

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) have continued with the IGBST taking the lead in these efforts. Notably, several special reports have been produced including: “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), which was released for public comment and peer review. In response to comments received during this document, a 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” (IGBST 2012) (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. This 2012 document is attached to this 2016 Conservation Strategy as Appendix.

The goal of these IGBST workshop efforts is to assemble internal and outside experts to review existing methods and to develop new population estimation methods in order to assure that population estimation and mortality management methods for the GYE grizzly bear population is based on the best available science. 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:

The population has basically stabilized inside the DMA since 2002 with the model-average population estimate 2002–2014 (using the Chao2 population estimate this average number is 674). This population stabilization over 13 years is strong evidence that the population is exhibiting density dependent population regulation inside the DMA and this has recently been documented (van Manen *et al.* 2015, entire). The fact that the population inside the DMA has stabilized due to density dependent effects is strong support that the population has achieved recovery within the DMA. Thus, the selection of the average population size 2002–2014 when the population has been essentially stable is biologically credible as a population that is recovered and at the carrying capacity of the suitable habitat in the ecosystem.

Table 1. Annual mortality thresholds by sex and age cohorts¹ of grizzly bears in the Greater Yellowstone Ecosystem under the protocol to manage for a population at the average annual population estimate for the period 2002–2014 in the Demographic Monitoring Area (DMA) (using the Chao2 estimator this average number is 674).

	Population estimate inside the DMA using the model-averaged Chao2 method.			
	<674	674	675-747	>747
Maximum mortality rate for % of independent FEMALES	≤7.6%	7.6%	9%	10%
Maximum mortality rate for % of independent MALES	<15%	15%	20%	22%
Maximum mortality rate for % of DEPENDENT YOUNG	≤7.6%	7.6%	9%	10%

Table x. Application protocol for the Conservation Strategy population standards.

Scenario	Management response
1. If the population is less than 600 as measured with the model-averaged Chao2 method.	No discretionary mortality unless necessary to address human safety issues.
2. Exceeding independent female mortality limit at any time during the year.	Suspend grizzly hunting in the DMA upon exceeding the limit. The number exceeding the allowed mortality limit in any year will be subtracted from the next year's discretionary mortality for independent females.
3. Exceeding independent female mortality limit for 3 consecutive years.	Suspend grizzly hunting pending completion of an IGBST biology and monitoring review. FWS may implement a status review.
4. Exceeding independent male mortality limit for 3 consecutive years.	Suspend grizzly hunting inside the DMA pending completion of an IGBST biology and monitoring review. The number exceeding the allowed mortality limit in any year will be subtracted from the next year's discretionary mortality for independent males.
5. Exceeding dependent young mortality limit for 3 consecutive years.	No grizzly hunting inside the DMA pending completion of an IGBST biology and monitoring review. The number exceeding the allowed mortality limit in any year will be subtracted from the next year's discretionary mortality for dependent young.
6. Failure to meet distribution of reproductive females criterion.	IGBST biology and monitoring review.
7. Changes in Federal, State, or Tribal laws, rules, regulations, or management plans that depart significantly from the specifics in the Conservation Strategy.	FWS may initiate status review.

¹ Mortality threshold calculations (%) are the percentage of that cohort (i.e. male, female, young) within the total population estimate.

Methods used in this protocol are 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). Any change in the methods described below would be considered a change to the Conservation Strategy and would be revised through the Yellowstone Grizzly Bear Coordinating Committee process and based upon the best available science, as per p. xx of this Conservation Strategy. 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.

The IGBST will use the following methods to establish and track the total number of grizzly bears in the DMA and thereby establish the mortality limits for grizzly bear sex/age cohorts in the DMA as per Table 1. The current and approved method to estimate population size in the DMA uses the Chao2 estimator. The following procedures detail how population size and therefore mortality thresholds would be calculated:

1. Observations of sightings of females with cubs of the year¹ will be separated into an estimate of unique females with cubs of the year and repeat observations of the same female using the methods of Knight et al. (1995).
2. The Chao2 estimator (Keating et al. 2002) will be applied to sighting frequencies of unique females with cubs of the year to estimate the total number of females with cubs of the year in the population.
3. Only sightings of unique females with cubs of the year from within the DMA will be used for subsequent estimates.
4. The number of unique females with cubs of the year obtained from the Chao2 estimator each year will be added to the long-term dataset to conduct the model-averaging process described in the Supplement to the Reassessing Methods Document (IGBST 2006). This process involves fitting a linear and a quadratic trend model, followed by averaging of model parameters based on the respective Akaike's Information Criterion (AIC_c) weights of the linear and quadratic models. These model-averaged parameters are then used to estimate the number of females with cubs of the year.
5. The estimated number of females with cubs of the year obtained through model averaging will be used as the best estimate of the total number of independent females with cubs of the year in the DMA for that year.
6. The purpose of fitting the trend models is to obtain the best estimate of the current number of females with cubs of the year by using information from past estimates, recognizing that with each iteration some change is expected. Retrospectively adjusting estimates from previous years will not occur.
7. The estimated 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

¹ Adult female grizzly bears with cubs of the year less than one year old.

- estimate of the total number of females in the population ≥ 4 years old.
8. 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 (proportion = 0.844). The resulting value is the best estimate of the number of independent females (≥ 2 years old) in the population that year.
 9. The sustainable mortality limit for independent females is dependent on the population estimate of independent females (Table 1).
 10. 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).
 11. The number of independent males in the population will be based on the estimated ratio of independent males to independent females (ratio = 1:1) derived via stochastic modeling described in the Supplement to the Reassessing Methods Document (IGBST 2006). The number of independent females in the population will thus be multiplied by 1.0 and the resulting value represents the best estimate of the number of independent males that year.
 12. The sustainable mortality limit for independent males is dependent on the population estimate of independent males (Table 1).
 13. The number of cubs of the year in the annual population estimate will be calculated directly from the model-averaged estimate of females with cubs of the year (IGBST 2006). The number of cubs will be estimated by multiplying the model-averaged estimate by the mean litter size (litter size = 2.49; mortality adjusted estimate) observed during 2002–2011.
 14. 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 (cub survival = 0.553) observed during 2002–2011.
 15. 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.
 16. Unknown and unreported mortality will not be estimated for dependent young.
 17. Allowable mortality limits will be established annually following methods detailed here. Because model-averaged estimates are used, annual variability among estimates is explicitly 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).
 18. 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 2006) using update vital rates as documented in IGBST (2012).
 19. The objective of 48¹ females with cubs of the year as estimated with Chao2 will be evaluated based on the model-averaged estimate of females with cubs of the year

¹ 48 FCOY in the DMA is approximately equivalent to a population of 600 bears.

(IGBST 2012).

20. A biology and monitoring review by the IGBST will occur should the model-averaged Chao2 estimate decline below 48 females with cubs of the year for any 2 consecutive years.
21. Agencies will implement management to attempt to limit female mortality model-averaged Chao2 estimate decline below 48 females with cub of the year in any given year.
22. If the AIC_c weight favors the quadratic term (i.e., AIC_c weight > 0.5) in modeling the rate of change of females with cubs of the year as described in (IGBST 2006), a full review of the population's demographics will be undertaken to better understand its status.
23. If dead bears are reported in years subsequent to actual year of mortality, they will be tallied against year of death and total mortality 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).