

APPENDIX C: Calculation of total population size and mortality limits

Efforts to improve the population size estimation and management methods and to reevaluate the sustainable mortality limits in the Greater Yellowstone Area (GYA) began in 2000. These efforts produced two documents that are attached to this Final Conservation Strategy as Appendices N and O. The first document, “Reassessing Methods to Estimate Population Size and Sustainable Mortality Limits for the Yellowstone Grizzly Bear” (hereafter referred to as the Reassessing Methods Document, IGBST 2005) was released for public comment and peer review. In response to comments received during this process, the second document, “Reassessing Methods To Estimate Population Size And Sustainable Mortality Limits For The Yellowstone Grizzly Bear: Workshop document supplement on 19–21 June 2006” (IGBST 2006) was produced after further peer review. Most recently, a third document “Updating and Evaluating Approaches to Estimate Population Size and Sustainable Mortality Limits for Grizzly Bears in the Greater Yellowstone Ecosystem (hereafter referred to as the Updated Demographics document) was prepared in response to updated information and changes in population trajectory related to grizzly bear demographics.

The goal of these workshop efforts is to ensure that mortality management of the GYA grizzly bear population is based on the best available science and to minimize risks to long-term population viability. This effort was undertaken as per the commitment in the Conservation Strategy of all management agencies to employ adaptive management using the best available science to manage the GYA grizzly bear population. The Interagency Grizzly Bear Study Team (IGBST) will use the following procedures to establish and track sustainable mortality for grizzly bears in the GYA and recommends the following specific demographic targets for management. The following demographic criteria apply within the Conservation Strategy Area in Figure 3:

- For independent females (at least 2 years old), the current annual mortality limit, not to be exceeded in 3 consecutive years ~~when the population is ≤ 674~~ , and including all sources of mortality, is dependent on the annual population size (Table 1, Figure 1). Simulations have shown that a 7.6 percent adult female mortality rate allows a stable to increasing population 95 percent of the time (IGBST 2012).
- For independent males (at least 2 years old), the current annual mortality limit, not to be exceeded in 3 consecutive years ~~when the population is ≤ 674~~ , and including all sources of mortality, is dependent on annual population size (Table 1, Figure 2). Independent males can endure a higher rate of mortality compared to females without affecting the overall stability or trajectory of the population because they contribute little to overall population growth (Mace and Waller 1998, pp. 1009-1013; IGBST 2005).
- For dependent young (less than 2 years old), the mortality limit, not to be exceeded in 3 consecutive years and including only known and probable human-caused mortalities, is dependent on annual population size (Table 1) (IGBST 2005, 2012). This limit is less than the 15 percent human-caused mortality of dependent young documented for each sex from 1983 to 2001, a period of population growth and expansion (IGBST 2005). Although it is known that dependent bears experience higher natural mortality rates than independent bears (Schwartz et al. 2006b), there is no known way to accurately document these mortalities directly in the field. Instead, these rates are calculated from consecutive years of observing radio-collared females with young. Mortality thresholds for dependent young grizzly bears have never been exceeded in the GYA.

Table 1. Adaptive annual mortality thresholds by sex and age cohorts of grizzly bears in the Greater Yellowstone Ecosystem based on annual population estimates.

Annual Population Estimate →	≤ 674	675-747	> 747
	≤ _[HM1]		
Independent Aged Female Mortality Limit*	7.6%	9%	10%
Independent Aged Male Mortality Limit*	15%	20%	22%
	≤ _[HM2]		
Dependent Young Mortality Limit*	7.6%	9%	10%

*Mortality threshold calculations (%) are based on that particular segment (i.e, male, female, young) of the population within the overall population estimate.

- For genetic reasons (Miller and Waits 2003, p. 4338) it is desirable that the total population of grizzly bears in the GYA be maintained above 400 bears. To assure that this goal is met and in order to adopt a conservative approach, the total population will be maintained at or above 500 grizzly bears in the GYA using the most appropriate population estimation techniques. The population has been higher than 500 bears since 2002 and has never decreased back to this level (Figure 3). Currently the primary method to estimate population size is extrapolated based on counts of females with cubs of the year (Chao2), however methodologies may change based on approved new and more accurate techniques.

We no longer consider 1993 Demographic Recovery Criterion 1 or 3 to represent the best scientific and commercial data available nor the best techniques to assess recovery of the Yellowstone grizzly bear population because – (1) There are now methods that allow for calculation of total population size on an annual basis (IGBST 2005.; IGBST 2006, IGBST 2012) instead of minimum population size as used in the old method (U.S. Fish and Wildlife Service 1993, pp. 41-44); (2) There are methods to calculate the unknown and unreported mortalities (Cherry et al. 2002, pp. 176-181) and this allows more conservative mortality management based on annually updated information rather than the estimate of unknown and unreported mortality used in the Recovery Plan (U.S. Fish and Wildlife Service 1993); and (3) _[A3]_[HM4] There are now improved and updated data on: the reproductive performance of Yellowstone grizzly bears (IGBST 2012); survival of cub and yearling Yellowstone grizzly bears (IGBST 2012); survival of dependent and independent Yellowstone grizzly bears (Haroldson et al. 2006); the trajectory of the Yellowstone grizzly bear population under alternate survival rates (IGBST 2012); and the impacts of spatial and environmental heterogeneity on Yellowstone grizzly bear demographics (IGBST 2013). These improved data and analyses, since the development of the 1993 Demographic Recovery Criterion 3 (U.S. Fish and Wildlife Service 1993), allow much improved mortality management based on more accurate calculations of total population size and biologically sustainable mortality limits for independent females, independent males, and dependent young.

The IGBST will use the following procedures described in the Reassessing Methods Document (IGBST 2005), summarized in the Supplement to the Reassessing Methods Document (IGBST 2006), and revised in the Updated Demographics Rates Document

(IGBST 2012) to establish and track the total number of grizzly bears and sustainable mortality for grizzly bears in the GYA. The management of grizzly bear mortality will be adaptive, taking into account the most up to date and approved scientific methodologies to evaluate and estimate population trajectory and abundance. (Current approved methods incorporate use of the Chao2 estimator to calculate annual population size.) ~~Regardless of the method of population estimation, mortality thresholds will be calculated based on current population growth indices and size to maintain a population above the agreed upon minimum recovery levels within this Strategy.~~ The^[HM5] following procedures will be updated depending on the approved estimation techniques for the population but serve as an example as to how mortality thresholds would be calculated using current population estimation techniques:

Raw observations of sightings of females with cubs of the year will be separated into observations of unique females with cubs of the year and repeat observations of the same female using the methods of Knight et al. (1995).^[CS6]

1. The Chao2 estimator (Keating et al. 2002) will be applied to sighting frequencies of unique females with cubs of the year to estimate the number of females with cubs of the year in the population.
2. The number of unique females with cubs of the year obtained from the Chao2 estimator each year will be added to the dataset and the model averaging process described in the Supplement to the Reassessing Methods Document (IGBST 2006).
3. The predicted number of females with cubs of the year obtained from the model fit will be used as the best estimate of the total number of independent females with cub of the year in the population for that year.
4. The purpose of the model is to get the best estimate of the current number of females with cubs of the year borrowing information from past estimates, recognizing that with each iteration some change is expected. Retrospectively adjusting estimates from previous years will not occur.
5. The predicted number of females with cubs of the year will be divided by the proportion of females ≥ 4 years old estimated to be accompanied by cubs of the year (transition probability = 0.2965). The resulting value represents the best estimate of the total number of females in the population ≥ 4 years old.
6. The number of females ≥ 4 years old will be divided by the estimated proportion of females ≥ 4 years old in the population of females ≥ 2 years old (0.844). The resulting value is the best estimate of the number of independent females (≥ 2 years old) in the population that year.
7. The sustainable mortality limit for independent females is dependent on the population estimate of independent females (Table 1).
8. Unknown and unreported mortality will be estimated based on the methods of Cherry et al. (2002, p. 179) as described in the Reassessing Methods Document (IGBST 2005).
9. The number of independent males in the population will be based on the estimated ratio of independent males to independent females (1.0) derived via stochastic modeling described in the Supplement to the Reassessing Methods Document (IGBST 2006). The number of independent females in the population will be multiplied by 1.0 and the resulting value represents the best estimate of the number of independent males that year.
10. The sustainable mortality limit for independent males is dependent on the population

estimate of independent males (Table 1).

11. The number of cubs of the year in the annual population estimate will be calculated directly from the model-predicted estimate of females with cubs of the year (IGBST 2006). The number of cubs will be estimated by multiplying the modeled estimate by the mean litter size (2.49) observed from 2002-2011.
12. The number of yearlings will be estimated by multiplying the estimated number of cubs from the previous year by the mean survival rate for cubs (0.553) observed from 2002-2011.
13. The sustainable mortality limit for dependent young (cubs and yearlings) is dependent on the population estimate of dependent young (Table 1). Only human-caused deaths (reported known and probable) will be tallied against this threshold.
14. Unknown and unreported mortality will not be estimated for dependent young.
15. Allowable mortality limits will be established annually following methods detailed here. Because averaged model predictions are used, annual variability among years is addressed. Consequently, annual limits based on a 3-year running average as proposed in the Reassessing Methods Document (IGBST 2005) are not used. Instead, annual mortality limits will be based on the current year data as described in the Updated Demographic Rates Document (IGBST 2012).
16. Estimates of uncertainty about the number of independent females, independent males, dependent young, and total population size will be derived following methods detailed in the Supplement to the Reassessing Methods Document (IGBST 2012).
17. The objective of 48 FCOY from Chao2 will be based on the estimated number resulting from the model averaging technique (IGBST 2012).
18. A biology and monitoring review by the IGBST will occur should the predicted estimate from model averaging decline below 48 females with cubs of the year for any 2 consecutive years.
19. Agencies will implement management to attempt to limit female mortality if the model predicted estimate of Chao2 drops below 48 females with cub of the year in any given year.
20. A biology and monitoring review by the IGBST will occur if independent female mortality exceeds the annual mortality limit listed in Table 1, ~~when the population is $\leq$ 674~~, in any 3 consecutive years.
21. A biology and monitoring review by the IGBST will occur if independent male mortality listed in Table 1 ~~when the population is $\leq$ 674~~, exceeds the annual mortality limit in any 3 consecutive years.
22. A biology and monitoring review by the IGBST will occur if dependent young mortality exceeds the annual mortality limit in any 3 consecutive years.
23. If the AICc weight favors the quadratic term (i.e., >0.5) in modeling the rate of change of females with cubs as described in (IGBST 2006), a full review of the population's demographics will be undertaken to better understand its status.
24. If dead bears are reported in years subsequent to actual year of mortality, they will be tallied against year of death and the mortality total will be recalculated. If mortality exceeds the threshold for that year, the difference (total mortality minus threshold) will be counted against the current years' threshold. If sex cannot be determined, sex will be assigned randomly using ratio of 59:41 male:female as recommended in Appendix A of Schwartz and Haroldson (2001).
25. Any change in the methods described in the Updated Demographic Rates Document would be considered a change to this Conservation Strategy and would be revised through the Yellowstone Grizzly Bear Coordinating Committee process and based upon

the best available science, as per p. 63 of this Conservation Strategy. The methods described to estimate population size and calculate mortality thresholds may change in the future as new scientific approaches become available or new data are analyzed that might require such a revision. The IGBST would produce a peer-reviewed report evaluating any new scientific data or methods and present this report, along with recommendations, to the Yellowstone Grizzly Bear Coordinating Committee. Any such recommendations would then be open to public comment. After considering public comments, the Yellowstone Grizzly Bear Coordinating Committee would decide whether to append the recommended revisions to the Conservation Strategy through a majority vote. No changes in the population management systems will be made unless these changes are based on the best available science and the changes have been subject to peer review and an open public process.

Figure 1. Estimated percent mortality for independent aged (≥ 2 years old) female grizzly bears in the GYA, 2002-20014. See IGBST (2012) for method of estimating total mortality and numbers of independent females.

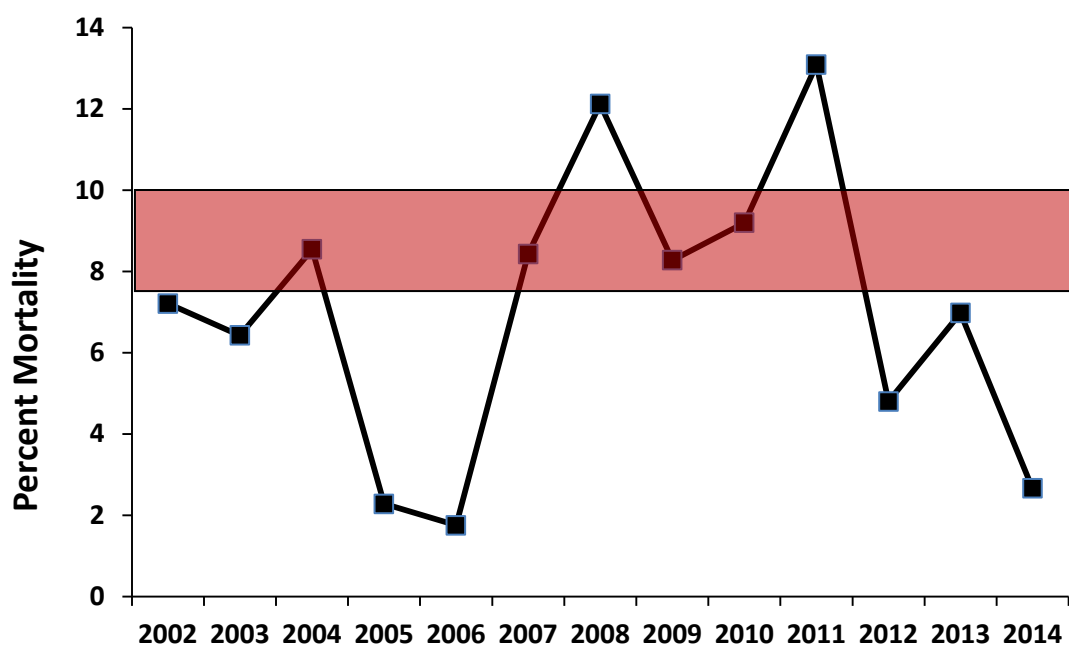


Figure 2. Estimated percent mortality for independent aged (≥ 2 years old) male grizzly bears in the GYA during 2002-20014. See IGBC (2012) for method of estimating total mortality and numbers of independent males.

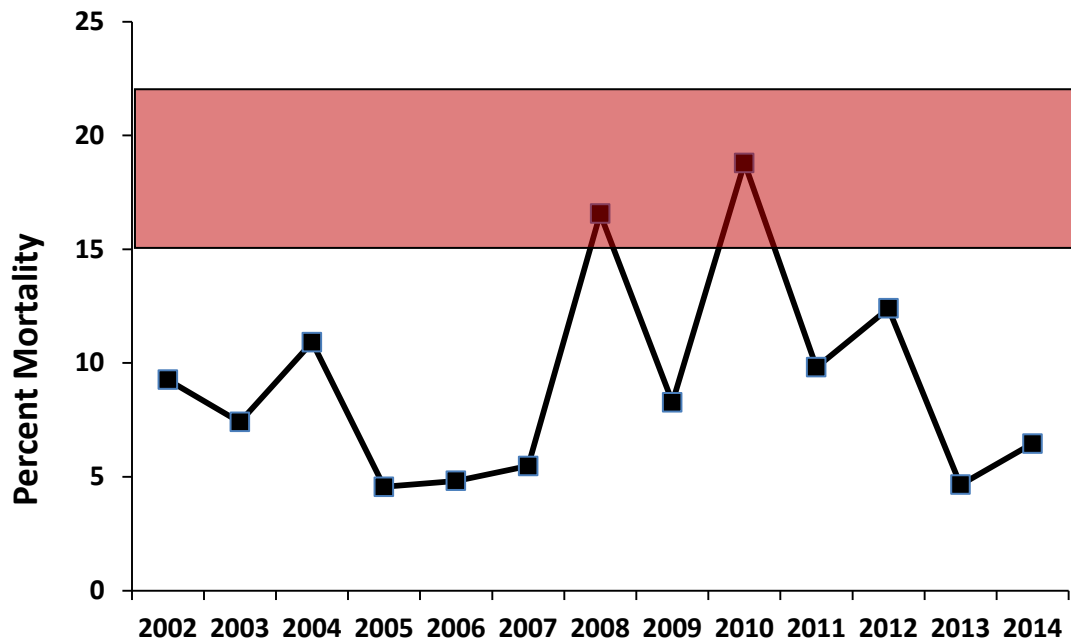
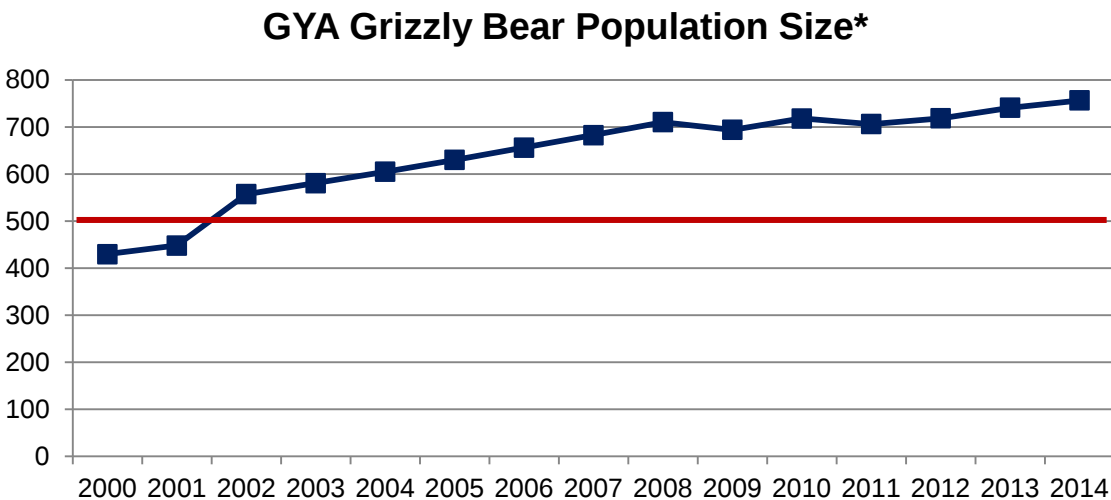


Figure 3. Population size estimated using the Chao2 estimator technique with the updated rates and ratios for grizzly bears in the GYA 2000 - 2014. The solid red line represents the minimum estimate to meet Recovery Criterion 1.



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