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Does body condition affect immediate post-capture survival of ungulates?

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Abstract: Many factors are known or are thought to increase vulnerability to capture-related mortality in ungulates. I compared body condition of Rocky Mountain elk (*Cervus elaphus nelson*), mule deer (*Odocoileus hemionus*), and pronghorn (*Antilocapra americana*) to assess whether those that survived capture differed from those that did not. Fate of ungulates was generally not related to condition ($F_{1,646}$ = 1.6; P = 0.21), and this relationship was similar among species (species × fate interaction: $F_{4,646}$ = 1.3; P = 0.29), season of capture (species × season × fate interaction: $F_{6,646}$ = 0.6; P = 0.732), and sex (species × sex × fate interaction: $F_{4,646}$ = 2.1; P = 0.08). The exception was male pronghorn that were in better condition showed a higher rate of mortality. Survival was not affected by number of times an individual previously had been captured, rectal temperature during handling, or mode of capture (helicopter darting or net-gunning). Individuals in poorer condition were not predisposed to capture-related mortality despite a significant proportion of individuals being in poor condition at capture (i.e., 60 to 67% of individual elk and mule deer <5% body fat [BF]; 19 to 23% <3% BF in late-winter captures). Similarly, proportions of individuals that lived or died during and within 30 days of capture in the extremes of condition (i.e., <5% BF or >7% BF in late winter or >12% BF in late-autumn captures for mule deer and elk; and individuals with 0 cm of subcutaneous rump fat versus 1.5 cm for pronghorn) never differed among individual captures or species (Fisher's exact $P \geq 0.14$). Although many factors can and do affect mortality associated with capture, low body condition did not predispose individuals to presumably capture-related mortality for any of these ungulate species, regardless of species, season, sex, or capture history of individuals.

Key words: body condition, capture, survival, ungulates

Exertional myopathy and other capture-related mortality have received significant attention regarding causes and methods to mitigate them (Williams and Thorne 1996, Kreeger 1999, Nielsen 1999, Arnemo et al. 2006). Percentage of mortality associated with capture and handling of free-ranging ungulates is highly variable and depends upon species and conditions of capture. For example, capture and immediate post-capture mortality can be as high as 47% for smaller, comparatively fragile species, such as pronghorn (*Antilocapra americana*; Figure 1; O'Gara et al. 2004), to as low as <1%, with larger, more robust ungulates, such as moose (*Alces alces*; Armeno et al. 2006). Often, the true extent of mortality associated with capture events is understated, as not all summaries include all causes of mortality (e.g., predation, accidents, etc.) that occurs within 30 days of capture as capture-related, despite evidence that capture effects can predispose wildlife to mortality for that period or longer (Berringer et al. 1996, Williams and Thorne 1996). Many factors contribute to capture and immediate (≤30 days) post-capture mortality (hereafter, presumably capture-related [CR]), including drug overdose, dart trauma, cervical dislocations during fall, stress, hyperthermia, hypothermia, exertional myopathy, or infection (Williams and Thorne 1996, Arnemo et al. 2006). Further, poor body condition has been identified as a contributor to anesthetic mortality in domestic animals (Hall et al. 2001) and is believed to predispose free-ranging wildlife to CR mortality, although I am aware of no data that addresses this topic.

Many studies of ungulates involve populations that are declining or showing poor survival or productivity, a frequent cause of which is poor individual condition (Lomas and Bender 2007, Bender et al. 2007, 2008, 2011, 2012, 2013). Because such populations are more likely to be studied, it is important to understand whether level of condition increases susceptibility to CR mortality. While levels of CR mortality can be low under ideal conditions (e.g., Armeno et al. 2006), wildlife research is objective driven, and capture operations correspondingly may not occur under ideal conditions. To be biologically meaningful, individual condition must be assessed during relevant periods, such as the seasonal peak in late autumn or the seasonal low in late winter (e.g, Bender et al. 2007, 2008, 2011, 2012, 2013). Capture and handling during these times can expose animals to high ambient temperatures (autumn), elevated stress levels (the rut in autumn), or extremely low condition (late winter) that may increase the likelihood of CR mortality above levels associated with ideal conditions. These conditions also could potentially increase the likelihood of individual ungulate differences, such as differences in condition, affecting post-capture survival.

I compared condition of individuals from 3 large ungulate species: Rocky Mountain elk (*Cervus elaphus nelson*), mule deer (*Odocoileus hemionus*), and pronghorn that successfully survived capture and handling with those that died from any factor during or within 30 days of capture. My goal was to determine when individual condition had any influence on susceptibility to mortality due to capture or immediately post-capture.

Figure 1. Pronghorn (*Antilocapra americana*; *photo courtesy Earl Watters).*

Methods

Study populations

My study populations included 36 capture events from 8 elk populations, 28 capture events from 4 mule deer populations, and 10 capture events from 3 pronghorn populations located primarily in the southwestern United States. In each case, ungulates were captured in late autumn (mid-November to early December) at the approximate peak of condition based on local plant phenology and climate, and in late winter to early spring (late March to early April) at the approximate seasonal low in condition. In all cases, capture occurred prior to the third trimester of gestation based on local parturition timing, while some mule deer captures included the early rut. In many cases, the same individuals were recaptured seasonally, some >6 times, for seasonal condition assessment.

Capture

I captured ≥2.5-year-old (hereafter, adult) female elk, adult male and female mule deer, and adult male and female pronghorn in late autumn or the following late winter by darting (90% of captures) or net gunning (10% of captures) from a helicopter. I included only adults in analyses because of 67 captures of yearlings and 41 captures of fawns and calves (solely by net gunning) during the same projects, only 1 CR mortality occurred. All darting, net-gunning, and condition assessment was performed by the author. I aged all individuals to exact age using cementum annuli or to categories of yearling or adult by tooth wear and replacement (Robinette et al. 1957, Hamlin et al. 2000, Lubinski 2001).

For darted individuals, I immobilized each ungulate species with carfentanil citrate and xylazine hydrochloride (elk = 3.0 to 4.5 mg carfentanil + 100 to 150 mg xylazine/elk; mule deer and pronghorn = 1.8 to 3.0 mg carfentanil + 75 to 100 mg xylazine/individual) and blindfolded individuals to calm them and prevent eye injury. I also treated each individual with penicillin, vitamin E/selenium, vitamin B, and an 8-way *Clostridium* bacterin. I reversed immobilants with naltrexone (elk = 350 to 500 mg, deer and pronghorn = 200 to 350 mg, administered half intravenous and half subcutaneous) and 800 to 1,000 mg tolazoline hydrochloride for elk and 200 to 4000 mg tolazoline hydrochloride (or 30 to 35 mg atipamezole hydrochloride) for mule deer and pronghorn, delivered intravenously. No immobilants were used during net-gun captures. Each captured animal was assessed

Table 1. Mean (SD) percent body fat (BF; elk and mule deer) or maximum subcutaneous rump fat thickness (pronghorn) among captures, range in mean condition among captures, mean (SD) proportions of individuals in each capture in good (>12% BF in autumn or >7% BF in spring [elk, deer]; >1.5 cm subcutaneous rump fat [pronghorn]) or poor (<5% BF and <3% BF [elk, deer]; 0 cm subcutaneous rump fat [pronghorn]condition classes, total percent presumably capture-related mortality (% CR) and total percent mortality immediately at capture (% mortality) for North American elk, mule deer, and pronghorn populations.

	Elk		Mule deer		Pronghorn	
	Autumn	Spring	Autumn	Spring	Autumn	Spring
Mean BF	10.6 (2.4)	4.9 (1.3)	10.4 (4.4)	4.5 (1.3)	0.6 (0.3)	0.2 (0.3)
Range $\bar{x}$ BF	6.2–14.0	3.6–7.2	6.3–19.0	2.5–6.7	0.1–1.0	0.0–0.7
% > 12% BF	40.6 (28.9)	—	33.9 (38.6)	—	11.5 (17.4)[a]	—
% > 7% BF	—	14.1 (15.4)	—	13.7 (24.0)	—	0.0 (0.0)[a]
% < 5% BF	13.2 (17.1)	67.0 (27.2)	10.6 (13.6)	60.1 (26.2)	—	—
% < 3% BF	1.9 (3.4)	22.7 (16.9)	1.7 (3.6)	18.8 (28.3)	48.0 (22.8)[b]	68.7 (46.2)[b]
N captures	19	17	16	12	6	4
% CR	2.2		5.1		8.4	
% mortality	0.4		1.3		4.0	
N individuals	730		640		201	

[a]Proportion of population with >1.5 cm subcutaneous rump fat for pronghorn.

[b]Proportion of population with 0 cm subcutaneous rump fat for pronghorn.

for body condition (see below); in the case of mule deer, tonsilar biopsies for testing for chronic wasting disease (Wolfe et al. 2002) also were performed on >50% of individuals. I processed all individuals at the capture site, and total handling time was usually <10 minutes. Individual pursuit times were seldom recorded but were ≤4 minutes.

Body condition

I determined a rump body condition score (rBCS) by palpation of the soft tissue of the rump near the base of the tail following Cook (2000) for elk and Bender et al. (2007) for deer and pronghorn. I scored results of rBCS measures from standards that ranged from 1.00 (emaciated) to 5.00 (obese) in intervals of 0.25 (Cook 2000). I used a SonoVet 2000 ultrasound (Medison, Seoul, South Korea) with a 5 mHz probe to measure maximum subcutaneous fat thickness (MAXFAT) along a straight line midway between the spine, at its closest point to the coxal tuber (hip bone), and the ischial tuber (pin bone) for each species (Cook 2000).

For elk, I estimated percent body fat (BF) using rLIVINDEX (Cook et al. 2001) where rLIVINDEX = rBCS when MAXFAT <0.3 cm; and rLIVINDEX = (MAXFAT – 0.3) + rBCS when MAXFAT ≥ 0.3 cm. I estimated BF from rLIVINDEX using $BF = -7.1527185 + 7.323081 \times L - 0.98980456 \times L^2 + 0.057445567 \times L^3$, where L = rLIVINDEX.

For mule deer, I estimated BF using BF = 5.68 + 5.93 × MAXFAT, where MAXFAT = maximum subcutaneous rump fat thickness as described above (Stephenson et al. 2002). Because the above equation can predict BF only down to 5.7% (Stephenson et al. 2002), I also used BF = 3.444 × rBCS – 0.746 to determine BF levels for Rocky Mountain mule deer (*O. h. hemionus*; Bender et al. 2007) and 4.014 × rBCS – 2.021 for desert mule deer (*O. h. crooki*) (Bender et al. 2012) when no subcutaneous fat was present. Because no models predictive of BF exist for pronghorn, I used MAXFAT as a relative index of condition for analyses (Bender et al. 2013).

Data analysis

I included captures only where ≥1 individual died during or within 30 d of capture for comparisons of surviving and dying individuals, whereas I used all captures from the same populations to determine total proportions of CR losses. I used ANOVA (Proc

GLM; SAS Institute Inc., Cary, North Carolina; Zar 1996) to compare condition of individuals that lived or died during or within 30 days of capture using 4 preplanned comparisons: fate (whether the individual lived or died during or within 30 days of capture), species × fate interaction (to see whether condition and fate relationship varied among species), species × sex × fate (to see if sex of species affected species relationships), and species × season × fate (to see if season of capture affected species relationships). Because condition can vary significantly among populations, time of capture (i.e., late autumn versus late winter), and indices used (Table 1), I normalized all condition data using score = $(BF_i - BF\bar{x}) / BF_{SD}$ or $(MAXFAT_i - MAXFAT\bar{x}) / MAXFAT_{SD}$, where BF_i = percent body fat of an individual in a capture; $BF\bar{x}$ = mean percent body fat of individuals in a capture; BF_{SD} = standard deviation of percent body fat of individuals in a capture; $MAXFAT_i$ = maximum subcutaneous fat thickness of an individual in a capture; $MAXFAT\bar{x}$ = mean maximum subcutaneous fat thickness of individuals in a capture; and $MAXFAT_{SD}$ = standard deviation of maximum subcutaneous fat thickness of individuals in a capture. This resulted in a normalized variable with $\bar{x} = 0$. Thus, individuals below mean condition level would have a negative coefficient, whereas individuals above mean condition would have a positive one. Because all individuals of all populations and species also would be distributed normally around $\bar{x} = 0$, this also allowed comparisons among populations and species regardless of differences in absolute levels of condition.

I also used Fisher's exact tests (Zar 1996) to compare CR mortality of individuals in poor condition with individuals in good condition. I defined poor condition as <5% BF, because reproduction in ungulates may be affected by this level of condition (Cook et al. 2004), and <2% BF has been defined as a "death threshold" for at least 1 ungulate (Depperschmidt et al 1987). I defined good condition as >12% BF in late autumn and >7% BF in late winter following condition criteria in Cook et al. (2004), although criteria from penned studies may underestimate performance of free-ranging individuals (Piasecke et al. 2009, Piasecke and Bender 2009). Fewer than 15% of individuals in any population were able to achieve these levels of condition in late winter, and ≤41% (elk) or 34% (mule deer) achieved these levels in late autumn (Table 1). Because BF estimates were not available for pronghorn, I used MAXFAT > 1.5 cm as a threshold of good condition and MAXFAT = 0 cm as a threshold for poor condition; <12% and >50% of individuals were at these condition levels regardless of season (Table 1); these levels were related to performance metrics of populations in the Southwest (Bender et al. 2013; L. Bender, unpublished data).

I used Fisher's exact tests (Zar 1996) to assess CR mortality by the number of times individuals were previously captured and between net-gun and darting captures by species. Last, I used bootstrapping with n = 1,000 iterations (Efron and Tibshitani 1993) to contrast CR mortality by maximum rectal temperature of individuals during handling for the subset of data for which rectal temperatures were available.

Results

Total CR losses were 2.2, 5.1, and 8.4% for elk, mule deer, and pronghorn, respectively (Table 1), and they included immediate capture-related mortalities (see below), as well as post-capture drowning, infections, falls, and exertional myopathy. Immediate capture-related mortalities (i.e., cervical fractures, death under anesthesia, nonresponsive following reversal of immobilants) were 0.4, 1.3, and 4.0%, respectively. Fate was generally not related to condition ($F_{1,646} = 1.6$; $P = 0.21$; normalized score of individuals dying = 0.17 and surviving = –0.04) and this relationship was similar among species (species × fate interaction: $F_{4,646} = 1.3$; $P = 0.29$) and season of capture (species × season × fate interaction: $F_{6,646} = 0.6$; $P = 0.73$), but was moderately affected by sex (species × sex × fate interaction: $F_{4,646} = 2.1$; $P = 0.08$). Normalized score of individuals dying versus those surviving among species were: pronghorn = 0.236 versus –0.10 ($P = 0.07$); mule deer = 0.13 versus –0.01 ($P = 0.41$); and elk = 0.14 versus –0.02 ($P = 0.40$). The sex effect occurred in pronghorn; males in better condition were more likely to suffer CR mortality (normalized score of CR mortalities = 1.04 versus –0.28 for survivors; $P = 0.01$), whereas pronghorn females ($P = 0.78$), mule deer males ($P = 0.40$), mule deer females

(P = 0.87), and elk females (0.40) showed no effect of condition on CR mortality.

For individuals in poor or good condition classes, incidence of CR mortality never differed for any capture event (Fisher's exact $P \geq 0.30$). Differences between proportions of individuals in poor or good condition that died from CR mortality similarly did not differ for elk (Fisher's exact $P = 0.14$), mule deer (Fisher's exact $P = 0.21$), and pronghorn (Fisher's exact $P = 0.42$; for only males Fisher's exact $P = 0.19$), or for all data pooled (Fisher's exact $P = 0.12$).

In all species, CR mortality did not vary based on the number of times an individual was captured (Fisher's exact $P \geq 0.50$) or maximum rectal (body) temperature during handling ($P_{BOOT} \geq 0.42$). Levels of CR mortality also did not differ by capture method for either mule deer or pronghorn (Fisher's exact $P \geq 0.61$); no elk were captured by net-gunning.

Discussion

Individuals in poorer condition were not more susceptible to CR mortality; in fact, individuals in better condition tended to show higher levels of CR mortality (see below). Many factors can cause CR mortality (Kreeger 1999, Nielsen 1999, Armeno et al. 2006). Thus, managers need to consider many factors to minimize CR mortality, including length of pursuit, skill and experience of capture personnel, appropriateness of methods and chemicals, timing of capture operations, terrain, idiosyncrasies of individual species, humaneness, and safety of wildlife and humans (Clark and Jessup 1992, Kreeger 1999, Nielsen 1999, Armeno et al. 2006, Jacques et al. 2009). However, my data from multiple captures of 3 North American ungulates totaling >1,500 individuals indicates that poor body condition of individuals is unlikely to affect rates of CR mortality. Moreover, this was true despite many populations in the analyses being in poor to marginal condition (Table 1), i.e. showing the type of "predisposition" that managers often are concerned may contribute to capture-induced mortality. Many individuals in the populations used in this analysis were in very poor condition, especially during late-winter captures (i.e., 60 to 67% of individual elk and deer <5% BF; 19 to 23% <3% BF; 2% BF is generally regarded as a death threshold below which individuals cannot recover [Depperschmidt et al. 1987]). Despite having multiple individuals near this threshold, poor condition did not increase levels of CR mortality. While managers should always be cautious when capturing and handling wild ungulates, concerns regarding possibly poor body condition of individuals in the target population should not be an overriding factor in scheduling capture operations.

I am uncertain as to why individuals in better condition tended to show higher rates of CR mortality. Pursuit and capture with or without immobilization can result in hyperthermia, tachycardia, and tachypnea (DelGiudice et al. 1989, 2001; Kreeger 1999, Nielsen 1999), and severe respiratory depression can result from chemical immobilization using carfentanil and xylazine (Kreeger 1999). Hyperthermia may be of particular concern during capture operations conducted in hot, dry conditions (such as was the case during many of the captures for this analysis), particularly when chemicals that depress respiration are used (Kreeger 1999, Nielsen 1999, DelGiudice et al. 1989). Increasing levels of BF may result in sedated ungulates being less able to radiate heat, thus, elevating body temperatures during capture. Of my study species, only male pronghorn showed significantly higher CR mortality for individuals in better condition. However, male pronghorn in good condition (>1.5 cm MAXFAT) did not differ in survival from those with 0 cm MAXFAT (Fisher's exact $P = 0.19$), nor was maximum rectal temperature higher for CR mortalities ($P_{BOOT} = 0.48$), arguing against differential heat dissipation associated with differing levels of body fat being related to survival.

My use of BF to index condition could have influenced results. I chose BF because most published standards for level of condition use BF (e.g., Depperschmidt et al. 1987, Cook et al. 2004). However, much work with my study species has shown that other indices of condition, particularly rBCS and MAXFAT, are often more closely tied to individual and population performance (e.g., Bender et al. 2007, 2008, 2011, 2012, 2013; Hoenes 2008; Bender and Piasecke 2010; Piasecke and Bender 2011; Halbritter and Bender 2011), and, thus, may be superior indices, particularly those that index both fat and lean tissue reserves.

However, an identical analysis I performed using rBCS rather than BF produced similar results (L. Bender, unpublished data). Thus, regardless of condition index used, low body condition did not predispose individuals to CR mortality for any of my study populations, regardless of species, season, sex, or capture history of individuals.

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