California Fish and Game 104(1): 28-33; 2018

Field method for estimating the weight of tule elk from chest circumference

Cristen O. Langner* and David S. Casady

California Department of Fish and Wildlife, Central Region, 1234 E. Shaw Avenue, Fresno, CA 93710, USA (COL)

California Department of Fish and Wildlife, Wildlife Branch, 1812 9th Street, Sacramento,CA 95811, USA (DSC)

**Correspondent: Cristen.Langner@wildlife.ca.gov*

Key words: California, *Cervus canadensis nannodes*, field techniques, girth, Tule elk, weight

---

Wildlife biologists with the California Department of Fish and Wildlife (CDFW) routinely use remotely delivered chemical immobilization agents to capture tule elk (*Cervus canadensis nannodes*). Many of the common immobilization and reversal agents for elk have dosages based on body weight (Kreeger et al. 2002) - but how do you determine the weight of an animal before you have it in hand? Wildlife manuals generally only provide a broad weight range for tule elk, and until now, biologists have been forced to use their best guess based on these unrefined estimates to determine drug dosages. Delivering the correct dosage of agonist is imperative because under dosing may lead to the non-recovery of a darted animal or unsafe handling conditions, while overdosing may lead to unnecessarily long anesthesia times or the death of an animal. In addition, under dosing the antagonist may lead to partial reversal or the animal may succumb to the agonist again, which may lead to injuries, leave animals vulnerable to predators and weather, and death.

However, obtaining the weight of such a large animal in the field is problematic; the required tripod and scale are heavy, cumbersome, and not easily transported into remote capture sites. Therefore, the goal of our study was to provide field personnel with an easy way to estimate tule elk weights in order to quantify, learn, and hone their estimates prior to drug delivery without having to pack cumbersome equipment into the field. We achieved our goal by developing a method of estimating the weight of tule elk from their girth based on approaches first developed by Parker (1987) and Cook et al. (2003) for Rocky Mountain elk (*C. c. nelsoni*). Our method allows biologists to obtain tule elk weights using just a measuring tape and a conversion table so that over time, they are able to refine their weight estimates to more effectively and ethically use chemical immobilization agents to capture tule elk.

We collected morphometric measurements during the capture and handling of tule elk associated with two field projects in Merced County, California from 2013 through 2017. The first project was at San Luis National Wildlife Refuge (37°

6'N, -120° 28'W), and the second project was near San Luis Reservoir (37° 01'N, -121° 01'W). All elk (*n*=52) were captured using helicopter net gunning or chemical immobilization via free-range darting following capture and handling protocols set forth by the CDFW Wildlife Investigations Laboratory (Wildlife Investigations Lab, 2014) and the American Society of Mammologists guidelines (Sikes et al. 2011).

For the free-range darting captures, Pneu-Dart® compression rifles (Pneu-Dart Inc., Williamsport, PA) and 2 ml Pneu-Dart® barbed tri-port darts with 3.8 cm needles were used to immobilize animals not captured with the helicopter and net gun. Laser rangefinders were used to determine the distance to each elk and animals were darted at distances from 20 m - 80 m. Specific individuals were not pre-selected for capture; animals were targeted that presented a safe shot for chemical immobilization within the specified sex and age classes required for each project.

All elk included in the analysis are either adults or subadults (i.e., yearlings); calves were excluded due to the low sample size. The presence or absence of the third molar (M3; Peek 1982), as well as the overall size and body conformation of the animal determined age class. Animals weighing less than 90 kg that had no M3 tooth were classified as calves. Adult males (63%, *n*=19) that were captured in March were in the early stages of antler development and the remainder of adult males (37%, *n*=11) had fully developed antlers. Single cast antlers weighed on average 2.59 kg (*n*=17, *SE*=0.18) and thus added relatively little weight to the overall estimate. Most adult female elk (91%, *n*=20) were captured during March near the end of pregnancy (McCullough 1971); the remaining two females were captured during December and February. All captured elk were weighed using the same Brecknell Model CS2000 digital scale suspended from a 454 kg chain hoist affixed to a 2.4 m collapsible metal tripod (Figure 1). A steel-framed helicopter litter and standard ratchet straps were used to suspend the elk from the scale. The weight of the litter and straps were subtracted from the final weight, which was recorded to the nearest pound and converted to kilograms. The chest circumference of each elk was measured with a flexible vinyl measuring tape positioned around the animal at the apex of the chest just posterior to the front legs (Figure 2). Measurements were recorded to the nearest centimeter.

All data were analyzed using r-programming language (R Core Team 2015). First, data were input into the weight/girth power functions with both sexes combined to assess fit (Cook et al. 2003; Parker 1987). Models were then constructed from the data using lm function for linear models and the nlm function for the power functions in the Metrics Package (Hamner 2017). Model fit was evaluated using root mean square errors (*RMSE*) in the pastecs package (Grosjean and Ibanez 2014); the error is expressed in the same units as the response variable (kg).

A total of 52 tule elk was captured: 22 females, 15 adults and 7 subadults; and 30 males, 16 adults and 14 subadults. The mean weight of adult female tule elk was 150 kg (95% *CI* 15.6, range 70–201 kg, *n*=22) and the mean weight of adult male tule elk was 171 kg (95% *CI* 16.6, range 91–235 kg, *n*=30). The power model fit best for the adult male elk and the linear model fit best for the adult female elk (Table 1).

We were initially concerned that the potential variability in fetal calf sizes might unduly increase the observed variability in mean adult female weights resulting in poor model fit, but this was not the case. Because we found only minor differences in fit between power and linear models for adult females, we suggest using the power model for calculating weight estimates due to the likely allometric relationship between body weight and chest girth (McMahon 1975) (Figures 3 and 4). Our data did not fit the models built for Rocky Mountain elk as well as the models built specifically for tule elk, which would be expected due to the allometric differences between the sub-species (McCullough 1971).

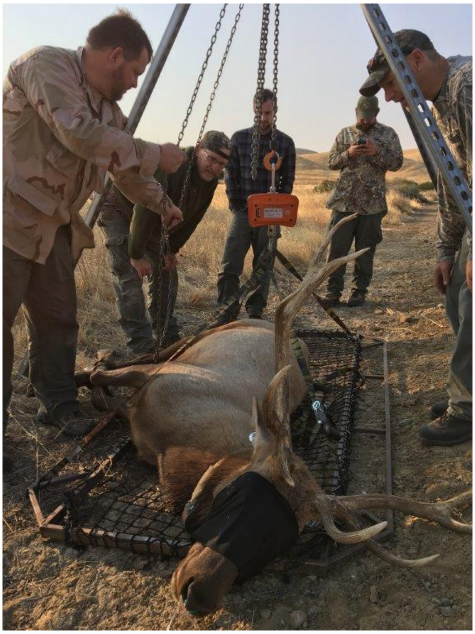

FIGURE 1. —Transportable apparatus for weighing tule elk including collapsible metal tripod, crane-scale, heavy-duty pulley, and metal-framed helicopter transport litter.

FIGURE 2. —Proper location of measuring tape to obtain chest circumference of laterally recumbent tule elk to estimate live weight.

TABLE 1. —Fit of linear and power models to predict live weight of adult tule elk from chest circumference.

Model	*n*	Equation	*RMSE*	*r – value*
Power – Adult Males	30	$y = 0.00001x^{3.321}$	11.7	0.96
Linear – Adult Males	30	y = 3.74x – 349.35	12.3	0.96
Power – Adults Combined	52	$y = 0.00003x^{3.171}$	12.9	0.95
Linear – Adult Females	22	y = 3.37x – 298.41	13.3	0.92
Power – Adult Females	22	$y = 0.00007x^{2.978}$	14.0	0.91
Linear – Adults Combined	52	y = 3.60x – 330.53	16.8	0.95
Parker 1987	8	$y = 0.00036x^{2.635}$	16.8	-
Cook et al. 2003	425	$y = 0.00046x^{2.618}$	22.5	-

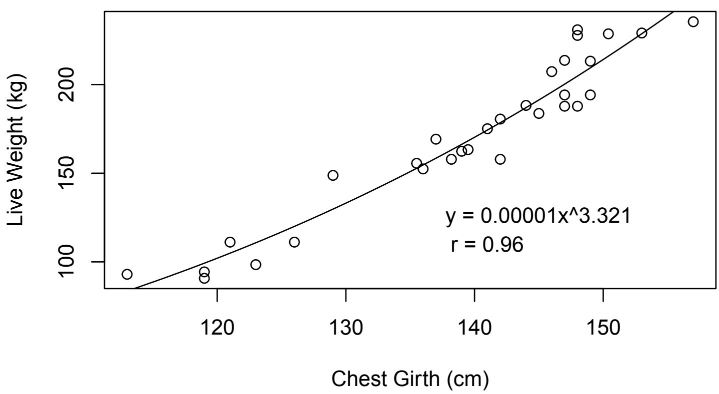

FIGURE 3. —Relationship between adult male tule elk chest girth and live weight (*n* = 30).

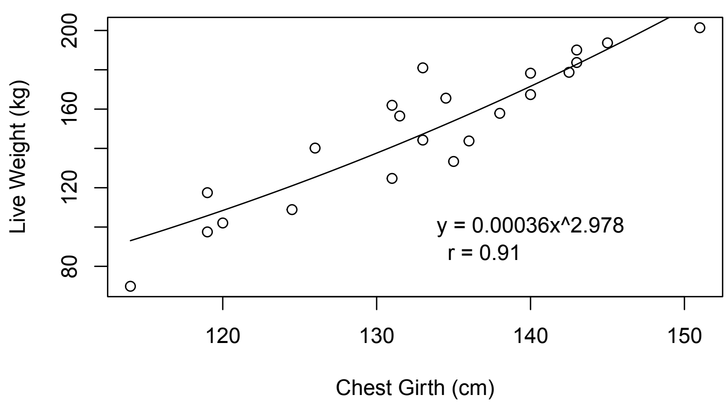

FIGURE 4. —Relationship between adult female tule elk chest girth and live weight (*n* = 22).

Our results provide a useful approach to estimate weights of tule elk in the field with only a measuring tape and a conversion chart (Table 2).

Table 2. —Live weight estimates from chest circumference for adult male and adult female tule elk.

Adult Male $y = 0.00001x^{3.321}$		Adult Female $y = 0.00007x^{2.978}$	
Chest Circumference (cm)	Weight (kg)	Chest Circumference (cm)	Weight (kg)
125	92	110	84
130	105	115	96
135	119	120	109
140	134	125	123
145	151	130	138
150	169	135	155
155	188	140	172
160	209	145	191
165	231	150	212

If greater accuracy is needed, the tripod and scale are required. Although these models were developed to aid in immobilizing animals, they are applicable in numerous scenarios where determining field weights of tule elk is desirable and transporting heavy equipment is not practical. It is recommended that CDFW biologists continue to collect both the scale weights and girth measurements of captured tule elk to hone the predictive models and further enhance the ethical chemical capture and handling techniques used in the field (Casady and Allen 2013).

Acknowledgments

C. Langner and D. Casady contributed equally to the preparation of this paper. The California Department of Fish and Wildlife, the Federal Aid in Wildlife Restoration Grant W-86-R, and the Rocky Mountain Elk Foundation generously provided funding for this study. We would also like to thank the United States Fish and Wildlife Service, the California Department of Water Resources, and the California Department of Parks and Recreation for their support and granting us access to their properties. We would also like to thank S. Langner for the tripod design and construction, D. Fidler, N. Graveline, E. King, and T. Kroeker for their capture expertise, J. Garcia for photo editing, J. Hobbs, the former CDFW elk program coordinator, for all his help and support, and the anonymous reviewers who provided useful comments and greatly improved the manuscript.

Literature Cited

Casady, D. S. and M. L. Allen. 2013. Handling adjustments to reduce chemical capture-related mortality in black-tailed deer. California Fish and Game 99:104-109.

Cook, R. C., J. G. Cook, and L. L. Irwin. 2003. Estimating elk body mass using chest-girth circumference. Wildlife Society Bulletin 31:536-543.

Grosjean, P. and F. Ibanez. 2014. Pastecs: package for analysis of space-time ecological series. R package version 1.3-18. Available from: https://www.R-project.org/.

Hamner, B. 2003. Metrics: evaluation metrics for machine learning. R package version 0.1.2. Available from: https://cran.r-project.org/web/packages/Metrics/index.html.

Kreeger, T., J. Aremo, and J. Raath. 2002. Handbook of wildlife chemical immobilization. Wildlife Pharmaceuticals, Inc., Fort Collins, Colorado, USA.

McCullough, D. R. 1971. The tule elk: its history, behavior, and ecology. University of California Press, Berkeley, California, USA.

McMahon, T. A. 1975. Allometry and biomechanics: limb bones in adult ungulates. The American Naturalist 109:547-563.

Parker, K. L. 1987. Body-surface measurements of mule deer and elk. Journal of Wildlife Management 51:630-633.

Peek, J. M. 1982. Elk (*Cervus elaphus*). Pages 851-861 *in* J. A. Chapman and G. A. Feldhamer, editors. Wild Mammals of North America. The Johns Hopkins University Press, Maryland, USA.

R Core Team. 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: https:/www.R-project.org/.

Sikes, R. S., W. L. Gannon, and the Animal Care and Use Committee of the American Society of Mammalogists. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92:235-253.

Wildlife Investigations Lab. 2014. Wildlife restraint handbook. Tenth edition. California Department of Fish and Wildlife, Rancho Cordova, California, USA.

Received: 01 January 2018
Accepted: 18 March 2018
Associate Editor was: D. Wright