

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 Ecosystem (GYE) have continued with the Interagency Grizzly Bear Study Team (IGBST) leading 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, Appendix L), which was released for public comment and peer review. In response to comments received during this process, 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” (hereafter referred to as the Supplement to the Reassessing Methods Document, IGBST 2006, Appendix M) 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, IGBST 2012) 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 N.

The goals of these IGBST workshops were to assemble internal and external experts to review and enhance existing methods and, to the extent feasible, use existing data to develop new population estimation methods in order and ensure that population estimation and mortality management methods for the GYE grizzly bear population are 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 GYE grizzly bear population.

The IGBST will use the protocol described in this Appendix to annually estimate population size within the Demographic Monitoring Area (DMA), and then set mortality limits inside the DMA for the following year based on the sliding scale in Table 1. 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, or adoption of an alternative population estimation method, would be considered a change to the Conservation Strategy and would be developed and/or evaluated by the IGBST, and revised through the Yellowstone Grizzly Bear Coordinating Committee process with the requirement that any proposed changes:

1) be based upon the best available science; 2) go through public review before they are accepted, as per p. 99 of this Conservation Strategy, and 3) be consistent with the recovery criteria (RP 2016).

Table 2. Total mortality rates used to establish annual total mortality limits for independent females, independent males, and dependent young inside the DMA. For populations less than 600, there will be no discretionary mortality unless necessary for public safety or management of bear-human conflicts.

	Total Grizzly Bear Population Estimate*		
	≤674	675-747	>747
Total mortality rate for independent FEMALES ,	57.6%	9%	10%
Total mortality rate for independent MALES ,	15%	20%	22%
Total mortality rate for dependent young.	57.6%	9%	10%

*using model-averaged Chao2

The following procedures detail how population size and 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).

¹ Adult female grizzly bears accompanied by cubs that are less than one year old.

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2. Only sightings of unique females with cubs-of-the-year from within the DMA will be used for subsequent estimates.
3. 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.
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 quadratic trend model, followed by averaging 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 the model averaging will be used as the best estimate of the total number of independent females with cub-of-the-year in the DMA for that year.
6. The purpose of fitting the trend model 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) observed during 2002–2011. The resulting value represents the best 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) observed during 2002–2011. 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) as described in the Reassessing Methods Document (IGBST 2005).

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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) observed during 2002–2011 and 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 of females with cubs-of-the-year 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 the threshold for dependent young.
16. Unknown and unreported mortality will not be estimated for dependent young.
17. Sustainable mortality limits will be established annually based on the data collected in that year and the calculations described here. These mortality limits will then apply the following year. 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 sustainable mortality limits for any year will be based on the data and calculations for the previous year (as described in this protocol and the Updated Demographic Rates Document, IGBST 2012, Appendix N).
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

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Supplement to the Reassessing Methods Document (IGBST 2006) using updated vital rates as documented in IGBST (2012, Appendix N).

19. The objective of 48² 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 (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 3 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. In modeling the rate of change (trend) of females with cubs-of-the-year as described in the Supplement to the Reassessing Methods Document (IGBST 2006), if the AIC_c weight favors the quadratic term and corresponding $\Delta AIC_c \geq 2.0$ compared with the linear model for 3 consecutive years, a full review of the population's demographics will be undertaken to better understand its status. Given evidence of a population nearing carrying capacity and a population fluctuating around a long-term mean, this approach allows timely detection of a sustained increasing or decreasing trend (van Manen *et al.* 2015).
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.
24. For bears that are estimated to be independent of age, 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).

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² 48 independent females with cubs of the year in the DMA is approximately equivalent to a population of 600 bears.

Table 1. Annual sustainable mortality limits by sex and age cohorts³ 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).

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

% of DEPENDENT YOUNG	<7.6%	7.6%	9%	10%
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³ Sustainable mortality estimates are based on the sustainable mortality percentage of the respective population segment relative to the population estimates.

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