MULTI-TROPHIC LEVEL ECOLOGY OF WOLVES, ELK, AND VEGETATION IN YELLOWSTONE NATIONAL PARK: ELK CALF MORTALITY STUDY

NRPP Project #71604
Final Completion Report, FY2003-FY2005

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Introduction

Annual trend counts of northern Yellowstone elk decreased from 19,045 to 9,545 during 1994-2005 and indices of recruitment during 2002-2005 were among the lowest recorded during the past several decades. Many people attributed these changes to the restoration of wolves in Yellowstone since elk comprised more than 85% of documented wolf kills during 1997-2002 (Smith et al. 2003*b*). Prior to wolf restoration (1987-1990), survival rates for northern Yellowstone elk calves during summer were 50-85% and 72% of all calf deaths during summer were due to predators (i.e., bears and coyotes; Singer et al. 1997). We conducted a similar study of radio-tagged elk calves during 2003-2005 to: 1) estimate the relative causes and timing of calf deaths; 2) estimate survival rates; and 3) evaluate factors that may predispose calves to death.

Methods

To the extent feasible, we replicated the methodology and experimental design used by Singer et al. (1997) to capture and monitor elk neonates during 1987–1990. This study provided a baseline for comparison post-wolf restoration data. Each year, we captured a sample of 44–56 calves $\leq$6 days old. Calves were captured from four general areas, including: 1) Sepulcher Mountain foothills and Mammoth; 2) Swan Lake and Gardners Hole; 3) Blacktail Deer Plateau and Tower; and 4) Lamar Valley. We captured calves born in the early (May 17–26), middle (May 27–June 5), and late (June 6–15) portions of the calving season. Ground searches for calves were conducted during May 15–June 15 from vehicles or by using spotting scopes to survey areas where calves were suspected based on maternal behavior or information from park visitors or staff. Aerial searches using a helicopter were conducted during three 2- or 3-day periods in the early, middle, and late portions of the calving season (i.e., a total of 6–9 days during each calving season). When a calf was spotted, the pilot landed in the vicinity and two biologists manually captured the calf. We did not attempt to capture calves if predators were observed nearby.

During captures, we collected age, sex, and weight measurements, general body condition data, and blood samples. We aged calves by examining their wobbly stance, incisor eruption, attached umbilicus, and status of hooves and dew claws (Johnson 1951). Each calf was fit with an ear-tag transmitter (Model 3430, Advanced Telemetry Systems, Inc., Isanti, Minnesota) weighing approximately 23 grams and designed to emit a radio signal for approximately a year. Each transmitter was designed to change pulse rate if it remained motionless for more than 4 hours. This change in pulse rate (i.e., "mortality mode/signal") alerted us that the animal was likely dead and enabled us to examine the carcass soon after death. Thus, the transmitters allowed us to quickly and conveniently monitor daily survival without visually locating each animal.

Signals of radio-tagged calves were monitored via airplane each day at dawn during mid-May through mid-July, when the risk of mortality to calves was relatively high. As calves became older and less prone to mortality, aerial monitoring was reduced to three times per week during mid-to-late July, twice per week during August–September, and bi-monthly thereafter. The pilot obtained locations for all dead calves using a Global Positioning System (GPS) unit and searched around carcasses for predators to reduce the risk that ground crews might walk in on a carcass with large predators nearby. Ground crews also monitored transmitter frequencies 3-4 times per day until approximately July 15 and once per day from July 15-September 30. Ground crews investigated mortality sites and conducted necropsies of dead calves to evaluate causes of death based on evidence such as predator tracks, consumption patterns, canine puncture measurements, and scat measurements. Crews also collected hair samples for predator identification and both a femur mid-section and metatarsus for calf-condition analyses.

Preliminary Results

One hundred and fifty-one elk were captured and processed during the summers of 2003–2005 (Table 1). Both sexes were captured across all areas fairly evenly, with slightly more female captures than males (Table 2). Estimated ages of elk calves at capture ranged from <0.5-6 days and were not significantly different between females and males among years (Table 3). Estimated birth dates of calves ranged between May 16 and June 10, with most calves born around June 1 each year (Table 4). Birth weights were estimated from capture weights using linear regression of estimated age versus capture weight (Figure 1). The estimated daily growth rate for each sex was applied to each calf's estimated age at capture to back-calculate estimated birth weights. Calf capture and birth weights were similar across years, averaging approximately 17–18 kg and 14–15 kg respectively, with males tending to be heavier (Tables 3 and 5).

One hundred and three tagged calves (68%) died within their first year of life (Table 6). Two calves were classified as missing and six calves lost their ear tag transmitters. Predators caused >90% of the deaths and >70% of this predation occurred within the first 15 days of life (Tables 7 and 8). Bears accounted for approximately 55–60% of all deaths (including both predation and non-predation) for tagged elk calves during their first 30 days of life, while coyotes and wolves each accounted for approximately 10–15% of deaths (Table 6). Causes of death for elk calves during summers 2003–2005 were generally similar.

Annual and seasonal survival rates for calves were not significantly different during 2003-2005 (Table 8). The annual survival (0.32) of 2003-2005 cohorts was within the range (0.14-0.63) reported for calves during 1987-1990, but significantly lower than mean survival (0.43) during 1987-1990 (Singer et al. 1997). There was significantly more predation and less winter-kill of elk calves during 2003-2005 compared to 1987-1990.

Blood samples collected from captured calves were sent to various laboratories for assays of bovine viral diarrhea (BVD-1), infectious bovine rhinotracheitis (IBR), bovine respiratory synctial virus (BRSV), *Brucella abortus* (BR/CF), and bovine parainfluenza-3 (PI3). Potential condition indicators including blood urea nitrogen (BUN, Kunkel and Mech 1994), thyroxine (T4), gamma-globulins (GG), gamma-glutamyl transferase (GGT), and cytokines (e.g., IGF-1, IL-6, and TNF-α) will also be investigated. Blood condition values will be compared between surviving calves and those killed by predators once we receive the results.

Discussion

Seventy-two percent of all calf deaths during summers in 1987-1990 were due to predators, primarily grizzly bears and coyotes (Singer et al. 1997). However, the ratio of predators to prey on the northern range has increased since that study. The minimum population estimate for grizzly bears in the greater Yellowstone area increased from 150 bears in 1987 to 431 bears in 2004 (Haroldson et al. 1998, Haroldson and Frey 2005; Figure 2). Similarly, the number of unduplicated sightings of female grizzly bears with cubs of the year increased from 13 sows in 1987 to 49 sows in 2004 (Haroldson et al. 1998, Haroldson and Frey 2005; Figure 3). Grizzly and black bears appear to concentrate in elk calving areas on the northern range during May and June. Thus, it was not unexpected that bear predation was a significant factor on the survival of elk calves during early summer.

Additionally, wolves were restored to Yellowstone National Park during 1995 and 1996 and rapidly increased in abundance and distribution throughout the park and the greater Yellowstone area (Figure 4). Approximately 171 wolves resided in Yellowstone National Park during 2004 and elk calves accounted for 15 percent of documented wolf kills (Smith et al. 2005). Thus, wolves could be a significant limiting factor for elk recruitment if much of this predation is additive to other mortality sources.

Our results indicate some form of compensatory mortality is likely occurring because summer predation increased from 72% of deaths during 1987-1990 to 94% during 2003-2005, but winter-kill decreased from 58% to zero during the same time period (Table 8). However, these cause-specific mortality results could easily be misinterpreted because they are necessarily biased towards early calf mortality and do not include possible sources of mortality during the winter season. Studies of caribou calf mortality in Denali National Park, Alaska, found that bear predation was predominant early in the calving season and declined with calf age, while wolf predation peaked later in the season (Adams et al. 1995). Thus, we anticipated that bear predation may be a relatively high source of early calf mortality in northern Yellowstone elk, with wolf predation increasing during winter. In May and June, bears search in grid-like patterns for hiding neonate calves (Gunther and Renkin 1990), whereas wolves tend to select vulnerable prey while testing groups of elk (Smith et al. 2003*a*). Thus, wolves may be more likely to kill calves in groups of elk during winter when bears are in their winter torpor.

In addition, the survival and relative causes of death for northern Yellowstone elk calves may change substantially among years (e.g., Singer et al. 1997) due to numerous factors. For example, poor foraging conditions may prompt bears to find alternate food sources such as elk calves to meet their nutritional requirements (Smith and Anderson 1996). Thus, the extent of bear predation on northern Yellowstone elk calves may vary among years in response to the availability of a seasonally important alternative food sources such as carcasses of ungulate winter-kills or whitebark pine (*Pinus albicaulis*) nuts. Ungulate carcasses can be prevalent on the northern range during severe winters, but have decreased since the restoration of wolves which selectively prey on chronically undernourished animals (Singer et al. 1989, DelGuidice et al. 1991, Northern Yellowstone Cooperative Wildlife Working Group 2004). Also, whitebark pine is a masting species that yields abundant nut crops in some years and poor crops in others (Felicetti et al. 2003). When bears emerge from their dens in spring, they depend upon the previous year's crop of white-bark pine as a food source. Therefore, in the spring following a year of poor nut crops, other food, including elk calves, could become more important for emerging bears (Mattson 1997, Mattson et al. 1991, Felicetti et al. 2003).

Furthermore, our study was designed for comparison to the results of Singer et al. (1997) on northern Yellowstone elk calves during 1987-1990. Calves sampled during both of these studies likely constituted <1% of the total calf population, based on gross estimates derived from aerial trend counts and classifications, and are only representative of calves born on the northern range. These samples are not representative of calves born along migration routes of northern Yellowstone elk or in other areas of the park. In addition, results from this study cannot be fairly compared to results from other areas or periods with different complexes of predators and prey, different ratios of predators to prey, different elk behaviors (e.g., migratory versus nonmigratory), or different wolf management scenarios without considerably more study and qualification.

The results of this study have immediate relevance to resource managers of the Yellowstone ecosystem, the Montana Department of Fish, Wildlife, and Parks in setting harvest quotas for local elk hunts, and to the United States Fish and Wildlife Service regarding the delisting of wolves. The Montana Department of Fish, Wildlife and Parks has already decreased antlerless elk permits from 1,100 to 100 for the 2006 Gardiner Late Elk Hunt based on evidence of continued low recruitment of elk calves. Furthermore, information regarding the effects of wolves on ungulate population dynamics and, in turn, other interactions (e.g., elk–vegetation) has implications to areas throughout the United States and abroad where wolves and other large predators are recolonizing and increasing in density.

We will continue to monitor radio-tagged calves through winter 2006. The final results of the project will be summarized in a Ph.D. dissertation and one or more publications in peer-reviewed scientific journals.

Budget

The total project cost during FY2003-2005 was $386,500 of which $174,500 was NRPP funds (Table 9). Funding for this study was provided by the Natural Park Service, Biological Resources Discipline of the U.S. Geological Survey, Graduate School of the University of Minnesota, Annie and Bob Graham, Yellowstone Park Foundation, and Montana Fish, Wildlife, and Parks,.

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Table 1. Summary of capture methods, locations, and timing for northern Yellowstone elk calves during 2003-2005 in Yellowstone National Park, Montana and Wyoming, USA.

CAPTURES	**SUMMER 2003**	**SUMMER 2004**	**SUMMER 2005**	**TOTAL**
TOTAL CAPTURED	51	44	56	151
Ground captures	6	4	1	11
Aerial captures	45	40	55	140
CAPTURE PERIODS				
Early season	14	11	26	51
Middle season	17	20	18	55
Late season	20	13	12	45
CAPTURE AREAS				
Sepulcher foothills/Mammoth	14	12	13	39
Swan Lake/Gardners Hole	11	14	14	39
Blacktail Deer Plateau	9	10	11	30
Lamar Valley	17	8	18	43

Table 2. General locations and relative timing of captures for northern Yellowstone elk calves during 2003-2005 in Yellowstone National Park, Montana and Wyoming, USA (M = males; F = females).

CAPTURE PERIOD		SEPULCHER FOOTHILLS/MAMMOTH	SWAN LAKE/ GARDNERS HOLE	BLACKTAIL DEER PLATEAU/TOWER	LAMAR VALLEY	TOTAL
Early (mid to late May)	**Ground**	4 (3M,1F)	1 (1F)	0	0	5 (3M,2F)
	Air	13 (4M,9F)	4 (4F)	8(5M,3F)	21 (10M,11F)	46 (19M,27F)
	Total	17 (7M,10F)	5 (5F)	8 (5M,3F)	21 (10M,11F)	51 (22M,29F)
Middle (late May to early June)	**Ground**	4 (2M,2F)	1 (1F)	0	1 (1M)	6 (3M,3F)
	Air	6 (2M,4F)	22 (11M,11F)	11 (3M,8F)	10 (4M,6F)	49 (20M,29F)
	Total	10 (4M,6F)	23 (11M,12F)	11 (3M,8F)	11 (5M,6F)	55 (23M,32F)
Late (early to mid June)	**Ground**	0	0	0	0	0
	Air	12 (5M,7F)	11 (6M,5F)	11 (6M,5F)	11 (6M,5F)	45 (23M,22F)
	Total	12 (5M,7F)	11 (6M,5F)	11 (6M,5F)	11 (6M,5F)	45 (23M,22F)
Overall	**Ground**	8 (5M,3F)	2 (2F)	0	1 (1M)	11 (6M,5F)
	Air	31 (11M,20F)	37 (17M,20F)	30 (14M,16F)	42 (20M,22F)	140 (62M,78F)
	Total	39 (16M,23F)	39 (17M,22F)	30 (14M,16F)	43 (21M,22F)	**151 (68M,83F)**

Table 3. Average estimated birth weights, capture ages, and capture weights of northern Yellowstone elk calves during 2003-2005 in Yellowstone National Park, Montana and Wyoming, USA.

CALF CHARACTERISTICS	**SUMMER 2003**	**SUMMER 2004**	**SUMMER 2005**	**2003-2005**
MALE:FEMALE	19:32	21:23	28:28	68:83
CAPTURE AGE (DAYS)	2.5 (1.6 SD)	2.9 (1.5 SD)	2.4 (1.4 SD)	2.56 (1.53 SD)
- female	2.4 (1.5 SD)	2.7 (1.7 SD)	2.1 (1.3 SD)	2.38 (1.49 SD)
- male	2.7 (1.8 SD)	3.1 (1.4 SD)	2.6 (1.5 SD)	2.79 (1.55 SD)
CAPTURE WEIGHT (KG)	17.05 (2.48 SD)	17.35 (3.30 SD)	18.37 (3.41 SD)	17.64 (3.14 SD)
- female	16.91 (2.61 SD)	17.07 (4.23 SD)	17.03 (2.74 SD)	17.00 (3.15 SD)
- male	17.26 (2.32 SD)	17.65 (1.88 SD)	19.82 (3.52 SD)	18.41 (2.96 SD)
BIRTH WEIGHT (KG) BY YEARS	14.42 (1.94 SD)	14.17 (3.31 SD)	14.47 (2.20 SD)	14.36 (2.49 SD)
- female	13.87 (1.78 SD)	11.93 (2.72 SD)	13.75 (1.83 SD)	13.27 (2.25 SD)
- male	15.27 (1.90 SD)	16.62 (1.82 SD)	15.24 (2.32 SD)	15.68 (2.13 SD)
BIRTH WEIGHT (KG) POOLED YEARS	13.80 (2.01 SD)	13.77 (2.58 SD)	15.51 (2.85 SD)	14.44 (2.64 SD)
-female	13.18 (1.83 SD)	12.94 (2.80 SD)	13.93 (2.04 SD)	13.37 (2.23 SD)
-male	14.75 (1.94 SD)	14.67 (2.01 SD)	17.10 (2.68 SD)	15.70 (2.55 SD)

Table 4. Estimated birth dates of northern Yellowstone elk calves by primary calving area during 2003-2005, Yellowstone National Park, Montana and Wyoming, USA.

CALVING AREA	NO.	BIRTH DATE			
		MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Sepulcher foothills/Mammoth	39	May 28	7.5	May 18	June 9
Swan Lake/Gardners Hole	39	May 30	5.0	May 16	June 10
Blacktail Deer Plateau/Tower	30	May 30	7.3	May 16	June 9
Lamar Valley	43	May 27	7.0	May 18	June 9

Table 5. Estimated birth weights (kg) of northern Yellowstone elk calves by primary calving area during 2003-2005, Yellowstone National Park, Montana and Wyoming, USA.

CALVING AREA	NO.	BIRTH WEIGHT			
		MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Sepulcher foothills/Mammoth	37	14.3	2.5	8.8	18.7
Swan Lake/Gardners Hole	38	14.8	2.6	7.2	21.0
Blacktail Deer Plateau/Tower	30	14.2	3.0	5.4	18.5
Lamar Valley	43	14.1	2.0	10.8	20.5

Table 6. Fates of northern Yellowstone elk calves radio-tagged during 2003-2005 in Yellowstone National Park, Montana and Wyoming, USA.

CAUSE[a]	2003		2004		2005		2003-2005	
	NO.	**%**	**NO.**	**%**	**NO.**	**%**	**NO.**	**%**
Bear	20	54	17	49	23	55	60	53
Grizzly Bear	(11)	(30)	(7)	(20)	(15)	(36)	(33)	(29)
Black Bear	(6)	(16)	(7)	(20)	(8)	(19)	(21)	(18)
Unknown Bear	(3)	(8)	(3)	(8)	(0)		(6)	(5)
Wolf	4	11	4	11	7	17	15	13
Coyote	4	11	4	11	2	5	10	9
Wolf or Bear (both at scene)	1	3	1	3	0		2	2
Mountain Lion	1	3	0		2	5	3	3
Wolverine	1	3	0		0		1	1
Golden Eagle	0		1	3	0		1	1
Hunter	1	3	0		0		1	1
Unknown Predator	1	3	1	3	3	7	5	4
Not Predation[b]	2	5	2	6	1	2	5	4
Missing	1	2	1	3	0		2	2
Transmitter pull-out	0		4	11	3	7	7	6
Unknown[c]	1	2	0		1	2	2	2
TOTAL FATES (CAPTURES)	37 (51)	73%	35 (44)	80%	42 (56)	75%	114 (151)	75%

[a] Includes missing animals and possible transmitter pull-outs.

[b] In 2003, one calf likely drowned and another possibly died from excess fluoride. In 2004, one calf's lungs never fully expanded and another likely died from exposure to cold. In 2005, one calf likely died from pneumonia.

[c] In 2003, one possible mortality was unable to be examined due to fires near Mt. Chittenden. In 2005, one possible mortality was unable to be examined due to high waters in Cache Creek.

Table 7. Estimated age at death (days) for northern Yellowstone elk calves radio-tagged during 2003-2005 in Yellowstone National Park, Montana and Wyoming, USA.

CAUSE OF DEATH[a]	NO.	MEAN $\pm$ SD	RANGE (days)
Bear	60	10 (8)	0.5 - 42
Grizzly Bear	(33)	(9 (7))	(0.5 - 42)
Black Bear	(21)	(12 (10))	(1.5 – 42)
Unknown Bear	(6)	(9 (3))	(4.5 – 14)
Wolf	15	35 (53)	3.5 - 213
Coyote	10	29 (72)	2 - 235
Wolf or Bear (both at scene)	2	9 (9)	3 - 15
Mountain Lion	3	107 (24)	80 – 122
Wolverine	1	4	--
Golden Eagle	1	42	--
Hunter	1	239	--
Unknown Predator	5	33 (63)	1.5 – 145
Not Predation[b]	5	11 (10)	0.5 - 25
Missing	2	54 (69)	6 - 103
Transmitter pull-out	7	137 (106)	2.5 - 333
Unknown[c]	2	45 (32)	23 - 68
Overall	114	30 (56)	0.5 - 333

[a] Includes missing animals and possible transmitter pull-outs.

[b] In 2003, one calf likely drowned and another possibly died from excess fluoride. In 2004, one calf's lungs never fully expanded and another likely died from exposure to cold. In 2005, one calf likely died from pneumonia.

[c] In 2003, one possible mortality was unable to be examined due to fires near Mt. Chittenden. In 2005 one possible mortality was unable to be examined due to high waters in Cache Creek.

Table 8. Gross estimates of survival and mortality for northern Yellowstone elk calves radio-tagged during 2003-2005 and 1987-1990 (Singer et al. 1997) in Yellowstone National Park, Montana and Wyoming, USA.

Survival/Mortality[a]	**2003**	**2004**	**2005[b]**	**2003 - 2005**	**1987-1990**
Annual survival	0.31	0.32	0.34	0.32	0.43 (0.14-0.63)
Annual mortality due to predation	0.94	0.93	0.97	0.95	0.45
Summer survival[c]	0.35	0.32	0.34	0.34	0.65
Summer mortality due to predation	0.94	0.93	0.97	0.95	0.72
Winter survival[d]	0.89	1.00		0.94	0.72
Winter mortality due to malnutrition	0	0		0	0.58
Bear predation[e]	0.57	0.57	0.62	0.59	0.23

[a] Annual or seasonal survival was estimated as $\hat{s} = 1 - (d/n)$, where *d* was the number of calves that died and *n* was the number of calves at risk. Estimates do not include missing, unknown, or possible transmitter pull-outs.

[b] Estimates for 2005 are based on monitoring through October 31, 2005.

[c] Summer is defined as capture through October 31.

[d] Winter is defined as November 1 through May 15.

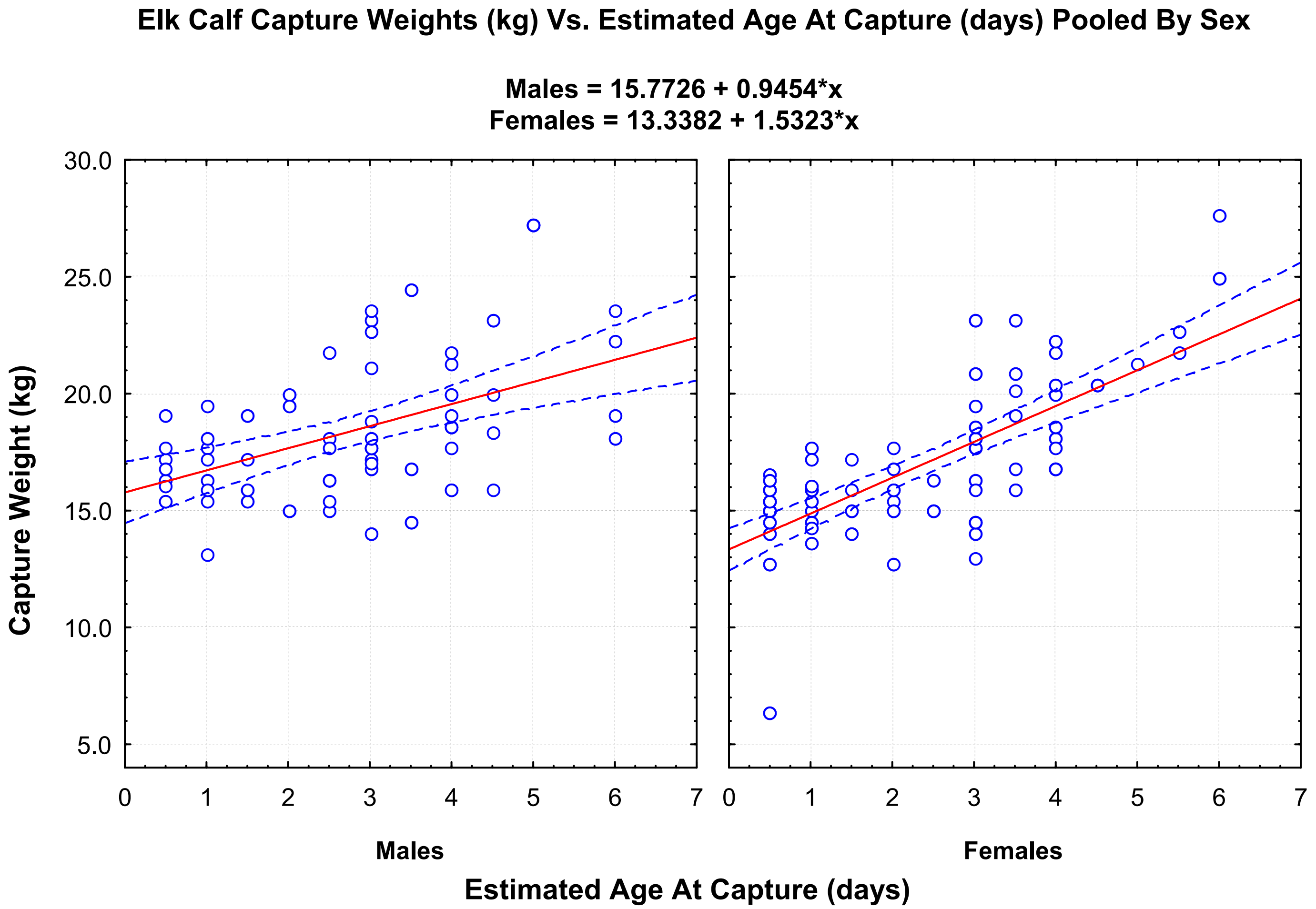
[e] Percent of deaths due to bear predation.

Table 9. FY2003-FY2005 budget ($1000) for the elk calf mortality study on the northern range of Yellowstone National Park, Montana and Wyoming, USA.

Costs	FY03 NRPP	FY03 USGS	FY03 Other[a]	FY04 NRPP	FY04 USGS	FY04 Other[a]	FY05 NRPP	FY05 USGS	FY05 Other[a]
Personnel Services									
Term GS-6 (5mo)			14			14			1
Graduate student stipend		3	15		3	15			18
Volunteers (6 @ $15/day for 60 days)	4		1.5	4		1.5	4		1.5
Volunteer housing	2		1.5	2		1.5	2		1.5
Travel and Transportation									
Travel (collaborators)		2			2				2
Contractors and Cooperators									
Helicopter capture – elk calves	38		3	38		3	38		3
Aerial monitoring of elk calves		23	10		23	10		18	15
Blood and condition analyses		2			2				2
Supplies and Equipment									
Mortality transmitters (ear tag)	10			9			8.5		
Telemetry and other miscellaneous equipment	5			5			5		
TOTAL	**59**	**30**	**45**	**58**	**30**	**45**	**57.5**	**18**	**44**

[a] The Yellowstone Park Foundation committed $15,000 during FY 2003 and FY 2004 for a graduate student stipend. In addition, Ms. Annie Graham donated $10,000 through the Yellowstone Park Foundation and Doug Smith during FY 2003.

Figure 1. Linear regression to determine growth rates of northern Yellowstone elk calves during their first six days of life using capture weights and estimated age at capture by gender during 2003–2005, Yellowstone National Park, Montana and Wyoming, USA.



Males: r=0.4930, p=0.000 / Females: r=0.7304, p=0.000

Figure 2. Minimum population estimates for grizzly bears in the greater Yellowstone area during 1987-2004 (data from Haroldson et al. 1998; Haroldson and Frey 2005).

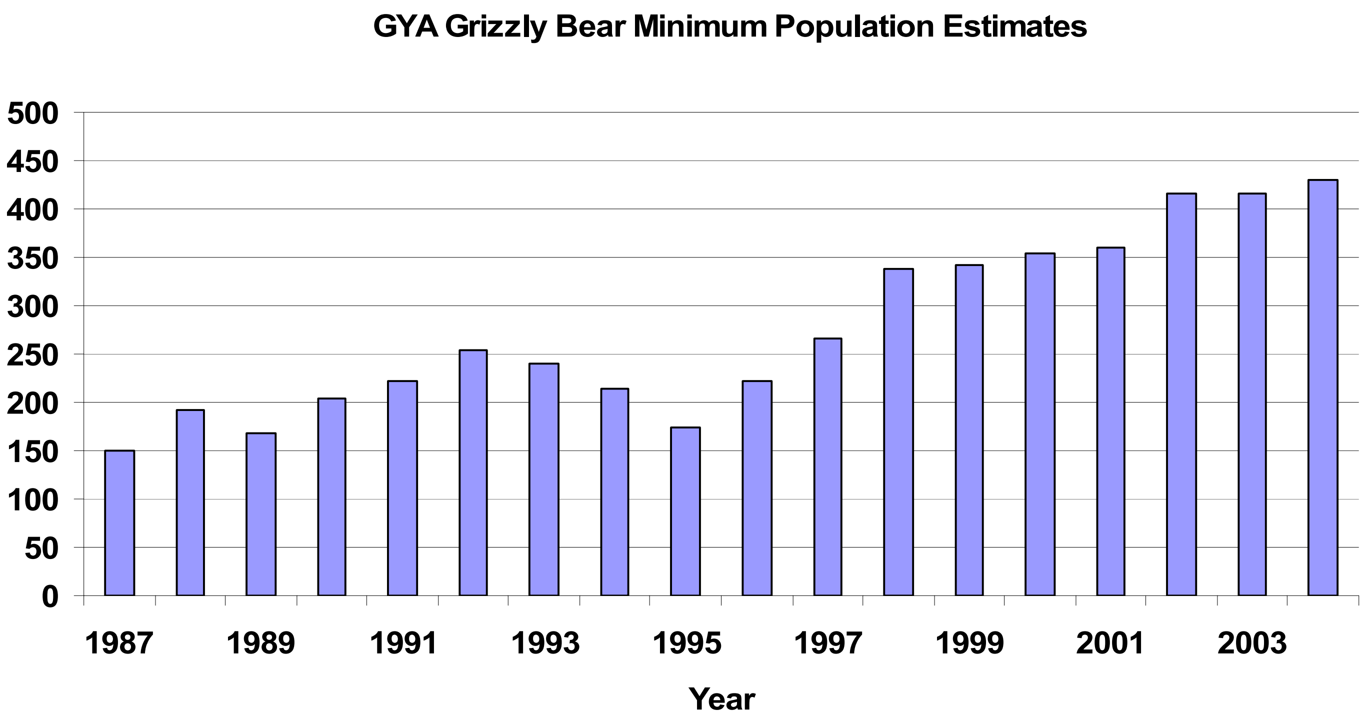


Figure 3. Unduplicated sightings of female grizzly bears with cubs of the year in the greater Yellowstone area during 1987-2004 (data from Haroldson et al. 1998, Haroldson and Frey 2005).

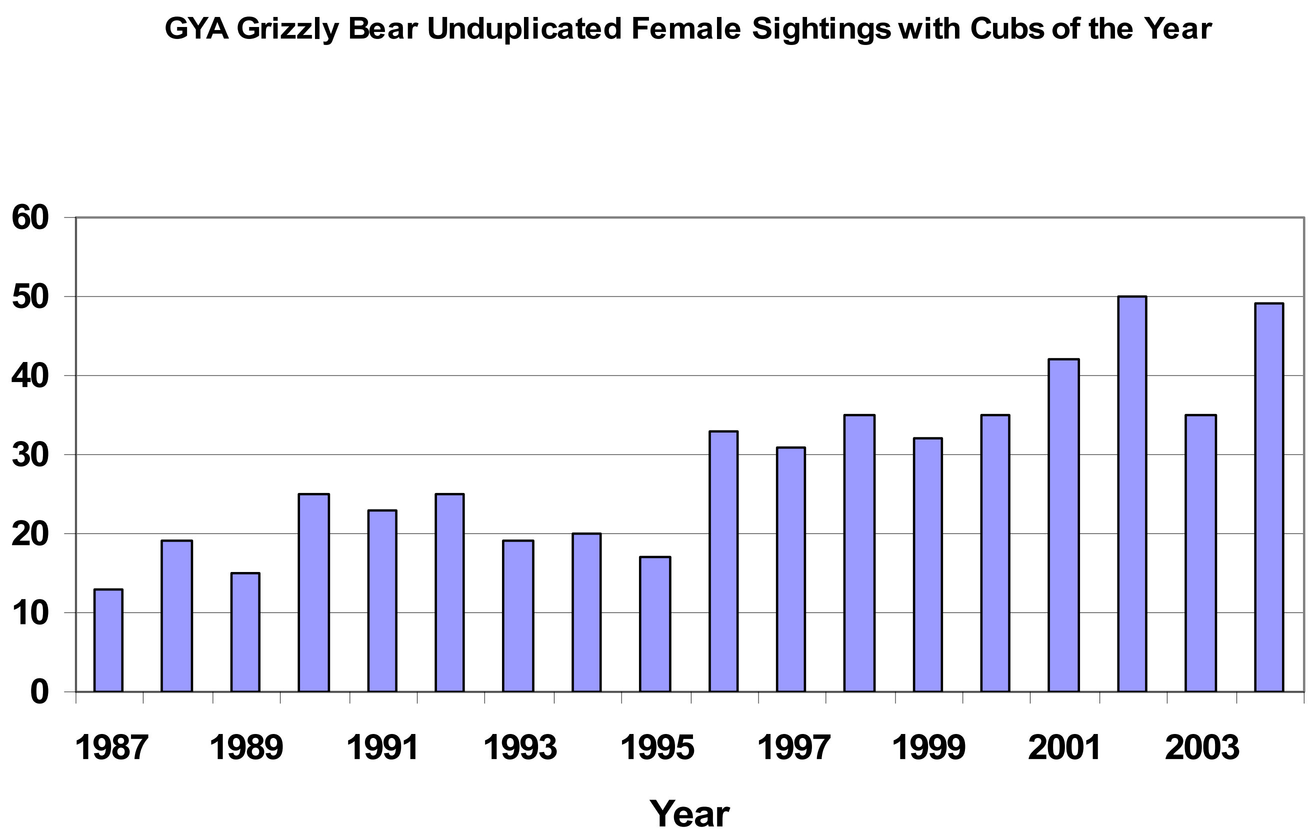


Figure 4. Wolf population estimates for the greater Yellowstone area during 1995-2004 (data from Smith et al. 2005, USFWS et al. 2005).