be used to separate duplicated from unduplicated sightings (*see Appendix C for more information*).