



Original Article

Demographic Characteristics of Elk in the Glass Mountains, Texas

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ABSTRACT Historically distributed throughout North America, most populations of elk (*Cervus elaphus*) were extirpated by the early 20th century. Merriam elk (*C. e. merriami*) were once native to Texas, USA, and became extinct after the beginning of the 20th century through excessive hunting and degradation of habitat. Since then, landowners and state agencies have reintroduced Rocky Mountain elk (*C. e. nelsoni*) into the Trans-Pecos region of Texas. We determined herd composition, density, and survival rate of elk in the Glass Mountains, Texas. Twenty-six total density surveys were conducted in September and October of 2009 and 2010. Survival rate was determined by monitoring radiocollared elk. Collectively, calf:adult female:adult male ratios were found to be at moderate levels of 49:100:39. Our density estimate of 0.39 elk/km² (95% CI = 0.18–0.78 elk/km²) indicated the population could have stayed the same or possibly doubled in size since 1983 (0.21–0.22 elk/km²; Grace 1983). The elk density in the Glass Mountains was much higher than that estimated for the much larger Trans-Pecos region, which was 0.14 elk/km² (95% CI = 0.03–0.33 elk/km²). We estimated annual survival of mature male elk at 97.1% and of female elk at 94.4%, both of which are comparable to other sustainable populations in arid lands. Elk are not subject to a regulated harvest in Texas. Forming a cooperative management program and improved estimates of population dynamics will result in better management recommendations to resource managers. © 2014 The Wildlife Society.

KEY WORDS *Cervus elaphus*, demographics, density, elk, Glass Mountains, Texas, Trans-Pecos.

Elk (*Cervus elaphus*) were historically distributed throughout most of North America. Most populations were extirpated by the early 1900s after European settlement through hunting and overgrazing. Well-established, contiguous populations are presently found throughout western North America in the Rocky Mountains and Pacific Northwestern United States. Elk have been restored throughout these regions where populations generally are stable or slightly increasing (Toweill and Thomas 2002). Small, reintroduced populations also occur in eastern provinces and states (Toweill and Thomas 2002). Elk populations have shown to be well-suited for some arid regions in western North America (McCorquodale and Eberhardt 1990; Heydlauff et al. 2006; Bender and Piasecke 2010; Halbritter and Bender 2011a, b; Tolleson et al. 2012). A significant amount of research has been conducted on elk in North America, including some research on elk populations in arid lands similar to the Trans-Pecos region of Texas, USA. Many of the studies have addressed key ecological features of populations, as well as population dynamics, reproduction, mortality, and habitat selection (Noyes et al. 1996; Singer et al. 1997; Lubow and Smith 2004; Shannon et al. 2009; Halbritter and

Bender 2011a, b). Unlike other prominent populations, there has been minimal research on the elk population of Texas.

As recently as the early 20th century, a native population of Merriam's elk (*C. e. merriami*) inhabited the southern Guadalupe Mountains of Texas (O'Gara and Dundas 2002, Schmidly 2004). Excessive hunting of Merriam elk and degradation of habitat by overgrazing led to their extirpation shortly after the start of the 20th century (Toweill and Thomas 2002). Since then, landowners and state agencies have reintroduced Rocky Mountain elk (*C. e. nelsoni*) into the Trans-Pecos region of Texas (Coykendall 1990). In most states, elk are classified as a game species. In 1959, Texas Game and Fish Commission listed elk as a game species; at this time, the population was estimated at 300 (Schmidly 2004). Because the present subspecies is non-native, elk were designated as exotic livestock in 1997 by the 75th Texas legislature (Toweill and Thomas 2002). The exotic status means that elk in Texas do not have any harvest restrictions.

Schmidly (2004) reported that free-ranging elk in Texas existed in small herds within 5 mountain ranges including the Guadalupe, Glass, Wylie, Davis, and Eagle mountains. Although populations have been established throughout the Trans-Pecos region, few studies have been conducted to provide information concerning habitat use, population dynamics, and demographic characteristics of elk in this region. To manage a population effectively, knowledge of

Received: 15 June 2011; Accepted: 6 November 2013
Published: 14 April 2014

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these factors is vital. Adding to 2 related studies that focused on habitat selection (Witt 2008) and landowner attitudes about elk (Guevara 2009) in the Trans-Pecos region, this study provides necessary information to better manage elk herds in the Glass Mountains. Specifically, our objectives were to estimate elk demographic characteristics including herd composition, density, and survival rates.

STUDY AREA

The Glass Mountains lay within the Trans-Pecos region of Texas. The Glass Mountains were located 32 km east of Alpine in Brewster and Pecos counties between the towns of Marathon and Fort Stockton (Grace 1983). Topography of the Glass Mountains varied in elevation from 1,200 m to 1,980 m. The southwestern portion was characterized by rugged sheer cliffs while the northeastern part consisted of moderately rolling hills. The study area consisted of 417 km² in the southwestern portion of the Glass Mountains. The Glass Mountains was divided into many private ranches, 8 of which granted trespass privileges for this study.

Climate of the Trans-Pecos was characterized as arid with an average rainfall of 35.6 cm/year, typically occurring in mid- to late summer (Warnock 1977). Ephemeral water sources were also available for short periods after sporadic rains. Rainfall events supplied water to dirt tanks as well as rock and road depressions.

Witt (2008) delineated 8 broad vegetation communities in the Glass Mountains. These communities included riparian, tobosa (*Hilaria mutica*) grassland, juniper (*Juniperus pinchotii*) woodland, mesquite (*Prosopis glandulosa*)–tarbush (*Flourensia cernua*) scrubland, creosote (*Larrea tridentata*)–mariola (*Parthenium incanum*) shrubland, desert grassland, desert scrubland, and evergreen woodland. Witt (2008) noted that elk primarily used juniper woodland, riparian, and evergreen woodland communities, all of which were predominately found on the eastern portion of the range. Vegetation within the Glass Mountains was very diverse. Typical species included beargrass (*Nolina texana*), catclaw acacia (*Mimosa aculeaticarpa biuncifera*), sotol (*Dasyllirion leiophyllum*), gray oak (*Quercus grisea*), junipers (*Juniperus* sp.), pinyon pine (*Pinus cembroides*), tobosa, mesquite, tarbush, creosote, mariola, lechuguilla (*Agave lecheguilla*), skeletonleaf golden-eye (*Viguiera stenoloba*), brickellbush (*Brickellia coulteri*), and little leaf sumac (*Rhus microphylla*).

METHODS

Capture

In addition to Witt's (2008) radiocollared adult females ($n = 14$) and adult males ($n = 3$), we darted and captured (Scientific Permit no. 0592-525) 7 males in the Glass Mountains from September to November 2009. We immobilized elk with a mixture of 600 mg xylazine and 200 mg telazol (Kreeger 1996). In the 3 months preceding capture, we determined common areas utilized by elk. We darted elk through blinds, on foot, and by helicopter at predetermined locations.

Once immobilized, capture personnel restrained, hobbled, and blindfolded elk. We placed Lotek GPS 3300 (Newmarket, ON, Canada) collars on the immobilized elk. We adjusted collars to allow for growth of male elk during rut. We determined age by tooth replacement and wear (Heffelfinger 1997). After data collection, we injected 1,000 mg of the reversal drug Tolazoline into a muscle (Kreeger 1996). Capture personnel left the area after the elk was awake and determined to be fully functional.

Herd Composition and Recruitment

We estimated adult sex ratios during June–September and calf:female rates during July–September of 2009 and 2010 using survey routes. This allowed us to gather calf:female data at biological significant times during the “at weaning” period. We surveyed elk from ranch roads that were randomly selected in the Glass Mountains. We considered a “sighting” to be an individual elk or group of elk. We recorded the number of females, calves, and males for each sighting event. In order to demonstrate population potential, we decided to estimate maximum potential finite rate-of-increase because our data were collected before post-weaning mortality and calf recruitment into the adult population. We estimated maximum potential finite rate of population increase as λ ($\lambda = \text{ad F survival} + 0.5 \text{ calf:female ratio at weaning}$; White and Bartmann 1997).

Density

We determined density estimates using data from 26 distance sampling surveys conducted in September and October of 2009 and 2010, when access to land was possible. We delineated 4 random road surveys (using ArcGIS) that we believed to be adequate representation of the study area and its vegetation communities. When possible, we conducted concurrent surveys, which consisted of 2–4 vehicles driving separate surveys at the same time. This reduced the possibility of elk being counted twice because of movement between survey routes. We drove survey routes, during peak hours of elk activity, between 0700–1100 hours and 1600–2030 hours. We drove survey routes at 16 km/hour for approximately 16 km. We recorded time, group size, and herd composition. Additionally, we recorded observer location (GPS location) and the azimuth and distance to the elk. We estimated distance to the elk using a laser rangefinder. We determined population size from our recorded data and the area of the Glass Mountains (780 km²) using Distance software 6.0 (Thomas et al. 2010). Within Distance 6.0, we selected a line-transect survey, single-observer configuration, radial distance and angle, and clusters of objects observations. We measured units for data as yards for distances, miles for transects, and acres for area. We used the half-normal-cosine model with 2 parameters and an Akaike Information Criterion value of 492.25. Absolute densities (elk/km²) were then determined by dividing population size by area (780 km²). Grace (1983) noted the Glass Mountains to encompass 780 km² and estimated the elk population to be from 161 (SE = 44) to 168 (SE = 57) elk within this area. In order to compare density

estimates, we converted Grace's estimate to elk/km² by dividing them by 780 km² to equal 0.21–0.22 elk/km².

We used data from Texas Parks and Wildlife Department (TPWD 2010) helicopter surveys to estimate elk density across the Trans-Pecos. Texas Parks and Wildlife Department used a stratified random sampling design for their annual mule deer surveys, which were flown by TPWD employees during the months of January–February 2010 (Fig. 1). Texas Parks and Wildlife Department surveys were flown on randomly selected transects with varying lengths. In 2010, TPWD included elk observations in their survey for the first time. A TPWD team of 1 pilot and 2 observers flew surveys at an altitude of 15–18 m above ground level from sunrise to 1000 hours and the last 3 hours of daylight. The TPWD surveys observed elk in the Davis Mountains, Glass Mountains, Marathon Basin, and the Stockton Plateau. Therefore, we extrapolated elk densities for these mountain ranges.

Survival

In our calculations, we used previously collected weekly locations of 17 elk (14 F, 3 M) wearing Lotek VHS collars from 2006 to 2009 (Witt 2008). In September 2009, we captured an additional 7 male elk and continued collecting data for all 24 elk (14 F, 10 M) with the same aerial telemetry method up to twice a week. We determined weekly aerial

locations using 2 H-antennas (Model RA-2AK; Telonics, Mesa, AZ) mounted to the wing struts of a Cessna-172 fixed-wing aircraft. A pilot and 2 passengers used a receiver (Model TR-2; Telonics) and directional control unit (Model TAC-2-RLB; Telonics) to locate elk. We flew approximately 600 m above ground level. Flights were conducted between 0900 hours and 1300 hours. Data recorded included observers, weather, location of each elk, and mortality.

We determined survival rates based on mortality of collared elk ($n = 24$) during the course of the study (e.g., 2006–2010). All radios were outfitted with mortality-sensitive switches that put off a signal that was detected through aerial telemetry. When this signal was detected, we verified mortalities on the ground. We estimated annual survival for elk and males separately using seasonal intervals with a staggered-entry Kaplan–Meier method (Krebs 1999).

RESULTS

Herd Composition and Recruitment

We recorded 117 sightings from 24 June 2009 to 29 September 2010 (Table 1). In 2009, annual ratios were 63:100:38 and in 2010 they were 46:100:40. We determined the collective calf:female:male ratio to be 49:100:39 for 2009 and 2010 (Table 2). All reported calf:female:male ratios ranged from 0 to 100:100:0 to 100. Average group size seen

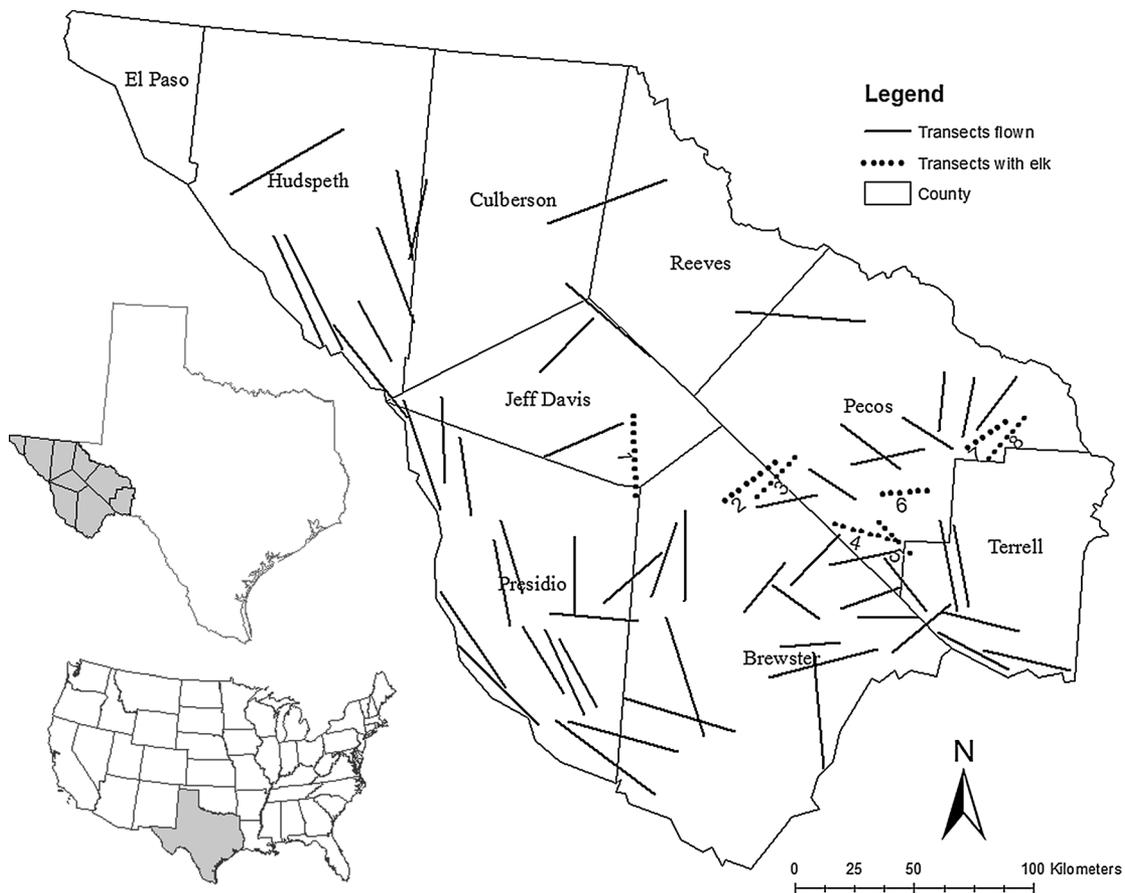


Figure 1. Location of Texas Parks and Wildlife Department aerial survey routes for elk surveys conducted in the Trans-Pecos, Texas, USA, January–February 2010.

Table 1. Herd counts of elk in the Glass Mountains, Texas, USA, February–October 2009, 2010.

Month	Total days		No. of groups observed	
	2009	2010	2009	2010
Feb	0	2	0	2
Mar	0	1	0	1
Apr	0	0	0	0
May	0	2	0	3
Jun	3	3	8	3
Jul	3	6	6	17
Aug	4	4	5	19
Sep	4	8	6	41
Oct	2	0	6	0

Table 2. Calf:female:male ratios for elk in the Glass Mountains, Brewster and Pecos counties, Texas, USA, June 2009–September 2010.

Time period	Calves/100 F (%)	M/100 F (%)
2009	63	38
2010	46	40
Jun	25	65
Jul	50	13
Aug	61	30
Sep	41	83
Collective	49	39

was 4.5 elk (SE = 5.0). We determined λ as $\lambda = \text{adult female survival} + 0.5 \text{ calf:female at weaning}$. We calculated the estimate of λ to be 1.19 ($=0.944 + 0.5 \times 0.49$).

Density

We recorded 37 unique elk sightings between September and October of 2009 and 2010. Based on these sightings, we determined elk density within the Glass Mountains to be 0.39 elk/km², varying from 0.18 elk/km² to 0.78 elk/km² (95% CI). Average distance from survey line was 385.8 m. Average encounter rate (groups observed per survey route) was 0.10 and ranged from 0.03 to 0.18.

Number of transects flown by TPWD throughout the Trans-Pecos was 60 and totaled 397 km² (Texas Parks and Wildlife Department 2010). Out of the 60 transects flown, 8 transects had elk and 55 total elk were seen. Elk were seen on transects located in Brewster, Jeff Davis, Pecos, and Terrell counties (Table 3). Total area of transects with elk was 41 km² (approx. 10% of survey area). We determined the number of elk within the Trans-Pecos region to be 0.14 elk/km² (95% CI), varying from 0.03 elk/km² to 0.33 elk/km².

Table 3. Observations of elk as documented by Texas Parks and Wildlife Department during annual surveys for mule deer, Trans-Pecos, Texas, USA, January–February 2010.

Line no.	County	Location	No. of elk observed	Area observed (km ²)
1	Jeff Davis	Davis Mountains	3	6.47
2	Brewster/Pecos	Glass Mountains	19	5.33
3	Brewster–Pecos	Glass Mountains	5	4.86
4	Pecos	Marathon Basin	10	5.71
5	Pecos–Terrell	Marathon Basin	2	4.53
6	Pecos	Marathon Basin	4	4.44
7	Pecos	Stockton Plateau	10	4.47
8	Pecos	Stockton Plateau	2	4.86

Survival

Three of the 24 radiocollared elk died during the course of the study. Two radiocollared females died in the spring of 2007 (Witt 2008). Witt (2008) noted that the causes of deaths were unknown because they were found 3–4 days post-mortem. The third mortality was a radiocollared male elk that was legally harvested by a hunter in November 2009. Three male elk had collar malfunctions in the spring of 2008, winter of 2009, and spring of 2010. These male elk were considered censored in our staggered-entry Kaplan–Meier analysis (Krebs 1999). We estimated annual survival of mature radiocollared male elk to be 97.1% (95% CI, SE = 10.5%) and mature radiocollared female elk to be 94.4% (95% CI, SE = 11.6%).

DISCUSSION

Herd Composition and Recruitment

Calf:female ratios are practical indices of herd productivity (Gaillard et al. 2000, Bender and Piasecke 2010). Collection of calf:female ratio data before post-weaning mortality and calf recruitment into the adult population gave us the maximum potential finite rate-of-increase. By calculating λ , we were able to compare our results with other studies. Bender and Piasecke (2010) reflected a high maximum estimate of λ for 3 consecutive years as 1.22, 1.22, and 1.08, which were comparable to the Bender et al. (2002), who recorded $\lambda = 1.22$ for the fastest growing elk herd ever documented. We believe our estimate of $\lambda = 1.19$ mostly indicates the population is productive and growing. The high variance in the calculated average encounter rate of 4.5 (SE = 5.0) might be explained by varying habitat in each survey route.

On average, the gestation period for elk is 249–262 days, with the main calving period extending from the middle of May to the middle of June (Demarais and Krausman 2000, Vore and Schmidt 2001, Toweill and Thomas 2002, Schmidly 2004). Calves are not routinely observed until about 1 month of age; therefore, the number of calves observed/100 females can be higher in July than June, although the actual total number of calves might be lower (Toweill and Thomas 2002). This discrepancy in calf:female ratios was apparent in our study, where the ratio of calves doubled from June to July. Toweill and Thomas (2002) demonstrated that the estimated loss of calves between birth and August can be as much as 25 calves/100 females.

Although our results do not show this decrease in the same months, it does decrease by 20.1 calves/100 females between our highest month of August (60.9:100) and lowest month (excluding June when they are not routinely observed) of September (40.8:100). Early winter estimates from Coughenour and Singer (1996) and Bender and Piasecke (2010) reflect our September estimate of 40.8:100 by averaging 33.8:00 and 41:100, respectively.

Factors influencing calf:female ratios include, but are not limited to, forage condition, winter severity, changes in annual precipitation, and predation. Declining birth rates and increased abortion rates (Coughenour and Singer 1996), smaller calves, calves born later in the season (Singer et al. 1997), and increased mortality of calves (DelGiudice et al. 1991) have been attributed to poor adult fitness. Conditions of adult elk can be influenced by reductions in forage quantity and quality. Calf:female ratios are commonly used to determine population trajectories and can exhibit potential for growth or suppression in a population. Therefore, along with herd composition and density, natality rates can be a vital prerequisite for understanding herd dynamics and management.

We were unable to collect male:female ratio data at a period when the sexes were freely intermixed; therefore, it is likely that our data were biased because it was a time of sexual segregation. We found that overall male:female ratio of 39.1:100 in the Glass Mountains was in the higher end of the medium range (16–39:100). This ratio (39:100) suggests a desirable male:female ratio for an elk population. Although there is an optimum number of males in the Glass Mountains, it is important to note that there might not be a high proportion of breeding by mature males, which most management strategies emphasize (Bender 2002). Future data collection directed toward management strategies should include determining mature male:female ratios rather than focusing on a single demographic variable of male:female ratios that includes immature and mature males.

Common techniques to manipulate ratios to meet management goals include attempts to affect rate-of-increase, age structure, and adult sex ratios in populations (Bender 2006). Population productivity and adult mortality rates can provide managers with information such as the maximum sustainable mortality rates for a population and annual adult mortality rates.

Density

Grace (1983) gave the most recent population estimate of elk in the Glass Mountains as 0.21–0.22 elk/km². Our estimate (0.39 elk/km², 95%CI = 0.18 elk/km²–0.78 elk/km²) indicates that the elk population could have stayed the same or possibly doubled since 1983. For the population to have doubled in this 17-year period, λ would equal about 1.04. This rate-of-increase is below our estimated maximum rate-of-increase at $\lambda = 1.19$, which shows the population could have at least doubled.

Some limiting factors that play a role in long-term and short-term elk population density (specifically in arid environments) include hunting, quality of habitat, and

particularly spring precipitation (McCorquodale and Eberhardt 1990; Bender and Piasecke 2010; Halbritter and Bender 2011a, b). We can compare our population rate-of-increase of 4–6%/year to Bender and Piasecke (2010), who experienced a 6% reduction (from 10% to 4%) in rate-of-increase due to 2 years of dry springs. Possible reasons for our low 4–6% rate-of-increase might be high hunting pressure or possibly low calf survival. With a high recruitment (41–61:100), the population should be expected to double every 5–6 years. Population rates of increase over time might also be related to the amount of forage available (e.g., carrying capacity and availability). When food availability decreases, it affects population density because of the typically larger home range sizes (McNab 1963). Supplemental feed might help overall nutritional quality of pregnant and lactating females. The amount of water available in arid lands such as the Trans-Pecos is also believed to have an impact on the number of elk the land can support (McCorquodale and Eberhardt 1990; Toweill and Thomas 2002; Shannon et al. 2009; Bender and Piasecke 2010; Halbritter and Bender 2011a, b). Throughout the Trans-Pecos, elk utilize water provided by private landowners through water troughs intended for cattle operations. Without these permanent water sources, it is believed that elk would not be able to sustain current population numbers (McCorquodale and Eberhardt 1990; Bender and Piasecke 2010; Halbritter and Bender 2011a, b). Although we have listed several reasons for the rate-of-increase in the Glass Mountains elk population, it is likely that it might be most attributable to a combination of factors mentioned above.

Although elk were only recorded as being seen in Brewster, Jeff Davis, Pecos, and Terrell counties during TPWD surveys, Guevara (2009) also included Hudspeth, Culberson, Reeves, and Presidio counties based on landowner surveys. Therefore, elk were found in all counties of the Trans-Pecos region excluding El Paso County, which was not surveyed by either TPWD or Guevara (2009). The inability of TPWD to observe elk in these counties, suggest that those populations occur at very low densities or screening cover was so high they were not observed (e.g., core regions of the Davis Mountains). The elk populations in the Glass and Davis mountains are thought to be some of the higher densities in Texas (Schmidly 2004).

Survival

Annual survival of the Glass Mountains elk herd from 2006 to 2010 was relatively high (94.4% F to 97.1% M). Throughout their range, causes of juvenile and adult mortalities in the winter include starvation, late birth, poor nutrition during the summer, and predation (Toweill and Thomas 2002). Coykendall (1990) noted possible mortality factors in the Trans-Pecos region of Texas as malnutrition and predation by mountain lions (*Puma concolor*). Carpenter (1993) noted mange (*Chorioptes bovis*) as a cause of death for a female elk in the Guadalupe Mountains. Grace (1983) also noted that predation by mountain lions, coyotes (*Canis latrans*), and bobcats (*Lynx rufus*) was a probable cause for low natality rate and low

subadult:adult ratio. Causes of death for our study included hunter harvest for 1 male and 2 other deaths that were unknown.

Our high survival rate of 97.1% (SE = 10.5%) for mature male elk and 94.4% (SE = 11.6%) for mature female elk suggests that the elk population is performing well and has the potential to continue to perform well. The survival rate for elk in the Glass Mountains is comparable to Bender and Piasecke (2010), who determined survival rate of an elk population in northwestern New Mexico to be 94–100% (SE = 0.06–0.00%) for females. Our survival rates are also comparable to Halbritter and Bender (2011*b*), who determined survival rate of an elk population in southern New Mexico to be 95–100% ($P \geq 0.116$). Survival rates on mature elk in arid regions of North America have been recorded on several occasions (Coykendall 1990, Bender and Piasecke 2010, Halbritter and Bender 2011*b*). When compared with fecundity rates, survival rates have a greater impact on rates of population increase (Gaillard et al. 2000, Toweill and Thomas 2002, Bender and Piasecke 2010). Our skewed male:female ratio (39:100), 4–6% rate-of-increase, and high survival rate of 97.1% (SE = 10.5%) for male elk indicate that either we missed a large segment of males during the surveys or a considerable amount of male harvest must be taking place.

MANAGEMENT IMPLICATIONS

Our data provide essential elements for managing elk in the Trans-Pecos. The estimated 4–6% population growth potential per year may indicate that it is not economically viable for private landowners to manage the resource for a sustainable yield at this time. Managing the Glass Mountains elk population for a sustainable yield and desired productivity and age structure may be possible through cooperative efforts to monitor elk population demography and dynamics. Although we provide data to advance our understanding of elk in Texas, data on limiting factors such as forage and water should be assessed when establishing management plans. Collectively, our results describe the population dynamics of elk in the Glass Mountains.

ACKNOWLEDGMENTS

We thank Texas Parks and Wildlife Department for their contribution of data. We also would like to thank the Sul Ross State University volunteers who assisted collecting field data and the landowners of the Glass Mountains for access to their property. We also acknowledge our pilots, G. Vose and C. L. Woodward, for the numerous safe flights. Funding was provided by the Rocky Mountain Elk Foundation, San Antonio Livestock Exposition, and Borderlands Research Institute.

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Associate Editor: Rominger.

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