SIMULATIONS OF GRIZZLY BEAR POPULATION AUGMENTATION ON TREND ESTIMATES IN THE CABINET-YAAK RECOVERY ZONE

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Abstract: Recent population trend (λ or lambda) calculations for the Cabinet-Yaak ecosystem grizzly bear population indicate decline (λ = 0.930). Improved survival of bears and population augmentation are necessary in this area to reverse this decline. Grizzly bear population augmentation has been tested successfully in the Cabinet Mountains and has been continued during 2005 with the addition of another adult female. Simulations of additional augmentation suggest that 12-24 grizzly bear transplants would be necessary under 2 different improved survival scenarios to produce a stable population trend (λ = 1.000). Successful recovery of the Cabinet-Yaak grizzly population will require a combination of improved survival, augmentation of additional bears, and functional linkage between the Cabinets and Yaak portions of this ecosystem.

Introduction

This analysis was completed to understand the number of augmentation bears necessary to return the population trend (λ or lambda) in the Cabinet-Yaak ecosystem to ≥1.0 from the current estimate of 0.930 (Kasworm in prep. 2006).

Methods

We used the software program BOOTER 1.0 (© F. Hovey) to estimate the finite rate of increase (λ or lambda) for the study area's grizzly bear populations. The estimate of λ was based on adult and subadult female survival rates, yearling and cub survival rates, age at first parturition, reproductive rate, and maximum age of reproduction. The data files from previous calculations were updated with data through 2005 and additional bears incrementally added under two survival scenarios to produce a resulting λ ≥ 1.000 (Hovey and McLellan 1996,

Wakkinen and Kasworm 2004, Kasworm et al.2005). All simulations with BOOTER were performed with the unpaired reproductive data option and 5,000 bootstrap runs (5,000 is the maximum allowed by the software).

We treat these simulations as results for the Cabinet-Yaak ecosystem as a whole because the data sets used are from the entire ecosystem. We recognize that currently the Cabinet Mountains are fragmented from the Yaak River area, however the recovery unit in the 1993 Grizzly Bear Recovery Plan (USFWS 1993) is the Cabinet-Yaak ecosystem and our objective is recovery of the area as a whole. We further assume that by placing bears into the Cabinet Mountains this will eventually increase the probability of reestablishing connection between these two areas within this ecosystem as long as our ongoing efforts to identify linkage areas and to implement management to maintain movement opportunities in these linkage areas continue and are funded. Therefore our conclusions are valid under the assumption that the Cabinet and Yaak ecosystems become functionally connected. Additional assumptions utilized in this calculation were:

- Bears added in this simulation can occur as transplants by population augmentation, however subsequently captured native bears may affect the estimate of λ through their additive survival and reproductive rates;
- Additional bears were added as 3 year olds on August 1;
- Additional bears are female and 50% have first parturition at 6 years-old and 50% at 7 years-old;
- Additional female bears are assumed to breed successfully with native males;
- Bears and their offspring survive as stated in a particular simulation;
- Litter size of bears added in the simulation is always 2 cubs;
- Sex ratio at birth was 50:50;
- Litter interval is 3 years for additional bears and all offspring stay with their mothers for about 2.5 years;
- Family break-up and weaning among additional bears occurs on June 15 when young are 2 year-olds;
- Maximum age of female reproduction was set at 27 years-old (Schwartz et al.2003);
- Survival rates similar to estimates from the Selkirk Mountains (λ = 1.019, Wakkinen and Kasworm 2004) formed the first set of simulations and rates similar to the North Fork of the Flathead River (λ = 1.085, Hovey and McLellan 1996) and the Cabinet-Yaak 1983-98 (λ = 1.067, Wakkinen and Kasworm 2004) were used in the second set of simulations. Survival rates were assumed to be indicative of good but attainable rates for this population;
- Mortality of cubs and yearlings produced by additional bears was assumed to be 50% males and 50% females;
- The first mortality in cub and yearling age classes was assumed to be female;
- Adult female bears and any attendant offspring were censored or terminated in the database (not counted as mortality) after weaning their first litter of cubs;
- Seasonal timing of simulated deaths was similar to and representative of previous mortality;
- Reproductive rates remain similar to those observed for this population from 1983-05 (Wakkinen and Kasworm 2004, Kasworm et al. 2005);
- Transplanted bear retention in target area is 75% (based on 1990-94 Cabinet Mountains augmentation results).

Results

Improving population trend

Survival rates of bears must improve dramatically over those observed for the Cabinet-Yaak 1983-05 to produce a trend estimate that moves towards λ=1.0 as more bears are added to the population. If survival rates remain at the values calculated for 1983-05 (Kasworm et al. in prep), λ (as calculated by Booter software) will never reach 1.0 regardless of how many bears are added. This occurs because this software uses only vital rates to calculate λ and does not use population numbers. If vital rates (death or birth rates) do not improve, λ calculated by BOOTER will not improve. Improvements in survival rates can occur from a variety of efforts designed to reduce human caused mortality (e.g. information, sanitation, enforcement, habitat security, hunting regulations).

Grizzly bear population trend calculations from other studies in similar habitat were examined to provide upper bounds for survival estimates that could be used in this simulation (Table 1). Survival estimates from the Selkirk Mountains, North Fork of the Flathead River, and the Cabinet-Yaak prior to 1999 were utilized as guides for attainable improved rates (Hovey and McLellan 1996, Wakkinen and Kasworm 2004, Kasworm et al. 2005). Thus, survival must improve in addition to augmentation for these results to be valid.

Table 1. Survival rates and trend for various grizzly bear studies.

	Cabinet-Yaak 1983-05[a]	Selkirk 1983-02[b]	Cabinet-Yaak 1983-98[c]	N Fork Flathead 1979-94[d]
Ad F Survival	0.896	0.935	0.948	0.946
Sa F Survival	0.766	0.878	0.901	0.931
Ygl Survival	0.851	0.785	1.000	0.944
Cub Survival	0.571	0.875	0.867	0.867
Age first parturition	6.6	6.5	6.3	6.4
Reproductive rate	0.287	0.288	0.330	0.422
Maximum age	27	27	27	20
Trend (λ)	0.930	1.019	1.067	1.085
Decline probability	91.4%	32.7%	16.1%	<1%
Bear-years[e]	82.1	77.0	69.2	118.1

[a]Kasworm et al. In prep
[b]Wakkinen and Kasworm 2004
[c]Wakkinen and Kasworm 2004, Kasworm unpublished data
[d]Hovey and McLellan 1996
[e]Bear-years in sample excluding cubs

Two simulated improved survival rate scenarios were developed based on documented rates from other studies in neighboring recovery areas with habitat similar to the Cabinet-Yaak (Table 2). Scenario 1 has overall lower survival rates than scenario 2. Scenario 1 (Table 2 column 1) involves survival rates for additional bears similar to those from the Selkirk Mountains study, 1983-02 and scenario 2 (Table 2 column 3) involves survival rates similar to those from the N. Fork Flathead, 1979-94. Therefore these survival rates appear attainable based on other studies of similar bear populations. Simulations for each scenario start with the

Cabinet-Yaak 1983-05 database-bears and add subadult female bears with 2 different survival rate scenarios described above and resulting population trends (Table 2 columns 2 and 4). Sufficient bears were added under each scenario to provide a resulting $\lambda \geq 1.000$.

Improved survival scenario 1 (lower survival) required approximately 24 additional bears and resulting reproduction to result in $\lambda \geq 1.000$ (Table 2, column 1). Simulated mortality among bears added in scenario 1 included 5 adult females, 4 subadult females, 5 yearlings, and 7 cubs. Two of the transplanted subadult females died prior to reproduction. The remaining 22 subadult females matured and produced 44 cubs of which 7 died. Five of 37 yearlings died and two of the sixteen subadult females died. Five of the transplanted females died after reaching adult age and reproducing. The twenty-four subadult females and resultant offspring were added to the BOOTER database accumulated for Cabinet-Yaak bears from 1983-05 (Table 1, column 1) and the model was run again to produce the calculated $\lambda = 1.000$ (Table 2, column 2).

Improved survival scenario 2 (higher survival) required approximately 12 additional bears and resulting reproduction to result in $\lambda \geq 1.000$ (Table 2, column 3). Simulated mortality among bears added in scenario 2 included 2 adult females, 1 subadult female, 2 yearlings, and 3 cubs. One of the transplanted subadult females died prior to reproduction. The remaining 11 subadult females matured and produced 22 cubs of which 3 died. Two of the 19 yearlings died and none of the eight subadult females died. Two of the transplanted females died after reaching adult age and reproducing. The twelve subadult females and resultant offspring were added to the BOOTER database accumulated for Cabinet-Yaak bears from 1983-05 (Table 1, column 1) and the model was run again to produced the calculated $\lambda \geq 1.000$ (Table 2, column 4).

Table 2. Simulated improved survival rates and trend with 95% CI for Cabinet-Yaak ecosystem and placement of augmented bears into the Cabinet Mountains portion of this ecosystem.

	Scenario 1 with simulated survival rates and reproduction for 24 additional subadult female bears and offspring[a]	Cabinet-Yaak 1983-05 plus 24 additional subadult females with scenario 1 simulated survival rates from previous column	Scenario 2 with simulated survival rates and reproduction for 12 additional subadult female bears and offspring[b]	Cabinet-Yaak 1983-05 plus 12 additional subadult females with scenario 2 simulated survival rates from previous column
Ad F Survival	0.937 (0.884-0.987)	0.927 (0.878-0.971)	0.950 (0.874-1.0)	0.928 (0.864-0.982)
Sa F Survival	0.902 (0.796-0.979)	0.859 (0.759-0.948)	0.941 (0.796-1.0)	0.863 (0.738-0.969)
Ygl Survival	0.864 (0.762-0.972)	0.870 (0.778-0.956)	0.897 (0.762-1.0)	0.887 (0.761-1.0)
Cub Survival	0.818 (0.705-0.932)	0.736 (0.625-0.833)	0.864 (0.727-1.0)	0.700 (0.580-0.820)
Age first parturition	6.5 (6.3-6.7)	6.6 (6.4-6.7)	6.5 (6.3-6.8)	6.6 (6.3-6.8)
Reproductive rate	0.284 (0.204-0.436)	0.284 (0.204-0.436)	0.284 (0.206-0.441)	0.284 (0.204-0.429)
Maximum age	27	27	27	27
Trend (λ)	1.030 (0.974-1.090)	1.000 (0.947-1.056)	1.059 (0.987-1.125)	1.000 (0.937-1.063)
Decline probability	14.9%	48.2%	5.2%	48.3%
Bear-years	165.4	247.5	82.8	165.0

[a]Simulated survival estimates were based on the Selkirk Mountains, 1983-02 (Table 1, Wakkinen and Kasworm 2004).
[b]Simulated survival estimates were based on the Cabinet-Yaak, 1983-98 and North Fork of the Flathead River 1979-94 (Table 1, Hovey and McLellan 1996, Wakkinen and Kasworm 2004, Kasworm et al. 2005).
[c]Bear-years in sample excluding cubs.

The model did not attempt to estimate the time required to reach a stable lambda because it was unknown when bears would be available for transplant. However, each bear added in our simulations as 3 year-olds would require at least 5 or 6 years to successfully reproduce and wean 2 year-old cubs depending upon age at first reproduction.

In the previous test of population augmentation in the Cabinet Mountains during 1990-95, 4 subadult females were added to the population (Kasworm et al. 1998). Only 3 of the 4 (75%) animals satisfied the first criteria for success which was that animals remain in the target area for at least one year. It appears unlikely to expect all transplanted animals to remain in the target area. Use of this estimated fidelity to the target area (75%) should be factored into estimates of the numbers of augmentation subadult females that would contribute to the improved population trend. Reproduction with native males is the ultimate goal of augmentation. Hair collection from 2002-04 and genetic analysis of extracted DNA determined that at least one of the bears transplanted to the Cabinet Mountains has reproduced (Kasworm et al. 2005). It is important to reiterate that trend can also be affected by monitoring native female bears. Any native female bears captured and monitored for survival rates from 2006 forward and subsequent reproduction would contribute toward the final trend estimate.

Augmentation and resulting numbers of adult female bears

Though this analysis answers the questions posed, we suggest another approach that may be valuable in compensating estimated incidental take of adult female bears associated with project impacts and movement towards recovery in this population. Accounting for site fidelity among transplanted bears and mortality during various life stages may provide a rough estimate of transplants needed to balance incidental take. If actual survival rates of transplanted bears vary from those projected then numbers of transplanted bears may be adjusted. We suggest that the measure of success in this approach involve successfully reproducing females (bears that survive to adulthood, produce at least one litter of young at 7 years-old, and at least one of those young survive to weaning age, typically 2 years-old).

Estimates of the number of transplanted bears necessary to replace one adult female killed would vary depending on the age of the bears being transplanted at the time of augmentation and the assumed survival rate. With augmentation, both the success rate (75%) and survival rates (Table 1, column 1) must be considered.

Table 3. Projected fidelity and survival of transplanted bears until weaning first litter of young assuming no improvement from current survival rates (Table 1, column 1).

Initial age	Fidelity	Survival Age 2	Survival Age 3	Survival Age 4	Survival Age 5	Survival Age 6	Survival Age 7	Survival Age 8	Survival Age 9	Overall Survival
2	0.75	0.766	0.766	0.766	0.896	0.896	0.896	0.896	0.896	0.195
3	0.75		0.766	0.766	0.896	0.896	0.896	0.896	0.896	0.254
4	0.75			0.766	0.896	0.896	0.896	0.896	0.896	0.332
5	0.75				0.896	0.896	0.896	0.896	0.896	0.433
6	0.75					0.896	0.896	0.896	0.896	0.483

If 2 year old bears were transplanted, it would require 6 bears to produce one reproducing female (cumulative survival ≥ 1.0, 6 x 0.195 = 1.17). Transplanting 3 or 4 year old bears would require 4 bears to replace the original female (4 x 0.254 = 1.016 or 4 x 0.332 = 1.328). Transplanting 4 year old bears would require 4 bears to replace the original female (4 x 0.332 = 1.328). Transplanting 5 or 6 year old bears would require 3 bears to replace the original female (3 x 0.433 = 1.299 or 3 x 0.483 = 1.449). Augmentation to replace just one reproducing adult female would require 3-6 bears depending on assumed survival rate and their age at the time of relocation. Survival rates other than the current projected rates will affect the results. We also believe that this program should not stop at replacement, but provide for overall increases in numbers of bears in this recovery zone.

Discussion

Previous simulations of augmentation with VORTEX population modeling software suggested that about 13 bears over 10 years would be required to achieve $\lambda \approx 1.0$ (Proctor et al. 2004, Fig 2a). This calculation simulated reproduction and survival the same as bears in the Cabinet-Yaak from 1983-02 (Wakkinen and Kasworm 2004). Improved growth rate was only for the 10 years during augmentation. If survival rates did not improve simultaneously, the improvement in growth rate decreased over time. Improved survival rates could reduce probability of extinction for a population of 50 animals over 100 years from > 80% to < 20% (Proctor et al. 2004, Fig 4b). The resultant λ from the addition of 12-24 bears with improved survival characteristics in this paper differed somewhat from the simulation produced by Proctor et al. (2004). The Proctor et al. (2004) analysis of augmentation did not attempt to estimate or incorporate site fidelity. This paper reports simulations with different modeling software (BOOTER) that produced similar but slightly different results partially because of different survival rates in the simulations. This simulation used the most recent rates from 1983-2005 and Proctor et al. 2004 used rates from 1983-2002. Lower survival rates and effects of site fidelity during augmentation increased the number of bears required to improve λ in this analysis.

Numerous factors could change the results of simulations presented. If survival or fidelity rates are lower than the improved simulated rates (but still produce $\lambda>1.0$), then more transplants would be required. Changes in reproductive rates would also affect the calculation. If reproductive rates are better than those simulated, then fewer transplants may be required. If bears can be monitored beyond their first reproductive interval and shown to successfully reproduce and wean additional offspring, this could reduce the number of bears but extend the time necessary to produce the λ desired.

Another important factor involves the ongoing monitoring program. Because our sample sizes are low, the calculated λ could be affected by survival and reproductive data from native bears monitored now and in the future. If newly monitored native female bears survive and reproduce at rates above those calculated for 1983-05, the number of bears required for augmentation may decrease. If newly monitored native female bears survive and reproduce at rates less than those calculated for 1983-05, the number of bears required for augmentation may increase. As of January 2006 we have 2 radio collared subadult females and one adult female that was transplanted to the area in 2005 that will be monitored and contribute to future trend calculations.

The availability of subadult females for transplant is difficult to predict. Optimal results would be expected with bears from habitats with food similar to the Cabinet-Yaak ecosystem in

order to attain the best rates of target site fidelity and subsequent survival. Availability of bears from the Flathead River drainage in the Northern Continental Divide recovery zone will be influenced by their population levels and mortality patterns. Placement of bears from other areas such as the Yellowstone ecosystem could be successful, but we have little data to make a firm statement about such success. If bears were moved from the Yellowstone ecosystem, we suggest this be done as test with at least 2 subadult female bears moved and with careful monitoring to evaluate retention, movement patterns, and subsequent survival and reproduction. The addition of subadult male bears should be considered in the future to insure sufficient numbers of males for reproduction, but it should be recognized that male bears do not influence or contribute to these λ calculation results and are less likely to stay in the target area.

We reaffirm that these simulations assume that grizzly bears inhabiting the Yaak River drainage and Cabinet Mountains are one population however, there are no movement data from radio collared bears that demonstrate such connection. Current management direction is to provide or enhance population linkage between these two areas and population augmentation is expected to occur only in the Cabinet Mountains during the initial phase of population augmentation. Growth of populations in both areas may be necessary to provide internal population pressures to cause bears to move into the adjacent portion. Reconnecting the Yaak drainage with the Cabinet Mountains is essential for the long-term persistence of the Cabinet component of the recovery zone.

In conclusion, both Proctor et al. (2004) and this effort demonstrate that augmentation can improve λ estimates to produce a stable population. However, without a long-term decrease in human-caused mortality with resulting increases in female survival, and population linkage, augmentation alone is not sufficient to stabilize, increase, and eventually recover the Cabinet-Ecosystem grizzly population. The simultaneous application of a suite of management actions including augmentation, mortality control, linkage zone management, outreach and education, and improved security in key habitat areas are necessary if this population is to be recovered. Augmentation alone could increase reproduction in the area, but this will provide only a temporary fix, especially if mortality risk remains high. Thus, we remain committed to the comprehensive program of intensive management that we have detailed in Proctor et al. (2004) and that we have begun to implement in this ecosystem.

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