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ESTABLISHMENT OF SEROLOGICAL REFERENCE RANGES FOR ELK IN KENTUCKY AND EFFECTS OF QUARANTINE AND TRANSLOCATION ON ELK

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ESTABLISHMENT OF SEROLOGICAL REFERENCE RANGES FOR ELK IN KENTUCKY AND EFFECTS OF QUARANTINE AND TRANSLOCATION ON ELK

THESIS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOREST AND NATURAL RESOURCES IN THE COLLEGE OF AGRICULTURE, FOOD AND ENVIRONMENT
AT THE UNIVERSITY OF KENTUCKY

By

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2017

ABSTRACT OF THESIS

ESTABLISHMENT OF SEROLOGICAL REFERENCE RANGES FOR ELK IN KENTUCKY AND EFFECTS OF QUARANTINE AND TRANSLOCATION ON ELK

Establishing blood serum profiles is important for understanding animal disease ecology and nutrition, the effects of capture and immobilization, and general physiological variation among individuals and populations. Elk (*Cervus elaphus nelsoni*) have been successfully translocated to several states for reintroduction or population augmentation, including most recently in Kentucky, where over the course of three years (2011-13) wild elk were captured, temporarily quarantined, and subsequently moved to Missouri and Virginia to establish populations in those states. I used this opportunity to collect a variety of biological samples, including blood from which I present and compare serological profiles for a variety of elk age and sex classes. Additionally, I took the opportunity to investigate the effects of the translocation process on some morphological and physiological parameters of elk. Quarantine and processing of elk can be stressful for animals and lead to injury or death. I characterized how elk respond to this process by measuring biochemical serum values along with various physiological parameters at 5 handling events from the time of capture until final transport to recipient states. Changes observed in parameters between paired workups were indicative of the physical exertion and stress associated with handling activities.

KEYWORDS: blood serum chemistry, elk, Kentucky, quarantine, reintroduction, translocation

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ESTABLISHMENT OF SEROLOGICAL REFERENCE RANGES FOR ELK IN KENTUCKY AND EFFECTS OF QUARANTINE AND TRANSLOCATION ON ELK

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CHAPTER 1

BLOOD SERUM PROFILES OF ELK IN KENTUCKY

Abstract

Establishing blood serum profiles is important for understanding animal disease ecology and nutrition, the effects of capture and immobilization, and general physiological variation among individuals and populations. Elk (*Cervus elaphus nelsoni*) have been successfully translocated to several states for reintroduction or population augmentation, including most recently in Kentucky, where over the course of three years (2011-13) wild elk were captured, temporarily quarantined in captivity, and subsequently moved to Missouri and Virginia to establish populations in those states. I used this opportunity to collect a variety of biological samples, including blood from which I present and compare serological profiles for a variety of elk age and sex classes. Differences for 14 of 24 blood parameters were found between all sex and age classes, with adult males being significantly different ($P \leq 0.05$) for 21 of 24 parameters when compared to adult females, calves, and yearlings. Glucose and creatinine were higher during winter months compared to spring and summer for adult males. In comparisons between capture types, potassium, aspartate aminotransferase, and creatine phosphokinase levels were elevated, indicating physical capture may be more strenuous than chemical capture. Parameter values were similar to those previously reported for elk in the western United States, but this is the first documentation of serological profiles for elk in the eastern U.S.

Introduction

Wildlife health encompasses a broad range of values and concepts. Hanisch et al. (2012) conceptually framed wildlife health as an inherently multidisciplinary attempt to characterize individual animal and population viability and resiliency as influenced by multiple stressors that include habitat quality, predation, competition, and disease. The health of an individual or group of individuals has been traditionally used to make inferences about the overall condition of a population (Karesh and Cook 1995, Deem et al. 2001). The relationship between wildlife health and population viability dictates the need for establishing reference values for key biological parameters indicative of wildlife health (Karesh and Cook 1995, Deem et al. 2001) and status. Measurement of these parameters across time intervals can provide information critical for addressing specific management or research questions (Waas et al. 1999, Corn and Nettles 2001, Rostal et al. 2012).

Blood is an important nutrient transport medium of vertebrates that delivers oxygen, nutrients, and hormones to cells, harbors major components of the immune system, and moves waste products from cells to organs for eventual excretion. A blood sample can be easily obtained from most captured vertebrates, and this availability, the low risk to animals involved in collecting samples, and its physiological importance make it a frequently used medium for rapid assessment of individual or population health (Lassen 2004, Rostal et al. 2012). Blood can also be used to assess the impact of management activities, such as health screenings and capture and immobilization, on animal physiology and well-being (Wesson et al. 1979, Spraker 1993, Millspaugh et al. 2000).

A fundamental requirement for being able to use blood parameters to aid in wildlife management is establishment of species-specific physiological reference values (Weiser and Allison 2012). Because blood parameter values can vary widely depending on sex, age, method of capture, season, body condition, pregnancy, and geographic area (Seal et al. 1972, LeResche et al. 1974, Mautz et al. 1980, Kie et al. 1983, Millspaugh et al. 2000, Rostal et al. 2012), a minimum of 40 individuals has been recommended to establish a reference range for a species. Maximum precision of blood parameter values is usually achieved at ~ 120 individuals (Lassen 2004, Weiser and Allison 2012), with samples of < 40 individuals recommended as a guide rather than a reference range (Rostal et al. 2012).

The elk (*Cervus elaphus*) is a large cervid species that historically occupied much of temperate North America (Bryant and Maser 1982), and is a popular species for hunting and wildlife watching; consequently, elk have been reintroduced to many areas of North America. Several eastern U.S. states and Canadian provinces, including Kentucky, Tennessee, and Ontario have established elk populations within the past two decades (Larkin et al. 2003, Rosatte et al. 2007, Kindall et al. 2011). Elk in Kentucky have grown sufficiently in number that other states have requested elk from the state be translocated to source their own reintroduction programs. I used the capture, immobilization, and holding of Kentucky elk used as translocation stock for other states, in addition to two ongoing elk radio-telemetry projects as opportunities to: 1) establish a blood parameter reference range of elk in Kentucky, and 2) determine what effects method of capture had on blood parameter profiles of elk. Sex, age, season, and capture

type are likely to impact serological values in a variety of ways. Capture type and combinations of sex and age are likely to have the greatest impact.

Study Area

The Kentucky elk restoration zone includes 16 counties in the southeastern part of the state and comprises 1.2 million ha of the Cumberland Plateau physiographic region, an area characterized by steep, rugged hills and narrow valleys (Olsson et al. 2007). The climate is generally characterized by warm summers and mild winters. Annual precipitation averages 125 cm and the mean temperature is 13.3°C (National Oceanic and Atmospheric Administration 2001). The ecosystem is predominately (~79%) second and third growth mixed-deciduous forest fragmented by active and reclaimed surface coal mines (~10%), agricultural grasslands including pasture and row crops (~9%), and urban areas (2%, Olsson et al. 2007). The mixed-mesophytic forest can be comprised of up to 30 co-dominant tree species, including several species of oak (*Quercus* spp.), hickory (*Carya* spp.), ash (*Fraxinus* spp.), magnolia (*Magnolia* spp.), tulip poplar (*Liriodendron tulipifera*), basswood (*Tilia* spp.), and maple (*Acer* spp.; Braun 1950). Plants commonly found on reclaimed coal mines included lespedeza (*Lespedeza* spp.), crown vetch (*Coronilla varia*), birdsfoot trefoil (*Lotus corniculatus*), Kentucky-31 tall fescue (*Festuca arundinacea*), perennial ryegrass (*Lolium perenne*), and orchard grass (*Dactylis glomerata*; Olsson et al. 2007).

Methods

Elk blood samples were opportunistically obtained: a) during the capture and translocation of Kentucky elk used to supply Missouri and Virginia with reintroduction stock, and b) as part of two separate (cow and bull) elk survival studies. Elk were

captured using: a) alfalfa (*Medicago sativa*), shelled corn (*Zea mays*), and Buck Jam (Evolved Habitats, Baton Rouge, LA) placed within corral traps, or b) chemically immobilized via a rifle-propelled dart containing a dose of ~0.01 mg/kg carfentanil citrate (Zoopharm, Windsor, CO; Mace 1971, Larkin et al. 2003, Kreeger et al. 2010) from 15 January - 23 July 2012, 6 January - 10 July 2013, and 14 Feburary - 24 March 2014. Chemically immobilized elk were reversed using naltrexone at a dosage of 100 mg/mg carfentanil administered (Miller et al. 1996). Chemically immobilized animals were immediately processed once recumbent. Corral caught elk were either processed at the capture site using a portable head gate attached to the corral trap, or they were loaded onto a trailer and transported to a handling facility for later processing. Both processing facilities were comprised of a series of metal holding pens connected to a gated, peripheral passageway that allowed elk to be funneled to a terminal, standard cattle squeeze chute for processing. Once contained in the squeeze chute, elk were immediately blindfolded, and their heads manually restrained to help calm them and limit impact injuries. The time from capture to handling for all methods ranged from < 1 hour – 16 hours. Elk capture and handling protocols were approved by the Institutional Animal Care and Use Committee of the University of Kentucky (#2010-0726) and a Kentucky Department of Fish and Wildlife Resources (KDFWR) veterinarian.

During processing, I recorded the sex, rectal temperature, age, and body condition of each elk. Age was determined either by tooth eruption and wear (Quimby and Gaab 1957) for corral caught animals or by tooth extraction and examination of cementum annuli for darted animals (Hamlin et al. 2000). Elk were classified into 6 groups: adult male (AM), adult female (AF), yearling male (YM), yearling female (YF), calf male

(CM), and calf female (CF). I determined general body condition using palpations of the rump, withers, and ribs of each elk (Gerhart et al. 1996, Cook et al. 2001*a*, Cook et al. 2010) and classified each elk on a scale of 1 - 5 (1 = emaciated, 5 = fat). From those scores, I classified each elk as in either poor (1 - 2) or good (3 - 5) physical condition. I recorded the time in the working facility and time in the chute for each corral captured elk, and the capture pressure and induction time for chemically immobilized animals. Capture pressure was divided into three subjective categories: calm, slightly pressured, and highly pressured. Calm individuals exhibited no flight response upon seeing humans around the time of darting or appeared unaware of the gunner prior to darting. Slightly pressured individuals appeared agitated by human presence and would slowly move away from the gunner. Highly pressured individuals ran away from the gunner one or more times before being darted.

I collected a 20 ml blood sample using a jugular venipuncture $\leq$ 30 minutes of immobilization for darted animals (Rostal et al. 2012) and $\leq$ 3 minutes of entering the head chute for corral caught animals. Blood samples were allowed to clot before being temporarily stored on ice prior to centrifugation and serum collection. Serum was kept frozen at -20°C until a total blood panel analysis was performed using a Beckman Coutler AU480 Chemistry System (Beckman Coulter, Brea, California, USA) for glucose, blood urea nitrogen (BUN), creatinine, chloride, sodium, potassium, carbon dioxide (CO_2), calcium, magnesium, phosphorus, cholesterol, alkaline phosphatase (ALP), total bilirubin, direct bilirubin, indirect bilirubin, aspartate aminotransferase (AST), gamma-glutamyltransferase (GGT), creatine phosphokinase (CPK), osmolality, total protein, albumin, globulin, albumin:globulin ratio (A:G ratio), and anion gap.

I established reference ranges for serum parameters following the suggested methodology in Lassen (2004) and Weiser and Allison (2012). For groupings with < 40 individuals, I followed the same methodology for establishing a reference range, but considered these findings as a guide instead of an established range per the recommendations of Rostal et al. (2012). I used summary statistics and QQ plots to assess the normality of data, which upon examination were not normally distributed. I determined the reference range for nonparametric data by ranking the values and removing the upper and lower extreme 2.5% of values.

Elk were grouped based on season of capture, capture method, age, and sex. I divided the seasons as follows: winter (December 20-March 19), spring (March 20-June 19), and summer (June 20-September 19) to correspond with the celestial seasons and changes in photoperiod. I assigned individuals to the following 3 age cohorts: calf (< 1 year old [hereafter yo]), yearling (1- <2 yo), and adult (≥ 2 yo). Age and sex cohorts were grouped together for parameters where there was no significant difference between them as determined using a Wilcoxon Mann-Whitney rank-sum test for nonparametric data (hereafter WMW; Glantz 2005, Rostal et al. 2012). I used a Spearman correlation to examine the relationship between time in the chute and time in the working facility for corral caught animals, and for examining the relationship between drug induction time and time chemically immobilized for darted animals using the parameters rectal temperature, AST, CPK, creatinine, glucose, and potassium (Franzmann et al. 1984, Glantz 2005, Arnemo and Caulkett 2007, Rostal et al. 2012, Miller et al. 2013). I used the WMW to determine if darting pressure affected rectal temperature, AST, CPK, creatinine, glucose, and potassium for chemically immobilized adult elk by sex. I used

the WMW to determine if body condition affected glucose, BUN, creatinine, potassium, ALP, AST, GGT, CPK, total protein, and albumin between sex and age classes (Glantz 2005, Caldiera et al. 2007). Individuals were excluded from WMW and correlation analyses for low samples sizes ($n \leq 10$), missing data, dual capture methods (caught in a corral trap and immobilized with carfentanil citrate), and if they required additional immobilization drugs. All statistical analyses were performed using SAS 9.3 (SAS Institute, Cary, North Carolina, USA). Comparisons were considered statistically significant for all WMW analyses if p-values were ≤ 0.05 and for correlation analyses if r-values were ≥ 0.3 and p-values were ≤ 0.05.

Results

From 2012-14, 290 elk (AM = 118, AF = 75, YM = 16, YF = 21, CM = 24, CF = 36) were captured and blood sampled. When examining the differences between sex and age classes, yearlings were pooled due to small sample size. No differences in blood parameters were found between sexes of calves, and these data were subsequently pooled. Adult female, adult male, calf, and yearling elk means differed significantly between all groups for glucose, BUN, chloride, CO_2, calcium, magnesium, cholesterol, ALP, direct bilirubin, AST, GGT, albumin, A:G ratio, and anion gap (Table 1.1).

Adult male elk serum chemistry values differed from all other groups in all but 3 parameters (CPK, total protein, and globulin). Seasonal differences in blood parameters were assessed for 118 adult males (winter = 65, spring = 36, and summer =17). Differences in chloride, calcium, magnesium, total bilirubin, osmolality, and A:G ratio were found between all seasons in adult males (Table 1.2).

I examined samples from 146 individual elk (AF = 66, Y = 31, and C = 49) to compare effects of capture type on serum parameters. A total of 62 (AF = 16, Y = 12, and C = 34) elk were captured by corral trapping and 84 (AF = 50, Y = 19, and C = 15) by chemical immobilization. I grouped adult females, calves, and yearlings together for the analysis, but individual analyses can be found in the appendices. Parameter means differed significantly between corral caught and darted elk for all but magnesium, ALP, GGT, and total protein (Table 1.3).

A regression analysis of 150 elk (AM = 106 and AF = 44) elk was performed to examine the relationship between blood parameters and capture metrics for chemically immobilized individuals. Adult males and adult females were analyzed separately due to differences between the sexes in prior analyses. Drug induction time ranged from 2 - 15 min ($\overline{x}$ ± SD; 5 ± 2 min) and 1 - 16 min (5 ± 3 min) for adult male and adult female elk, respectively. Time immobilized ranged from 6 - 156 min (36.9 ± 15.8 min) and 15 - 53 min (35.4 ± 9.1 min) for adult male and adult female elk, respectively. No relationship was found between any of the tested blood parameters and induction time or time immobilized for adult male or adult female elk (Tables 1.4 and 1.5).

I examined 62 elk (AF = 16, Y = 12, and C = 34) samples in a regression analysis examining the relationship between blood parameters and capture metrics for corral trapped individuals. Time in the chute ranged from 2 - 17 min (5 ± 2 min). Time in the facility ranged from 6 - 66 min (23 ± 14 min). Glucose was negatively correlated with time in chute (ρ=-0.322, P=0.016) and positively with time in facility (ρ=0.321, P=0.022, Table 1.6). I found no significant correlations between any other tested parameters and time in chute or time in facility.

I examined samples from 150 elk (AM = 106 and AF = 44) to compare the effects of darting pressure on select blood parameters and rectal temperature by sex. Parameter means of rectal temperature differed significantly (Z = 3.08, *P* = 0.002) between unpressured (38.5 ± 0.7°C) and pressured (39.0 ± 0.5°C) adult male elk. Parameter means of rectal temperature differed significantly (Z = 3.08, *P* = 0.002) between unpressured (38.3 ± 0.6°C) and pressured (38.8 ± 0.4°C) adult female elk. Parameter means of potassium differed significantly (Z = -2.60, *P* = 0.009) between unpressured (6.8 ± 5.7 mmol/L) and pressured (6.7 ± 6.8 mmol/L) adult female elk. I observed no other significant differences in parameter means between unpressured and pressured elk for glucose, creatinine, AST, and CPK.

I examined samples from 281 elk (AM = 114, AF = 74, Y = 34, C = 59) to compare the effects of body condition on select blood parameters by sex and age class. Parameter means of GGT differed significantly between adult male elk in good (43 ± 32 IU/L) and poor (92 ± 112 IU/L) physical appearance (Z = 2.31, *P* = 0.021). Parameter means of CPK differed significantly between adult male elk in good (277 ± 401 IU/L) and poor (136 ± 91 IU/L) physical appearance (Z = -2.35, *P* = 0.019). Parameter means of albumin differed significantly between adult male elk in good (3.3 ± 0.4 g/dL) and poor (2.8 ± 0.4 g/dL) physical appearance (Z = -3.33, *P* = 0.001). Parameter means of glucose differed significantly between adult female elk in good (172 ± 41 mg/dL) and poor (134 ± 43 mg/dL) physical appearance (Z = -2.06, *P* = 0.039). Parameter means of potassium differed significantly between adult female elk in good (5.7 ± 1.8 mmol/L) and poor (15.5 ± 13.0 mmol/L) physical appearance (Z = 2.20, *P* = 0.028). Parameter means of total protein differed significantly between adult female elk in good (7.0 ± 0.5 g/dL)

and poor (6.6 ± 0.3 g/dL) physical appearance (Z = -2.00, P = 0.046). Parameter means of potassium differed significantly between calf elk in good (6.4 ± 2.5 mmol/L) and poor (10.7 ± 4.8 mmol/L) physical appearance (Z = 2.26, P = 0.024). Parameter means of AST differed significantly between yearling elk in good (92 ± 58 IU/L) and poor (64 ± 10 IU/L) physical appearance (Z = -1.97, P = 0.049). Parameter means of GGT differed significantly between yearling elk in good (29 ± 24 IU/L) and poor (43 ± 25 IU/L) physical appearance (Z = 1.97, P = 0.049).

Discussion

Knowledge of typical physiological values can be important to managers involved with capture and immobilization of elk, particularly with translocation efforts where monitoring of animal health is critical for successful outcomes. It is important for reference ranges to be established using animals in good physical condition that are representative of the population, otherwise factors such as disease, nutritional status, and infections may skew results (Fettmann et al. 2004, Rostal et al. 2012).

I opportunistically used multi-year elk capture efforts in Kentucky to establish a set of blood serum reference values that should prove useful to elk researchers and managers. Although these serum values have been described for elk in the western U.S. (Hamlin and Ross 2002, Barber-Meyer et al. 2007; Table 1.7), I am unaware of similar studies in the eastern U.S. where habitat differs substantially from the western U.S. in primary productivity, parent soils, and species composition, and where winter severity and predation are greatly reduced. Lassen (2004) and Weiser and Allison (2012) recommended a minimum of 40 individuals per grouping to establish reference values, and most data in this study met that sampling threshold and should be informative to

managers and researchers, especially where knowledge of these blood parameters for measuring physiological responses to various activities is important.

Glucose is the most commonly utilized energy molecule in living organisms. It plays a vital role in brain and red blood cell function in ruminants, and neonatal and juvenile ruminants are dependent on glucose for energy prior to the full development of their digestive systems (Cook 2002). Glucose levels were highest in calves and yearlings and lowest in adult males. My findings fall within previously reported ranges (Millspaugh et al. 2000, Hamlin and Ross 2002, and Barber -Meyer et al. 2007), but only one of those studies included adult males (Millspaugh et al. 2000). Glucose levels for adult male elk were higher in winter compared to spring and summer. Nutritional status has been shown to have significant effects on glucose levels in white-tailed deer fawns (Seal et al. 1978), but not in adult white-tailed deer (Kie et al. 1983) or elk (Weber et al. 1984). Kie et al. (1983) did not find any differences between seasons for glucose in white-tailed deer. Carfentanil citrate is known to significantly elevate blood glucose levels, but can be ruled out as the cause of glucose elevation during winter months as all adult male elk captured in spring and summer were also captured using carfentanil citrate. Hyperglycemia has been observed after capture operations and could be related to catecholamine and glucocorticoid release from the excitement of capture (Franzmann and Thorne 1970, Seal and Hoskinson 1978, Kock et al. 1987, Kock 1992, Spraker 1993), but this doesn't explain seasonal changes in glucose levels. Bubenik et al. (1998) found glucose levels were related to feed consumption. Larsen et al. (1985) observed conflicting results when they found stable glucose levels in a feed restricted caribou population and decreases in another. Seasonal dietary changes similar to those previously reported by

Schneider et al. (2006) for elk in Kentucky may explain some of the seasonal variations in serum values.

Blood levels of glucose were noticeably higher for corral trapped elk when compared to chemically immobilized individuals. Glucose levels for corral caught animals were similar, albeit slightly lower, than those observed by Millspaugh et al. (2000) for Clover trapped elk. Values for chemically immobilized elk were similar to those found in Hamlin and Ross (2002) and Barber-Meyer et al. (2007). Topal et al. (2010) observed a similar elevation in red deer captured by physical versus chemical methods. Glucose levels may be elevated by a variety of factors related to capture including catecholamine and glucocorticoid release from excitement from handling (Spraker 1993) and immobilizing drugs. Carfentanil citrate is known to elevate blood glucose levels (Cook et al. 1994), yet corral captured elk had glucose levels nearly 15% higher on average compared to chemically immobilized elk. One explanation could be the short time-span between immobilization and blood collection (< 30 minutes) not allowing blood glucose levels to rise as a result of the immobilizing agent. Another explanation could be the lengthy time between capture and blood collection (~1-8 hours) for corral captured elk. Once captured and during transport a fight or flight response and its accompanying increase in metabolic rate and glucose levels are likely (Guyton and Hall 1996, Rand et al. 2002). The long time-span coupled with the excitement and fear of being captured likely elevated blood glucose levels.

Glucose levels were significantly correlated to both time in chute and time in the handling facility, but in opposite directions. Glucose levels had a negative relationship to increasing time in the chute and a positive relationship to increasing time in the handling

facility. The positive correlation between time in facility and increasing glucose levels is supported by previous studies finding elevated glucose levels resulting from excitability, muscle exertion, and increased catecholamine release (Franzmann and LeResche 1978, Kock et al. 1987, Millspaugh et al. 2000). Stress induced hyperglycemia has been reported in humans (*Homo sapiens;* McCowen et al. 2001), dasyurid marsupials (McDonald et al. 1981), and generally in free-ranging mammals (Reeder and Kramer 2005).

Due to its high impact on survival, capture myopathy (CM) is a serious concern for biologists involved in translocation efforts. Elevated levels of potassium, AST, and CPK are associated with muscle damage and capture myopathy (McAllum 1985, Kock et al. 1987, Spraker 1993). Aspartate aminotransferase is a good indicator of muscle injury with peak levels appearing at least a day after the event and returning to normal in 7-8 days for some species like horses (Spraker 1993, Allison 2012). Creatine phosphokinase by comparison peaks in 6-12 hours and returns to normal ranges within 1-2 days of the event (Spraker 1993, Allison 2012). Creatine phosphokinase is known to be a good indicator of exertional myopathy, and due to its tendency to rapidly elevate in the blood is a better gauge of exertion and muscle injury at the time of capture than AST which may not peak in the blood for 24 hrs after an event.

Azotemia is a blood condition characterized by elevated levels of nitrogen containing compounds (i.e. BUN, creatinine). Acidosis is characterized by a pH imbalance in cations and anions. The difference between anions and cations is called the anion gap and it can be used as an indicator of acidosis. Azotemia and acidosis are commonly the physiological cause of mortality in CM cases, and in particular those

associated with ataxic myoglobinuric syndrome (Spraker 1993). Blood levels of potassium, AST, CPK, and anion gap were noticeably higher for corral trapped elk compared to chemically immobilized individuals. Millspaugh et al. (2000) found elevated CPK and potassium levels for corral captured elk compared to chemical immobilization and Clover trapped elk. Marco and Lavin (1999) and Topal et al. (2010) observed elevated AST and CPK levels for red deer captured by physical means compared to chemical methods. The CPK levels for corral trapped elk were similar to the levels reported by Hamlin and Ross (2002) for elk captured primarily by drive-netting and net-gunning. While the potassium levels of corral trapped elk in my study were higher than chemically immobilized elk, the means of both groups fell near those reported in elk from other studies (Weber 1973, Millspaugh et al. 2000).

Potassium is the most abundant intracellular cation and is tightly regulated by the body (Engelking 2004, Stringer et al. 2011). The membrane potential created by the differences between potassium and the major extracellular cations such as sodium allow muscle contraction and neurotransmission (Carlson 1997). Corral trapped elk had higher potassium levels than chemically immobilized elk. Acute stress associated with capture method and handling activities has been found to cause hyperkalemia (excess potassium) in some ungulate studies (Wilber and Robinson 1958, Kock et al. 1987, DeLiberto et al. 1989), but not others (Kocan et al. 1981, Marco and Lavin 1999). Corral trapping coupled with the contact trauma from the traps and other captured elk has been attributed to elevated potassium levels in other studies (Jago et al. 1997, Millspaugh et al. 2000). Adult female and calf elk in poor physical condition displayed increased potassium levels compared to those in good condition. DelGuidice et al. (1992) questioned whether muscle

wasting during winter months led to elevated potassium levels in adult female white-tailed deer. It is worth noting that none of the adult female or calf elk in this analysis died of capture myopathy related factors. Although I have no reason to believe forage availability or quality were limiting factors for elk in Kentucky, a decline in serum potassium levels was reported in mule deer (*Odocoileus hemionus*) during fall and winter months when forage quality decreased (Anderson et al. 1972). The most likely cause of increased potassium levels for poor body condition elk is trauma associated with capture coupled with reduced kidney function due to dehydration.

Creatinine is a byproduct of muscle catabolism and can be a good indicator of renal function (Weber 1973). Creatinine levels are largely impacted by functions of body condition and muscle mass. Low serum levels are often associated with decreases in muscle mass, poor body condition, or young age, and are typically higher in well-conditioned animals (Schutte et al. 1981, Radin 1991). Kie et al. (1983) and DelGuidice et al. (1992) found seasonal differences in creatinine levels in white-tailed deer with winter levels being generally higher than spring and summer levels. DelGuidice et al. (1992) attributed those differences to dehydration associated with nutritional deprivation. Säkkinen et al. (2001) observed similar seasonal trends in free-ranging reindeer (*Rangifer tarandus tarandus, Rangifer tarandus platyrhynchus*) and suggested most of the difference was associated with changes in protein and feed intake. Johnson et al. (2010) found creatinine levels in boreal caribou (*Rangifer tarandus caribou*) were lower in late winter captures compared to spring captures. In my study, creatinine levels for adult male elk were higher in winter compared to spring and summer. Unfortunately, I was unable to

determine if the same pattern was present in adult cows, yearlings, and calves due to low sample sizes.

Alkaline phosphatase is a protein found in the body tissues that among other things helps with mineralization of bones and teeth (Golub and Battaglia 2007). Levels of ALP can be used to assess liver and bone health. Blood levels are affected by pregnancy, bone, and antler development, and vary widely among sex and age classes (Tietz 1976, Cook 2002). Alkaline phosphatase levels for adult males were noticeably higher than for adult females, calves, and yearlings. Kie et al (1983) found that adult male white-tailed deer (*Odocoileus virginianus*) had higher ALP levels than adult females. Additionally, they noted a decrease in ALP with age. Rostal et al. (2012) observed the same decreasing trend in ALP with increased age for moose (*Alces alces*). Cook (2002) found young, growing elk exhibited elevated levels of ALP compared to older elk. Chapple et al. (1991) found levels of ALP decreased with age in chital deer (*Axis axis*). Schroeder (1986) and Matula et al. (1977) reported elevated serum ALP levels in young black bears (*Ursus americanus*) compared to older individuals. For adult male chital deer, ALP levels varied seasonally being highest during times of active antler growth (Chapple et al. 1991), and Cook (2002) mentioned similar trends for adult male elk. The increase in ALP for adult male elk in each of the 3 seasons I sampled from winter through summer is likely attributed to antler development.

Calcium is an essential element in teeth and bone formation, nerve signaling, and muscle function. Absorption of calcium is hindered by glucocorticoid release (Radin 1991, Bohn 2012). Albumin is one of the components of total protein. It is synthesized by the liver and serves as a carrier of hormones and other ions (Radin 1991). Calcium and

albumin levels along with the A:G ratios were highest in calves and yearlings compared to adult males and females for elk in Kentucky. The protein-bound portion of calcium, the portion reported in a total panel, varies with albumin levels (Bohn 2012), and calcium levels may be higher in young, growing animals (Radin 1991). Rostal et al. (2012) observed an A:G ratio that was higher in calves compared to adults, but lower in yearlings than adults and calves.

Pressured adult male and female elk had statistically higher rectal temperatures than unpressured elk, but the difference may be biologically insignificant as the former group had only a 0.5°C increase that still fell close to the normal 39.0°C for elk body temperatures (Hudson and Haigh 2002). Rostal et al. (2012) found a positive correlation between chase time and increasing body temperatures. Similarly, Franzmann et al. (1984) found a positive relationship between increased excitability and rising body temperatures in moose. In their study, excited and highly excited moose average body temperatures between 40.2°C and 41.0 °C.

Monitoring the health of individual animals and their populations is paramount to improving the humane treatment and management of wildlife and improves the prospect of ensuring long-term species viability. Therefore, it is important for researchers and biologists to strive towards a better understanding of the complexity of factors affecting biologically relevant and measurable health parameters that can be safely and effectively monitored. In interpreting these health data, caution must be exercised in determining the most likely cause(s) of derivations from normal parameter values. For example, the causes of variation of some blood parameters (e.g. BUN) can be difficult to determine. A high energy diet with adequate protein can decrease BUN values (Kirkpatrick et al.

1975); conversely, both a high protein diet and a sub-maintenance diet resulting in protein catabolism can lead to elevated BUN values (Seal et al. 1978, Bahnak et al. 1979). Increases in handling time and/or ambient temperature can affect other parameters as well, thus making interpretation of findings more difficult. Increased handling time can increase glucose, BUN, creatinine, AST, and CPK levels (Franzmann et al. 1984, Arnemo and Caulkett 2007, Rostal et al. 2012). Body condition can impact serum biochemical values as well. Poor body condition can lead to decreased albumin, GGT, and CPK as well as increased BUN and creatinine values (Caldeira et al. 2007). Caldeira et al. (2007) reported elevated glucose levels in sheep (*Ovis aries*) with high body condition scores (BCS). In the same study, they observed elevated glucose levels in sheep with decreasing BCSs scores (Caldeira et al. 2007). The change was likely related to low serum insulin levels. A similar change was observed in domestic cattle (*Bos taurus*) undergoing a study to examine the effects of under nutrition (Delevaud et al. 2002). The previously stated are not intended to be all inclusive, but rather to give an idea of the complexity of interpreting the cause of the deviation from baseline values for biochemical parameters.

In summary, my results suggest chemical capture may be less stressful on captured animals compared to corral trapping; at least 2 previous studies (Seal and Bush 1982 and Arnemo et al. 1994) have reached similar conclusions. Additionally, chemically immobilized animals may provide more "normal" biochemical parameter measurements than physically restrained methods where stress can be more prolonged and intense. Despite statistical tests suggesting significant differences exist between certain blood parameters, I would caution that just because a statistical difference exists doesn't mean a

biologically significant difference is present. It is the responsibility of the researcher to understand the important difference that exists between statistical and biological significance.

Management Implications

Establishing reference ranges of serological profiles of elk in Kentucky will hopefully aid managers in Kentucky and elsewhere in making initial assessments of the physiological health of captured elk, and for interpreting physiological data during capture, immobilization, processing, and quarantine. Caution should be taken when interpreting serological profiles to ensure many of the wide variety of factors that do affect serum components are considered.

Table 1.1. Serum chemistry reference ranges for adult female, adult male, calf, and yearling elk (*Cervus elaphus nelsoni*) in eastern Kentucky by sex and age class sampled between 2012 and 2014.

	Adult Female							Adult Male						
Parameter[a]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]
Glucose (mg/dL)	75	109	288	169	43	163	F	117	48	226	148	53	153	M
BUN (mg/dL)	75	11	33	23	6	25	F	118	13	45	27	8	26	M
Creatinine (mg/dL)	112	1.59	2.72	2.18	0.32	2.21	FY	118	0.96	3.12	1.87	0.66	1.90	M
Chloride (mmol/L)	75	97	112	102	4	101	F	118	71	113	97	13	98	M
Sodium (mmol/L)	172	133	154	142	6	141	FCY	118	95	164	133	15	137	M
Potassium (mmol/L)	172	4.1	15.7	6.6	3.9	5.3	FCY	118	3.4	31.3	10.4	8.3	6.2	M
CO_2 (mmol/L)	75	11.5	29.7	21.7	4.8	21.9	F	118	13.4	32.2	22.6	4.5	22.0	M
Calcium (mg/dL)	75	8.5	10.2	9.2	1.1	9.3	F	118	6.2	11.2	9.3	1.2	9.4	M
Magnesium (mg/dL)	75	1.9	2.8	2.3	0.3	2.3	F	118	1.6	3.0	2.3	0.3	2.3	M
Phosphorus (mg/dL)	172	2.6	7.5	5.3	1.3	5.5	FCY	118	3.3	8.9	5.9	1.4	5.9	M
Cholesterol (mg/dL)	75	40	84	59	12	59	F	118	25	77	50	14	48	M
ALP (IU/L)	75	33	317	132	103	99	F	118	33	477	176	140	134	M
TBilirubin (mg/dL)	172	0.1	0.7	0.3	0.2	0.2	FCY	118	0.1	0.4	0.2	0.1	0.2	M
DBbilirubin (mg/dL)	75	0.0	0.2	0.1	0.1	0.1	F	118	0.0	0.1	0.1	0.1	0.1	M
IBilirubin (mg/dL)	172	0.1	0.5	0.2	0.1	0.2	FCY	118	0.1	0.3	0.1	0.1	0.1	M
AST (IU/L)	75	52	121	76	55	69	F	118	37	114	71	28	67	M
GGT (IU/L)	75	12	54	25	14	21	F	118	14	159	47	46	33	M
CPK (IU/L)	192	70	920	288	406	207	FM	192	70	920	288	406	207	FM
Osmolality (mOsm/L)	172	273.0	315.2	290.6	13.9	289.6	FCY	118	185.2	334.9	272.8	34.6	281.4	M
Total Protein (g/dL)	230	5.4	8.1	6.9	0.8	6.9	FMY	230	5.4	8.1	6.9	0.8	6.9	FMY
Albumin (g/dL)	75	2.9	3.9	3.4	0.3	3.5	F	118	2.2	4.0	3.3	0.4	3.3	M
Globulin (gms%)	193	2.7	4.9	3.6	0.7	3.5	FM	193	2.7	4.9	3.6	0.7	3.5	FM
A:G Ratio (g/dL)	75	0.76	1.29	0.99	0.13	0.97	F	118	0.45	1.20	0.92	0.16	0.95	M
Anion Gap	75	14.3	40.9	24.0	7.0	21.8	F	118	15.0	31.8	22.9	4.7	22.8	M

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

[b] C = Calf, F = Adult female, M = Adult male, Y = Yearling

Parameters grouped together are not statistically different ($P > 0.05$)

Table 1.1 (continued). Serum chemistry reference ranges for adult female, adult male, calf, and yearling elk (*Cervus elaphus nelsoni*) in eastern Kentucky by sex and age class sampled between 2012 and 2014.

	Calf							Yearling						
Parameter[a]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]
Glucose (mg/dL)	60	107	278	189	46	188	C	37	97	316	183	54	166	Y
BUN (mg/dL)	60	10	33	22	7	22	C	37	12	36	24	7	25	Y
Creatinine (mg/dL)	60	1.49	2.55	2.05	0.30	2.07	C	112	1.59	2.72	2.18	0.32	2.21	FY
Chloride (mmol/L)	60	94	108	100	4	100	C	37	96	108	102	4	102	Y
Sodium (mmol/L)	172	133	154	142	6	141	FCY	172	133	154	142	6	141	FCY
Potassium (mmol/L)	172	4.1	15.7	6.6	3.9	5.3	FCY	172	4.1	15.7	6.6	3.9	5.3	FCY
CO_2 (mmol/L)	60	11.0	27.3	19.9	4.5	20.1	C	37	13.0	29.6	22.0	4.9	22.2	Y
Calcium (mg/dL)	60	8.4	10.7	9.7	0.6	9.8	C	37	8.9	10.3	9.5	0.4	9.4	Y
Magnesium (mg/dL)	60	1.9	2.6	2.2	0.2	2.2	C	37	1.9	2.6	2.2	0.2	2.2	Y
Phosphorus (mg/dL)	172	2.6	7.5	5.3	1.3	5.5	FCY	172	2.6	7.5	5.3	1.3	5.5	FCY
Cholesterol (mg/dL)	60	34	85	60	15	59	C	37	35	73	54	12	53	Y
ALP (IU/L)	60	39	249	142	63	134	C	37	44	303	136	108	107	Y
TBilirubin (mg/dL)	172	0.1	0.7	0.3	0.2	0.2	FCY	172	0.1	0.7	0.3	0.2	0.2	FCY
DBbilirubin (mg/dL)	60	0.0	0.2	0.1	0.1	0.1	C	37	0.0	0.3	0.1	0.1	0.1	Y
IBilirubin (mg/dL)	172	0.1	0.5	0.2	0.1	0.2	FCY	172	0.1	0.5	0.2	0.1	0.2	FCY
AST (IU/L)	60	53	142	82	24	78	C	37	53	169	87	53	72	Y
GGT (IU/L)	60	17	102	33	30	23	C	37	15	135	36	33	21	Y
CPK (IU/L)	97	129	3960	838	1879	364	CY	97	129	3960	838	1879	364	CY
Osmolality (mOsm/L)	172	273.0	315.2	290.6	13.9	289.6	FCY	172	273.0	315.2	290.6	13.9	289.6	FCY
Total Protein (g/dL)	60	5.2	7.4	6.3	0.6	6.4	C	230	5.4	8.1	6.9	0.8	6.9	FMY
Albumin (g/dL)	60	2.9	3.9	3.5	0.3	3.6	C	37	3.3	3.9	3.6	0.2	3.5	Y
Globulin (gms%)	60	2.2	3.6	2.8	0.4	2.8	C	37	2.6	3.7	3.3	0.3	3.3	Y
A:G Ratio (g/dL)	60	0.97	1.64	1.28	0.19	1.28	C	37	0.89	1.42	1.08	0.13	1.07	Y
Anion Gap	60	18.4	39.5	29.0	6.8	29.2	C	37	15.1	37.2	24.9	6.6	24.3	Y

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

[b] C = Calf, F = Adult female, M = Adult male, Y = Yearling

Parameters grouped together are not statistically different ($P > 0.05$)

Table 1.2. Serum chemistry reference ranges for adult male elk (*Cervus elaphus nelsoni*) in eastern Kentucky by season sampled between 2012 and 2014.

	Winter (Dec 20-Mar 19)							Spring (Mar 20 - June 19)							Summer (June 20 - Sept 19)							
Parameter[a]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]
Glucose (mg/dL)	65	96	226	173	38	176	A	52	36	220	116	52	115	BC	52	36	220	116	52	115	BC
BUN (mg/dL)	101	14	45	28	9	27	AB	101	14	45	28	9	27	AB	17	13	30	22	6	20	C
Creatinine (mg/dL)	65	0.96	3.17	2.25	0.58	2.25	A	53	0.87	2.24	1.41	0.41	1.31	BC	53	0.87	2.24	1.41	0.41	1.31	BC
Chloride (mmol/L)	65	62	117	96	15	99	A	36	92	106	98	9	97	B	17	89	101	97	5	96	C
Sodium (mmol/L)	118	95	164	133	15	137	ABC	118	95	164	133	15	137	ABC	118	95	164	133	15	137	ABC
Potassium (mmol/L)	65	3.0	35.0	8.9	8.6	5.7	A	53	4.2	25.9	12.3	7.6	9.3	BC	53	4.2	25.9	12.3	7.6	9.3	BC
CO_2 (mmol/L)	82	13.4	28.7	21.5	3.8	21.3	AC	36	17.8	32.6	25.0	5.0	25.4	B	82	13.4	28.7	21.5	3.8	21.3	AC
Calcium (mg/dL)	65	4.8	11.2	9.2	1.5	9.3	A	36	8.7	10.6	9.5	0.7	9.5	B	17	8.3	9.7	9.1	0.5	9.0	C
Magnesium (mg/dL)	65	1.1	2.6	2.2	0.4	2.2	A	36	2.0	3.0	2.4	0.3	2.3	B	17	1.9	2.6	2.3	0.2	2.3	C
Phosphorus (mg/dL)	65	3.2	7.6	5.5	1.3	5.5	A	53	4.3	9.2	6.5	1.3	6.7	BC	53	4.3	9.2	6.5	1.3	6.7	BC
Cholesterol (mg/dL)	65	24	64	43	10	43	A	53	37	82	59	12	61	BC	53	37	82	59	12	61	BC
ALP (IU/L)	65	29	229	107	74	98	A	36	68	477	225	125	203	B	17	84	471	338	184	315	C
TBilirubin (mg/dL)	65	0.1	0.4	0.2	0.1	0.2	A	53	0.1	0.3	0.2	0.1	0.2	BC	53	0.1	0.3	0.2	0.1	0.2	BC
DBbilirubin (mg/dL)	65	0.0	0.1	0.1	0.1	0.1	A	53	0.0	0.1	0.0	0.1	0.0	BC	53	0.0	0.1	0.0	0.1	0.0	BC
IBilirubin (mg/dL)	118	0.1	0.3	0.1	0.1	0.1	ABC	118	0.1	0.3	0.1	0.1	0.1	ABC	118	0.1	0.3	0.1	0.1	0.1	ABC
AST (IU/L)	65	37	114	66	29	61	A	53	50	110	78	25	75	BC	53	50	110	78	25	75	BC
GGT (IU/L)	65	14	172	60	57	43	A	53	13	48	30	17	27	BC	53	13	48	30	17	27	BC
CPK (IU/L)	65	56	546	209	323	148	A	53	70	876	400	538	279	BC	53	70	876	400	538	279	BC
Osmolality (mOsm/L)	65	184.0	347.7	273.5	40.5	283.4	A	36	227.1	305.3	273.8	29.4	277.3	B	17	235.9	283.5	267.8	15.9	265.8	C
Total Protein (g/dL)	118	5.0	9.0	6.9	1.0	6.9	ABC	118	5.0	9.0	6.9	1.0	6.9	ABC	118	5.0	9.0	6.9	1.0	6.9	ABC
Albumin (g/dL)	118	2.2	4.0	3.3	0.4	3.3	ABC	118	2.2	4.0	3.3	0.4	3.3	ABC	118	2.2	4.0	3.3	0.4	3.3	ABC
Globulin (gms%)	118	2.7	5.4	3.7	0.8	3.5	ABC	118	2.7	5.4	3.7	0.8	3.5	ABC	118	2.7	5.4	3.7	0.8	3.5	ABC
A:G Ratio (g/dL)	65	0.55	1.21	0.95	0.16	0.97	A	36	0.45	1.09	0.87	0.16	0.89	B	17	0.69	1.13	0.94	0.14	0.94	C
Anion Gap	101	14.7	31.8	22.6	4.8	22.4	AB	101	14.7	31.8	22.6	4.8	22.4	AB	17	17.4	28.4	24.8	3.4	26.6	C

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

[b] A = Winter, B = Spring, C = Summer

Parameters grouped together are not statistically different (P > 0.05)

Table 1.3. Serum chemistry reference ranges for adult female, yearling, and calf elk (*Cervus elaphus nelsoni*) in eastern Kentucky by capture type sampled between 2012 and 2014.

	Corral							Dart						
Parameter[a]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]
Glucose (mg/dL)	62	134	316	200	52	192	C	84	108	259	171	40	166	D
BUN (mg/dL)	62	10	29	20	5	20	C	84	13	37	25	6	26	D
Creatinine (mg/dL)	62	1.70	2.68	2.23	0.28	2.24	C	84	1.55	2.58	2.06	0.28	2.05	D
Chloride (mmol/L)	62	97	109	103	4	103	C	84	95	105	100	3	100	D
Sodium (mmol/L)	62	134	153	145	5	145	C	84	133	149	139	5	139	D
Potassium (mmol/L)	62	3.8	16.2	7.8	3.5	7.1	C	84	4.3	9.1	6.0	4.4	5.3	D
CO_2 (mmol/L)	62	11.0	24.7	17.5	4.0	17.6	C	84	17.1	29.7	23.4	3.5	23.1	D
Calcium (mg/dL)	62	8.9	10.7	9.8	0.5	9.9	C	84	8.5	10.0	9.2	1.1	9.3	D
Magnesium (mg/dL)	146	1.9	2.6	2.2	0.3	2.2	CD	146	1.9	2.6	2.2	0.3	2.2	CD
Phosphorus (mg/dL)	62	2.4	7.1	4.6	1.4	4.6	C	84	3.7	7.9	5.9	1.1	5.8	D
Cholesterol (mg/dL)	62	53	89	68	11	68	C	84	38	76	54	11	52	D
ALP (IU/L)	146	34	290	138	89	122	CD	146	34	290	138	89	122	CD
TBilirubin (mg/dL)	62	0.2	0.7	0.4	0.2	0.4	C	84	0.1	0.4	0.2	0.1	0.2	D
DBbilirubin (mg/dL)	62	0.0	0.2	0.1	0.1	0.1	C	84	0.0	0.1	0.1	0.1	0.1	D
IBilirubin (mg/dL)	62	0.1	0.5	0.3	0.1	0.3	C	84	0.1	0.3	0.2	0.1	0.2	D
AST (IU/L)	62	53	152	88	28	82	C	84	52	94	74	52	68	D
GGT (IU/L)	146	15	102	31	27	23	CD	146	15	102	31	27	23	CD
CPK (IU/L)	62	195	3960	921	1264	459	C	83	107	549	229	157	205	D
Osmolality (mOsm/L)	62	277.8	315.2	296.3	11.0	296.5	C	84	270.2	303.3	284.1	13.6	285	D
Total Protein (g/dL)	146	5.7	7.7	6.8	0.5	6.8	CD	146	5.7	7.7	6.8	0.5	6.8	CD
Albumin (g/dL)	62	3.1	4.0	3.7	0.2	3.7	C	84	2.9	3.8	3.4	0.2	3.4	D
Globulin (gms%)	62	2.3	4.0	3.1	0.5	3.1	C	84	2.3	4.1	3.3	0.4	3.4	D
A:G Ratio (g/dL)	62	0.89	1.65	1.21	0.22	1.18	C	84	0.76	1.43	1.04	0.16	1.00	D
Anion Gap	62	25.4	42.1	32.5	5.0	32.2	C	84	13.8	34.1	21.4	5.2	21.0	D

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

[b] C = Corral, D = Dart

Parameters grouped together are not statistically different ($P > 0.05$)

Table 1.4. Correlation analysis of induction time and time immobilized with stress indicators in adult male elk (*Cervus elaphus nelsoni*) chemically immobilized with carfentanil citrate in eastern Kentucky, USA 2012-2014.

		Induction Time (2-15 min)			Time Immobilized (6-156 min)		
Parameter[a]	Range	*n*	ρ	*P*	*n*	ρ	*P*
Rectal temperature (°C)	36.4-40.6	77	0.0065	0.9555	89	-0.0035	0.9744
Glucose (mg/dL)	36-260	84	-0.1746	0.1121	98	-0.0359	0.6971
Creatinine (mg/dL)	0.76-4.35	85	0.0768	0.4846	99	0.1218	0.2296
Potassium (mmol/L)	3.0-40.9	85	0.0093	0.9324	99	0.0567	0.5774
AST (IU/L)	36-248	85	-0.1387	0.2056	99	-0.0922	0.3641
CPK (IU/L)	54-3963	85	-0.0922	0.4013	99	-0.1739	0.0852

[a] AST = Aspartate aminotransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Table 1.5. Correlation analysis of induction time and time immobilized with stress indicators in adult female elk (*Cervus elaphus nelsoni*) chemically immobilized with carfentanil citrate in eastern Kentucky, USA 2012-2014.

		Induction Time (1-16 min)			Time Immobilized (15-53 min)		
Parameter[a]	Range	*n*	ρ	*P*	*n*	ρ	*P*
Rectal temperature (°C)	37.0-40.3	34	-0.0470	0.7918	41	-0.0575	0.7209
Glucose (mg/dL)	65-305	35	-0.0644	0.7134	42	-0.0356	0.8228
Creatinine (mg/dL)	1.55-2.68	35	-0.2824	0.1002	42	-0.2203	0.1609
Potassium (mmol/L)	3.8-34.5	35	0.1006	0.5652	42	0.0596	0.7079
AST (IU/L)	42-527	35	0.3200	0.0610	42	0.2240	0.1539
CPK (IU/L)	102-415	35	0.1191	0.4955	42	0.0777	0.6247

[a] AST = Aspartate aminotransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Table 1.6. Correlation analysis of time in the chute and time in the handling facility with stress indicators in adult female, calf, and yearling elk (*Cervus elaphus nelsoni*) corral trapped in eastern Kentucky, USA 2012-2014.

		Time in Chute (2-17 min)			Time in Facility (6-66 min)		
Parameter[a]	Range	*n*	ρ	*P*	*n*	ρ	*P*
Rectal temperature (°C)	38.2-42.6	55	0.1778	0.1940	51	0.1322	0.3553
Glucose (mg/dL)	107-341	56	-0.3215	0.0157	51	0.3205	0.0218
Creatinine (mg/dL)	1.35-2.84	56	-0.0729	0.5935	51	-0.0490	0.7326
Potassium (mmol/L)	3.8-18.4	56	0.0486	0.7220	51	0.1732	0.2242
AST (IU/L)	47-178	56	-0.1756	0.1954	51	0.1884	0.1855
CPK (IU/L)	120-7061	56	-0.0738	0.5889	51	0.1726	0.2258

[a] AST = Aspartate aminotransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Table 1.7. Comparison of serum reference values in elk (*Cervus elaphus nelsoni*) by capture type from eastern Kentucky to averages of previously reported serological values of elk from the western U.S.

Demographic[a]	Present Study[c]	Present Study[c]	Barber-Meyer et al. 2007 (Adult females)	Hamlin and Ross 2002 (Adult females)	Wild (All ages and sexes)	Wild (All ages and sexes)	Wild (Pregnant cows)	Captive (All ages and sexes)	Captive (Calves)	Captive (Cows)
Method	Chemical	Physical	Physical	Mostly Physical	Chemical	Physical	Physical	Chemical	Chemical	Chemical
Parameter[b]	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Glucose (mg/dL)	171	200	176	172	196	173	198	118	131	120
BUN (mg/dL)	25	20	9	18	20	24	20	30	33	31
Creatinine (mg/dL)	2.06	2.23			3.14	3.35	3.35	1.79	1.30	1.99
Chloride (mmol/L)	100	103			105	102	-	103	102	103
Sodium (mmol/L)	139	145			148	140	147	142	143	141
Potassium (mmol/L)	6.0	7.8			4.7	7.8	4.6	12.8	4.1	16.2
CO_2 (mmol/L)	23.4	17.5			-	-	-	-	-	-
Calcium (mg/dL)	9.2	9.8	9.6	11.0	9.6	8.7	8.7	9.5	9.8	9.4
Magnesium (mg/dL)	2.2*	2.2*			-	-	-	-	-	-
Phosphorus (mg/dL)	5.9	4.6	6.6	5.3	4.2	4.3	4.6	7.1	7.4	6.7
Cholesterol (mg/dL)	54	68			70	75	81	63	53	69
ALP (IU/L)	138*	138*	170	141	467	200	216	158	191	126
TBilirubin (mg/dL)	0.2	0.4			-	1.0	1.2	0.4	0.5	0.4
DBbilirubin (mg/dL)	0.1	0.1			-	-	-	-	-	-
IBilirubin (mg/dL)	0.2	0.3			-	-	-	-	-	-
AST (IU/L)	74	88	84	107	131	100	123	57	65	62
GGT (IU/L)	31*	31*	51	43	20	41		22	20	23
CPK (IU/L)	229	921	308	632	-	62	62	727		727
Osmolality (mOsm/L)	284.1	296.3			-	-	-	-	-	-
Total Protein (g/dL)	6.8*	6.8*	8.5	7.2	6.9	6.6	6.7	6.6	6.5	6.8
Albumin (g/dL)	3.4	3.7	4.0	4.7	2.6	2.9	2.1	3.7	2.4	3.8
Globulin (gms%)	3.3	3.1			4.3	3.4	-	-	-	
A:G Ratio (g/dL)	1.04	1.21			-	0.85	0.85	1.57	-	1.57
Anion Gap	21.4	32.5			-	-	-	-	-	-

[a] Averages of the reported means from previously published values. Sources include Barber-Meyer et al. (2007), Follis (1972), Hamlin and Ross (2002), Herin (1968), Millspaugh et al. (2000), Quinlan-Murphy (1998), Vaughn et al. (1973), Weber et al. (1984), and Wolfe et al. (1982). Except for Barber-Meyer et al. (2007) and Hamlin and Ross (2002), other sources were grouped together by capture methods due to smaller sample sizes.

[b] BUN = Blood urea nitrogen, CO2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

c Since very few adult males were incorporated in the previously published references, adult males were excluded from this comparison. Since all other age and sex classes were pooled for the comparison with other sources, age and sex classes for this study were pooled for this comparison.

*Trapped and chemically immobilized animals were grouped together as no statistically significant differences were found in Kentucky

CHAPTER 2

CHANGES IN ELK BIOCHEMICAL SERUM PROFILES AND SELECT PHYSIOLOGICAL PARAMETERS DURING A QUARANTINE AND TRANSLOCATION EVENT

Abstract

Rocky Mountain elk (*Cervus elaphus nelsoni*) have been used as reintroduction stock for many states in the eastern United States. After a successful reintroduction of its own, Kentucky has become an important source state for elk used in other elk reintroductions in this region. Captured elk used as reintroduction stock are typically held in quarantine while they undergo disease testing. Quarantine and processing of elk can be stressful for animals and lead to injury or death. I characterized how elk respond to this process by measuring biochemical serum values along with various physiological parameters at 5 handling events from the time of capture until final transport to recipient states. Changes observed in parameters between paired workups were indicative of the physical exertion and stress associated with handling activities. I observed decreases in creatinine levels from the capture event at the 1st and 3rd workups. Potassium and aspartate aminotransferase levels increased between the 1st and 2nd workups and the 3rd and 4th workups. Some of the changes in parameter values from the time of capture were likely related to changes in season and a captive-fed diet. Despite the evidence showing some undesired changes in the biochemical profiles of elk, the high survival rate of elk, especially shortly after handling, indicates that the capture, processing, and quarantine

activities used in Kentucky were not detrimental to initial post-translocation survival of elk.

Introduction

The recently dubbed Anthropocene epoch (Crutzen and Stoermer 2000) has been characterized by widespread loss of species and habitats at various spatial scales, including the once highly visible passenger pigeon *(Ectopistes migratorius*; Greenberg 2014) and auroch (*Bos primigenius*; van Vuure 2005). Species reintroduction programs strive to return species to portions of their historic range in an attempt to satisfy human desires such as hunting and tourism opportunities, and to restore ecosystem components and functionality (Fyfe 1978, Kleiman 1989, Fritts et al. 1997).

Eastern elk (*Cervus elaphus canadensis*) were historically found in all eastern states except Florida and northern New England, but overexploitation caused regional extinction of the subspecies by 1867 (Bryant and Maser 1982). Translocation has been used for more than a century in attempts to restore locally and regionally extirpated populations of elk to their historic range, but success has been mixed (Witmer 1990). A variety of factors, including founder population size (Jackson 1961, O'Gara and Dundas 2002), disease/parasites (Allen 1965, Severinghaus and Darrow 1976, O'Gara and Dundas 2002), capture myopathy, poaching (Allen 1965, Cartwright 1995, O'Gara and Dundas 2002), and inadequate habitat availability/landowner conflicts (Wood 1943, Murphy 1963, George 1974) are suspected to have contributed to some failures. In other cases, the lack of poor post-release monitoring prevented causal determination of reintroduction failure (Larkin 2001).

Populations of Rocky Mountain elk (*Cervus elaphus nelsoni*) from western states have been used historically as the source populations for reintroduction efforts in the eastern United States (Gerstell 1936, O'Gara and Dundas 2002, Larkin et al. 2003). A total of 12 U.S. states east of 101st longitude have reintroduced elk, including most recently, Virginia, Missouri, Wisconsin, and West Virginia. Heightened concern over the spread of wildlife diseases, particularly chronic wasting disease (CWD), brucellosis, and bovine tuberculosis (bTB), has limited the locations from where source populations can originate. Kentucky has not had a positive case of CWD, brucellosis, or bTB in its free-ranging elk population. Consequently, states such as Missouri, Virginia, and Wisconsin have obtained free-ranging Kentucky elk to source their reintroductions.

In Kentucky, the risk of disease transmission from elk to livestock and other wildlife in recipient states is minimized via implementation of a quarantine period combined with a rigorous health assessment and disease testing protocols for all captured elk subject to translocation (Woodford 2000, Corn and Nettles 2001, Deem et al. 2001). Attempts to minimize capture-related mortality are made by using well-established capture methods, and by subsequently reducing handling and holding times. The two primary methods of elk capture in Kentucky have been baited corral traps (Schemnitz 1994, Larkin et al. 2003) and chemical immobilization via darting using the drug carfentanil or a combination of carfentanil and xylazine (Meuleman et al. 1984, Roffe et al. 2005, Kreeger and Arnemo 2007, Kreeger et al. 2010).

A variety of studies have examined the causes of ungulate mortality related to capture (Larkin et al. 2003, DelGiudice et al. 2005, Flueck et al. 2005, Jacques et al. 2009), and at least one study (Bender et al. 2007) examined the relationship between

rump body condition score and survival of adult female elk; however, no studies to my knowledge have examined the effects of capture and quarantine on standard physiological and body metrics that could be useful indicators of stress and that could be predictive of post-translocation survival. From 2012-13, I opportunistically characterized the physiological response of captured, processed, and quarantined Kentucky elk that were translocated to Virginia and Missouri to: 1) document biological changes associated with translocation events of elk, and 2) examine how those influenced post-translocation survival. I suspect changes in certain serological and physiological parameters will indicate that the translocation process is stressful for elk, but will ultimately have little impact on overall survival.

Study Area

The Kentucky elk restoration zone includes 16 counties in the southeastern part of the state and comprises 1.2 million ha of the Cumberland Plateau physiographic region, an area characterized by steep, rugged hills and narrow valleys (Olsson et al. 2007). The climate is generally characterized by warm summers and mild winters. Annual precipitation averages 125 cm and the mean temperature is 13.3°C (National Oceanic and Atmospheric Administration 2001). The ecosystem is predominately second and third growth mixed-deciduous forest (79%) fragmented by active and reclaimed surface coal mines (10%), agricultural grasslands including pasture and row crops (9%), and urban areas (2%; Olsson et al. 2007). The mixed-mesophytic forest can be comprised of up to 30 co-dominant tree species, including several species of oak (*Quercus* spp.), hickory (*Carya* spp.), ash (*Fraxinus* spp.), magnolia (*Magnolia* spp.), tulip poplar (*Liriodendron tulipifera*), basswood (*Tilia* spp.), and maple (*Acer* spp.; Braun 1950). Plants commonly

found on reclaimed coal mines occupied by elk included lespedeza (*Lespedeza* spp.), crown vetch (*Coronilla varia*), birdsfoot trefoil (*Lotus corniculatus*), Kentucky-31 tall fescue (*Festuca arundinacea*), perennial ryegrass (*Lolium perenne*), and orchard grass (*Dactylis glomerata*; Olsson et al. 2007).

Methods

One hundred and seven elk were captured between 2012 and 2013 in several areas within the Kentucky elk zone to supply Missouri and Virginia with reintroduction stock. Elk were captured primarily in Bell, Perry, and Knott Counties. Elk were captured using: a) alfalfa (*Medicago sativa*), shelled corn (*Zea mays*), and Buck Jam (Evolved Habitats, Baton Rouge, LA) placed within corral traps, or b) chemical immobilization via a carbon dioxide-propelled dart containing a dose of ~0.01 mg/kg carfentanil citrate (Zoopharm, Windsor, CO; Mace 1971, Larkin et al. 2003, Kreeger et al. 2010) from 10 January-5 February 2012 and 6 January-27 January 2013. Chemically immobilized elk were reversed using naltrexone at a dosage of 100 mg/mg carfentanil administered (Miller et al. 1996). Chemically immobilized animals were immediately processed once recumbent. Corral-caught elk were loaded onto a trailer and moved to a quarantine facility (QF) located in Bell County, Kentucky. The QF consisted of a ~ 2 ha, 2.4-meter high exterior perimeter woven wire fence that enclosed 3 main ~0.4 ha holding pens, 2 small sick pens, and a cattle processing corral comprised of a series of metal holding pens connected to a gated, peripheral passageway that allowed elk to be funneled to a terminal, standard cattle squeeze chute for processing. A covered shelter and gravity flow water were available within each pen.

The time from capture to handling for all methods ranged from ~30 min-16 hrs. Because of livestock disease regulations, recipient states mandated that all elk captured in Kentucky be quarantined for a minimum of 97 days after the last individual was placed in the QF. Elk were processed through the chute on days 1, 4, 94, and 97 (Figure 2.1) of quarantine to screen the animals for a variety of diseases (e.g. tuberculosis) prior to translocation, and to allow collection of physiological and morphometric data.

During processing, elk were first coaxed into entering the processing funnel, where they passed through a gated chamber with a floor scale to determine body mass. Afterwards, elk were moved into an adjacent squeeze chute, immediately blindfolded, and their heads manually restrained to help calm them and limit impact injuries. Each elk was then fitted with a plastic, numbered ear tag for individual identification. Elk were aged via tooth eruption and wear (Quimby and Gaab 1957). On processing days 1 and 94, I determined general body condition scores (BCS) of elk by palpating the rump, withers, and ribs (Stephenson et al. 1998, Cook et al. 2010) and classified each elk on a scale of 1 - 5 (1 = emaciated, 5 = fat). From those scores, I classified each elk as in either poor (1 - 2) or good (3 - 5) physical condition. I also used a portable ultrasound (Ibex Pro, E.I. Medical Imaging, Loveland, CO) to gather more specific measures of body condition on days 4 and 97 that included maximum thickness of the rump fat layer between the hip and pin bones (MAXFAT) and loin thickness between the 12^{th} and 13^{th} ribs using ultrasonography (Cook et al. 2001*a*, *b*, Cook et al. 2004, Gustine et al. 2007, Cook et al. 2011); elk were shaved prior to measurements in both of these areas to facilitate ultrasonography. I collected a 20 ml blood sample from each elk using a jugular venipuncture $\leq$ 30 minutes of immobilization for darted animals (Rostal et al. 2012) and

≤ 3 minutes of entering the head chute for corral-caught animals. Blood samples were allowed to clot before being temporarily stored on ice prior to centrifugation and serum collection. Serum was kept frozen at -20°C until a total blood panel analysis was performed using a Beckman Coutler AU480 Chemistry System (Beckman Coulter, Brea, California, USA) for glucose, blood urea nitrogen (BUN), creatinine, chloride, sodium, potassium, carbon dioxide (CO_2), calcium, magnesium, phosphorus, cholesterol, alkaline phosphatase (ALP), total bilirubin, direct bilirubin, indirect bilirubin, aspartate aminotransferase (AST), gamma-glutamyltransferase (GGT), creatine phosphokinase (CPK), osmolality, total protein, albumin, globulin, albumin:globulin ratio (A:G ratio), and anion gap. I measured core body temperature using a rectally inserted digital thermometer. I collected blood and fecal samples and recorded body morphometrics from elk that were chemically immobilized prior to transport to the QF to establish baseline values of physiological and morphometric parameters. I recorded initial capture time, time spent in transit, time of entry into the QF, time on scale, and holding duration within the head chute to assess potential relationships between capture and post-translocation survival of elk.

After processing at the QF, elk were segregated into 3 separate holding pens that included the following groups: adult cows and spike bulls, calves, and sick or injured elk. Elk held in the QF were given unlimited access to water, alfalfa/orchard grass hay, and covered shelter. Additionally, all elk were given 1.4-2.3 kg/head/day (3-5 lb/head/day) of a pelletized feed/grain combination. Calves received 28-57 g/head/day (1-2 ounces/head/day) of Calf-Manna (Manna Pro Products, Chesterfield, Missouri, USA).

Granulized erythromycin was poured on top of the pelletized feed and/or Calf-Manna at a dosage of 28-85 g/pen/day (1-3 ounces/pen/day).

Sampling and initial workup procedures at the time of capture changed between years as a result of modifications to the handling facility. In 2012, I was unable to collect blood, ultrasound, body condition scores, or obtain rectal temperatures on any elk that was caught using corral traps and initially handled in the working facility, but I was able to collect fecal samples (n = 30) from a subsample of the captured elk. Additionally, in 2012, elk were treated with pour-on Ivermectin at the time of initial handling as a dewormer, but were not in 2013.

On day 97, elk were fitted with global positioning system (GPS) collars by the recipient states to monitor movement and survival post-release. I monitored elk for 6 weeks post-release for mortality events that could be related to capture myopathy and stress from processing and translocation (Larkin et al. 2003). Elk were translocated to Missouri and Virginia on May 18 in 2012 and May 21 in 2013. Missouri translocated 35 (24 cows, 8 calves, 3 yearling males) elk in 2012 and 39 (20 cows, 19 calves) elk in 2013. The elk were transported via semitruck in a standard cattle transport trailer. Elk were transported to a holding facility in Missouri where they were temporarily quarantined until a soft-release was performed on June 19 in 2012 and June 8 in 2013. Virginia translocated 15 (8 cows, 5 calves, 2 yearling males) elk in 2012 and 10 (2 cows, 8 calves) elk in 2013. The elk were transported via truck and trailer to the release site where a hard-release was performed.

I estimated the probability of surviving the capture event, treating the outcome as a binomial trial and quantifying uncertainty with an exact binomial confidence interval

using R package Hmisc (Harrell 2014). I used Kaplan-Meier estimators to estimate survival of elk during quarantine and also to estimate survival after translocation to Missouri.

I used paired t-tests to compare changes from the time of capture with the 1st and 3rd workups for time in the working facility, time in the handling chute, rump BCS, withers BCS, ribs BCS, rump ultrasound, and loin ultrasound. All age and sex classes were pooled for these analyses.

I used linear mixed-effects models to test for changes in serological (glucose, blood urea nitrogen [BUN], creatinine, potassium, calcium, magnesium, phosphorus, cholesterol, alkaline phosphatase [ALP], gamma-glutamyl transferase [GGT], creatine phosphokinase [CPK], total protein, albumin, globulin, and albumin:globulin ratio [A:G ratio]), physiological (body temperature), and morphological (weight) parameters of elk during the quarantine period compared to baseline data collected at the time of capture. Random intercepts were used to account for repeated measurements on the same individuals through time. I only compared baseline capture data to information gathered at the 1st and 3rd workups following the initial handling event, thus excluding data from the 2nd and 4th workups. The data from the 2nd and 4th workups was not considered in this analysis due to physiological changes and associated serological parameters that may have been directly associated with the handling activities on the 1st and 3rd workups that occurred 3 days prior. Potential explanatory covariates were occasion (workup event = baseline, 1, or 3), age (calf or adult), sex (male or female), all 2-way interactions, and the 3-way interaction. I used Akaike Information Criterion for small sample size to evaluate and select the best-fitting candidate models (AIC_c; Hurvich and Tsai 1989, Burnham and

Anderson 2002). Right-skewed response variables were log-transformed to normalize data, all models were fit using R package lme4 (Bates et al. 2014), and AIC tables were produced using R package MuMIn (Barton 2014) to quantify model selection uncertainty. After fitting all possible models, models were removed that did not lead to a reduction in AIC of ≥ 2 units per added degree of freedom (df) over its nested counterpart (Arnold 2010). Model weights were recalculated for this potentially subsetted group of models which were then used to model average parameters and predict the response for each group. I report the top 2 models except in cases where only 1 model was supported, in which case I present the results from the top model and the null model.

In order to investigate the short-term effects of elk workups on serological parameters, I modeled the differences between workups 1 and 2 and workups 3 and 4 which were 3 days apart. I used linear mixed-effects models to determine if the changes in parameter values between consecutive workups were different from zero and if so, to determine if the effects were in the same direction and of similar magnitude between workup sets. I grouped all sex and age class for this analysis. All models were fit using R package lme4 (Bates et al. 2014) and uncertainty was quantified using bootstrap prediction intervals with R package merTools (Knowles and Frederick 2015).

All survival and linear mixed-effects analyses were performed using R 3.1.0 (R Foundation for Statistical Computing, Vienna, Austria). Paired t-tests and Wilcoxon signed-rank tests were performed using SAS 9.3 (SAS Institute, Cary, North Carolina, USA) to make comparisons between workups for paired parametric and nonparametric data, respectively. Comparisons in analyses were considered statistically significant if p-values were ≤ 0.05. Elk capture and handling protocols were approved by the

Institutional Animal Care and Use Committee of the University of Kentucky #2010-0726 and the Kentucky Department of Fish and Wildlife Resources (KDFWR).

Results

The probability of elk surviving the capture event was 0.991 (0.950-1.000) with only one (0.9%) mortality event associated with capture. Seven elk (6.5%) died while in the quarantine pens (6 in 2012 and 1 in 2013), with a probability of survival in the pens through quarantine at 0.902 (0.758-0.962; Figure 2.2). All elk translocated to Virginia survived the 6-week post-release monitoring period. The probability of surviving release in Missouri was 0.824 (0.717-0.894, Figure 2.3) with 13 of 74 (17.6%) elk dying within the 6-week post-release monitoring period (8 in 2012, and 5 in 2013).

Time in the working facility was significantly lower at the time of capture (23.0 ± 14.2 min) compared to the 1st (81.8 ± 48.6 min, t = -8.44, P < 0.0001) and 3rd (87.4 ± 51.3 min, t = -8.78, P < 0.0001) workups. Time in the chute was higher at the time of capture (7.4 ± 8.0 min) compared to the 1st (4.3 ± 3.5 min, t = 3.70, P = 0.0003) and 3rd (3.8 ± 3.0 min, t = 4.26, P < 0.0001) workups. Rump BCS was higher at the time of capture (4.0 ± 0.6) compared to the 1st workup (3.7 ± 0.6, t = 3.22, P = 0.0016), but didn't significantly change at the 3rd workup (4.1 ± 0.6, t = -0.98, P = 0.3277). Withers BCS was higher at the time of capture (3.9 ± 0.7) compared to the 1st workup (3.6 ± 0.8, t = 2.73, P = 0.0071), but didn't significantly differ from the 3rd workup (4.0 ± 0.7, t = -0.92, P = 0.3598). Ribs BCS was higher at the time of capture (4.1 ± 0.6) compared to the 1st workup (3.6 ± 0.7, t = 4.68, P < 0.0001), but didn't significantly differ from the 3rd workup (4.2 ± 0.6, t = -0.07, P = 0.9482). Rump ultrasound measurements were smaller at the time of capture (11.5 ± 6.9 mm) compared to the 1st workup (14.8 ± 6.8 mm, t = -

2.88, P = 0.0045), but were larger compared to the 3rd workup (7.7 ± 5.1 mm, *t* = 3.98, P = 0.0001). Loin ultrasound measurements from the time of capture (44.3 ± 6.2 mm) were similar to the 1st workup (45.0 ± 5.4 mm, *t* = -0.80, P = 0.4259) and smaller than at the 3rd workup (47.2 ± 5.7 mm, *t* = -3.01, P = 0.0031).

Rump BCS increased between the 1st and 3rd workups (3.7 ± 0.6, 4.1 ± 0.6, *t* = -4.83, P <0.0001). Withers BCS increased between the 1st and 3rd workups (3.6 ± 0.8, 4.0 ± 0.7, *t* = -4.20, P < 0.0001). Ribs BCS increased between the 1st and 3rd workups (3.6 ± 0.7, 4.2 ± 0.6, *t* = -5.69, P < 0.0001). Loin ultrasound measurements increased between the 1st and 3rd workups (45.0 ± 5.4 mm, 47.2 ± 5.7 mm, *t* = -2.88, P = 0.0044). Rump ultrasound measurements decreased between the 1st and 3rd workups (14.8 ± 6.8 mm, 7.7 ± 5.1 mm, *t* = 8.59, P < 0.0001).

I tested for changes in select physiological and serological variables at the time of capture compared to the 1st and 3rd workups while factoring in the covariates of occasion, age, sex, and their interactions (Table 2.1). Overall 16 of 17 (94%) variables significantly changed between time of capture and the 1st and/or 3rd workups. Male calf (CM) weights were higher at the 3rd workup compared to the time of capture ($\overline{x}$ ± SD, Time of capture, Workup 1 or 3; 129.1 ± 17.0 kg, 154.6 ± 11.0 kg, *t* = -5.53, P < 0.0001; Figure 2.4). Body temperatures of adult female (AF), adult male (AM), and females calves (CF) were significantly higher at the 3rd workup compared to the time of capture (AF = 39.9 ± 0.9°C, 40.7 ± 0.6°C, *t* = -3.98, P = 0.0002; AM = 39.4 ±1.1°C, 40.8 ± 0.9°C, *t* = -2.67, P = 0.0218, CF = 40.4 ± 0.5°C, 41.1 ± 0.5°C, *t* = -4.26, P = 0.0001; Figure 2.5). Body temperatures of calves (C) were noticeably higher than adult (A) elk at all workups (Baseline, A = 39.8 ± 0.9°C, C = 40.6 ± 0.7°C, *t* = -3.68, P = 0.0005; 1st workup, A =

40.0 ± 0.7°C, C = 40.9 ± 0.7°C, *t* = -6.63, P < 0.0001; 3rd workup, A = 40.7 ± 0.8°C, C = 41.2 ± 0.6°C, *t* = -3.33, P = 0.0012). Adult female elk had lower glucose levels at the 3rd workup compared to the time of capture (194.5 ± 60.4 mg/dL, 149.0 ± 59.6 mg/dL, *t* = 3.23, P = 0.0018). Female elk had noticeably lower BUN levels than males at the time of capture (F = 19 ± 5 mg/dL, M = 24 ± 6 mg/dL, *t* = -3.29, P = 0.0017), but their levels increased to similar ranges of males for the 1st and 3rd workups (Figure 2.7). Creatinine levels were lower at the 1st and 3rd workups compared to time of capture values for all sex and age classes except for adult males at the 1st workup (Baseline, 1st workup; AF = 2.27 ± 0.33 mg/dL, 1.68 ± 0.32 mg/dL, Z = 5.72, P < 0.0001; CF = 2.15 ± 0.23 mg/dL, 1.48 ± 0.34 mg/dL, Z = 4.49, P < 0.0001; CM = 2.20 ± 0.29 mg/dL, 1.46 ± 0.18 mg/dL, Z = 4.56, P < 0.0001; Baseline, 3rd workup; AF = 2.27 ± 0.33 mg/dL, 1.48 ± 0.19 mg/dL, *Z* = 6.74, P < 0.0001; AM = 2.23 ± 0.20 mg/dL, 1.47 ± 0.24 mg/dL, Z = 2.77, P = 0.0057; CF = 2.15 ± 0.23 mg/dL, 1.26 ± 0.16 mg/dL, Z = 5.20, P < 0.0001; CM = 2.20 ± 0.29 mg/dL, 1.19 ± 0.14 mg/dL, Z = 4.65, P < 0.0001; Figure 2.8). After starting near the same level as adults at capture, calf creatinine levels were lower than adults at the 1st and 3rd workups (1st workup, A = 1.71 ± 0.37 mg/dL, C = 1.47 ± 0.27, Z = -3.99, P = 0.0001; 3rd workup, A = 1.48 ± 0.19 mg/dL, C = 1.23 ± 0.15 mg/dL, Z = -6.66, P < 0.0001). Potassium levels of all age and sex classes were lower at the 1st and 3rd workups compared to the time of capture (Baseline, 1st workup; AF = 8.3 ± 6.0 mmol/L, 5.3 ± 1.1 mmol/L, Z = 3.41, P = 0.0006; AM = 6.2 ± 1.4 mmol/L, 4.6 ± 0.6 mmol/L, Z = 2.10, P = 0.0353; CF = 8.1 ± 3.7 mmol/L, 4.8 ± 0.6 mmol/L, Z = 2.32, P = 0.0202; CM = 7.0 ± 2.4 mmol/L, 5.2 ± 0.5 mmol/L, Z = 2.12, P = 0.0343; Baseline, 3rd workup; AF = 8.3 ± 6.0 mmol/L, 4.4 ± 0.7 mmol/L, Z = 5.65, P < 0.0001; AM = 6.2 ± 1.4 mmol/L, 4.3 ± 0.3

mmol/L, Z = 2.77, P = 0.0057; CF = 8.1 ± 3.7 mmol/L, 4.4 ± 0.4 mmol/L, Z = 3.24, P = 0.0012; CM = 7.0 ± 2.4 mmol/L, 4.6 ± 0.4 mmol/L, Z = 3.43, P = 0.0006; Figure 2.9). Calcium levels trended lower during the 1st workup for all age and sex classes compared to the time of capture, but were only significantly lower in adult female elk (9.6 ± 0.5 mg/dL, 9.2 ± 0.5 mg/dL, *t* = 3.22, P = 0.0018; Figure 2.10). Calcium levels in calves were higher than those observed for adults at all workups (Baseline, A = 9.5 ± 0.5 mg/dL, C = 10.0 ± 0.6 mg/dL, *t* = -3.47, P = 0.0010; 1st workup, A = 9.2 ± 0.5 mg/dL, C = 9.6 ± 0.5 mg/dL, *t* = -3.84, P = 0.0002; 3rd workup, A = 9.6 ± 0.9 mg/dL, C = 9.8 ± 0.3 mg/dL, *t* = -2.26, P = 0.0266). Baseline magnesium levels were higher in all age and sex classes compared to the 1st and 3rd workups except for adult males in the 3rd workup (Baseline, 1st workup; AF = 2.3 ± 0.2 mg/dL, 1.9 ± 0.2 mg/dL, Z = 5.98, P < 0.0001; AM = 2.2 ± 0.2 mg/dL, 1.7 ± 0.4, Z = 2.11, P = 0.0345; CF = 2.1 ± 0.2 mg/dL, 1.9 ± 0.2 mg/dL, Z = 3.39, P = 0.0007; CM = 2.2 ± 0.2 mg/dL, 1.9 ± 0.2 mg/dL, Z = 2.66, P = 0.0078; Baseline, 3rd workup; AF = 2.3 ± 0.2 mg/dL, 2.0 ± 0.2 mg/dL, *Z* = 5.62, P < 0.0001; CF = 2.1 ± 0.2 mg/dL, 1.9 ± 0.3 mg/dL, Z = 3.60, P = 0.0003; CM = 2.2 ± 0.2 mg/dL, 2.0 ± 0.3 mg/dL, Z = 2.52, P = 0.0117; Figure 2.11). Magnesium levels were fairly constant among all sex and age classes for the 1st and 3rd workups. Phosphorus levels increased for adult females and calf elk between the time of capture and the 1st workup (AF = 4.4 ± 1.6 mg/dL, 6.3 ± 1.5 mg/dL, *t* = -5.35, P < 0.0001; CF = 4.7 ± 1.1 mg/dL, 5.8 ± 1.8 mg/dL, *t* = -2.38, P = 0.0233; CM = 4.6 ± 1.2 mg/dL, 6.2 ± 1.3 mg/dL, *t* = -3.25, P = 0.0029; Figure 2.12). All sex and age cohorts except adult males displayed a significant decrease in cholesterol levels at the 1st workup compared to the time of capture followed by modest increases at the 3rd workup (AF = 66 ± 10 mg/dL, 50 ± 8 mg/dL, *t* = 7.63, P <

0.0001; CF = 71 ± 11 gm/dL, 44 ± 11 mg/dL, t = 7.52, P < 0.0001; CM = 67 ± 15 mg/dL, 44 ± 9 mg/dL, t = 5.52, P < 0.0001; Figure 2.13). Serum ALP levels changed little between capture and the 1st workup for all except adult males, which decreased (126 ± 65 IU/L, 34 ± 10 IU/L, Z = 2.49, P = 0.0129; Figure 2.14). Calves had higher ALP at the 3rd workup compared to the baseline (CF = 145 ± 38 IU/L, 327 ± 87 IU/L, Z = -5.17, P < 0.0001; CM = 185 ± 59 IU/L, 365 ± 124 IU/L, Z = -3.83, P = 0.0001). Gamma-glutamyl transferase levels trended downward with each subseqent workup among all age and sex classes, but were only significant between the time of capture and the 3rd workup for adult females and calves (AF = 24 ± 12 IU/L, 18 ± 7 IU/L, Z = 3.20, P = 0.0007; CF = 36 ± 32 IU/L, 23 ± 35 IU/L, Z = 4.08, P < 0.0001; CM = 32 ± 25 IU/L, 13 ± 13 IU/L, Z = 3.39, P = 0.0007; Figure 2.15). Total protein levels of adults were higher than those observed for calves during each workup (Baseline, A = 7.1 ± 0.5 g/dL, C = 6.4 ± 0.4 g/dL, t = 6.04, P < 0.0001; 1st workup, A = 7.0 ± 0.5 g/dL, C = 6.3 ± 0.6 g/dL, t = 6.43, P < 0.0001; 3rd workup, A = 7.5 ± 0.7, C = 6.4 ± 0.3, t = 11.80, P < 0.0001; Figure 2.16). Total protein levels of calves remained stable at each workup. Adult female total protein levels were higher at the 3rd workup compared to the time of capture (7.2 ± 0.5 g/dL, 7.6 ± 0.7 g/dL, t = -2.91, P = 0.0048). Albumin levels for all age and sex classes trended higher at the 3rd workup compared to the time of capture, but were only significant for female elk (AF = 3.7 ± 0.2 g/dL, 3.9 ± 0.5 g/dL, t = -2.07, P = 0.0420; CF = 3.7 ± 0.2 g/dL, 3.8 ± 0.1 g/dL, t = -2.09, P = 0.0479 Figure 2.17). Globulin levels for calf elk were noticeably lower at each workup compared to adult elk (Baseline, A = 3.5 ± 0.4 gms%, C = 2.8 ± 0.4 gms%, Z = -5.28, P < 0.0001; 1st workup, A = 3.4 ± 0.5 gms%, C = 2.7 ± 0.4 gms%, Z = -6.72, P < 0.0001; 3rd workup, A = 3.7 ± 0.6 gms%, C = 2.6 ± 0.3 gms%, Z =

-7.91, P < 0.0001; Figure 2.18). Calf elk had a higher A:G ratio than adults during all workups (Baseline, A = 1.07 ± 0.13 g/dL, C = 1.35 ± 0.21 g/dL, *t* = -6.14, P < 0.0001; 1st workup, A = 1.09 ± 0.18 g/dL, C = 1.39 ± 0.20 g/dL, *t* = -7.92, P < 0.0001; 3rd workup, A = 1.07 ± 0.22 g/dL, C = 1.48 ± 0.18 g/dL, *t* = -9.94, P < 0.0001; Figure 2.19).

When comparing the differences between the 1st and 2nd workups and the 3rd and 4th workups, I observed consistent increases for potassium, direct bilirubin, and AST (Table 2.2), and consistent decreases for glucose, BUN, sodium, magnesium, phosphorus, cholesterol, ALP, osmolality, and albumin. I observed mixed results for weight, chloride, CO_2, total bilirubin, indirect bilirubin, total protein, and globulin, and found no changes for body temperature, creatinine, calcium, GGT, CPK, A:G ratio, and anion gap.

Discussion

Translocations have become common practice in modern conservation to reintroduce extirpated species to portions of their native range and to improve depleted populations that have fallen below management objectives (Wolf et al. 1996, Woodford 2000, IUCN 2013). The introduction of novel pathogens to existing wildlife species, domesticated animals, and humans is one of the primary concerns associated with translocations (Daszak et al. 2000, Corn and Nettles 2001). Chronic stress can suppress immune system function in translocated individuals (Cichón et al. 2002, de Kloet 2005) and increase the likelihood of pathogen spread (Woodford 2000, Teixeira et al. 2007).

The connection between stress-related immune suppression and an animal's inability to combat potential pathogens during translocation events necessitates monitoring the health of translocated animals from the time of capture through release. In addition to the need for monitoring animal health for the benefit of wildlife, domesticated

animals, and humans through reduced pathogen spread and subsequent transmission, monitoring animal welfare during translocation is important (Woodford 2000, Harrington et al. 2013). I found that while there are some indications that all parts of the translocation process stress the elk, the number of elk that exhibit 'distress' as defined by Moberg (2000) are likely small in number and may be of little consequence in the ultimate goal of this translocation process.

Only one elk died during both years of capture and handling, and that was a calf that broke its back shortly after release into the pens. From the 7 elk that died during the quarantine period, 2 were associated with broken necks, 2 were associated with injuries sustained during quarantine leading to sepsis, 2 were likely related to capture myopathy following workups, and 1 was euthanized as it appeared to be neurologically compromised due to meningeal worm (*Parelaphostrongylus tenuis*) infection. Although only one elk (calf) died shortly (within 2 days) after transport to Missouri, 13 elk died within the 6-week post-release monitoring period between 2012 and 2013. Despite the fact all elk were collared, cause-specific mortality determinations were able to be made on only one elk (visceral congestion). Larkin et al. (2003) reported that out of 718 elk released in Kentucky, 71 of 72 mortalities within 6-weeks of release died of capture related injuries. A combination of the severe drought, the added stress of caring for neonatal calves, and a dramatic diet change as elk were moved from captivity to free-range likely contributed to the death of the 8 elk post-release in Missouri in 2012.

Time in the working facility was higher at the 1st and 3rd workups when compared to the time of capture due to the number of elk being processed. During the initial handling at the time of capture, there were between 1 and 11 elk to be processed, with

most groups averaging 3-4 elk. During the 1st and 3rd workups, around 15-20 elk would be moved into the working facility at a time. By contrast, time in the chute was lower at the 1st and 3rd workups compared to the time of capture. The initial handling required different processing steps that weren't undertaken on the 1st and 3rd workups and the initial handling was done with a smaller processing crew.

I observed an increase in body temperature for all sex and age classes except male calves at the 3rd workup compared to the time of capture. Additionally, calf temperatures were noticeably higher than adults at all workups. The increase in body temperature at the 3rd workup may be related to a couple of factors. First, the workup took place in May, a warmer month compared to January when elk were first captured. Second, not all elk had shed their winter 'coats' and nearly all yearling and adult cows were late in their gestation period, thus reducing their ability to effectively thermoregulate. One additional factor that likely increased body temperatures at the 3rd workup is increased stress associated with handling activities (Meyer et al. 2008). It is worth noting that in all but the 2nd workup, I recorded the body temperature of multiple elk to be between 42.2-42.8°C. At temperatures above 42.2°C, survival without negative effects is unlikely (Kreeger 1996). To help mitigate the effects of hyperthermia, I used combinations of ice and isopropyl alcohol to aid in evaporative cooling, and all elk with a temperature above 41.1°C received a weight specific Banamine injection.

I used body condition scores of the rump, withers, and ribs (Gerhart et al. 1996) as well as ultrasound measurements of the rump and loin (Cook et al. 2001*a*) as a method of assessing changes in physical body condition throughout the quarantine period. Body condition scores decreased between the time of capture and the 1st workup, and then

returned to original values by the 3rd workup. Loin measurements increased at the 3rd workup, but rump ultrasound measurement decreased by nearly half at the 3rd workup. Cook et al. (2010) strongly caution about misinterpretations that can be drawn from ultrasound measurements collected by untrained individuals. To minimize biases, the same individual took all ultrasound measurements and palpation scores. Additionally, all animals were restrained in the same manner and ultrasound measurements were taken from the same shaved location each time. The increases in most body condition scores I found from capture through the last workup make sense given that captive elk were well fed during quarantine and added body mass from their initial winter condition state; however, we cannot explain why the rump fat ultrasound measurement decreased over time in contrast to the increase in all other body scores and loin ultrasound meaurements. Given the high body condition scores of most individuals, with some bordering on obesity, I did not expect rump ultrasound measurements of fat decrease by nearly half. Body mass of elk also indicated a stable to slightly increasing trend among all sex and age classes despite only male calves being statistically significant. Loin thickness measurements should increase especially among the calf cohort as they are rapidly growing. Pregnancy and fetal development are metabolically taxing on any animal, but under good nutritional conditions with stable to increasing weights, body fat in the rump decreased. In humans, increases in body fat are one indicator of increases in birth weight (Villar et al. 1992).

The causes of variation in some blood parameters (e.g. BUN) can be difficult to determine. Blood urea nitrogen is a measure of the nitrogen component of ammonia released in urine and an indicator of liver and kidney function. Blood urea nitrogen levels

of female elk were elevated above capture levels for the 1st and 3rd workups. A high energy diet with adequate protein can decrease BUN values (Kirkpatrick et al. 1975); conversely, both a high protein diet and a sub-maintenance diet resulting in protein catabolism can lead to elevated BUN values (Seal et al. 1978, Bahnak et al. 1979). A study conducted on white-tailed deer found seasonal differences in BUN (Kie et al. 1983). Higher BUN levels during winter and spring months may be attributed to low dietary energy intake (Kirkpatrick et al. 1975) or high protein intake (Seal et al. 1978, Bahnak et al. 1979). Klinger et al. (1986) observed similar increasing trends in BUN levels from winter to spring in white-tailed deer. Harder and Kirkpatrick (1994) reported that protein catabolism led to elevated levels of BUN, but I don't believe this explains the elevated levels we observed, as loin thickness either stayed the same or increased slightly at the 1st and 3rd workups compared to capture. Elk were fed quality alfalfa/orchard grass hay and a pelletized grain-based supplement. Consequently, the elk were likely consuming a diet higher in protein than that prior to capture which led to the elevated BUN levels (Cook 2002).

Creatinine is a byproduct of muscle catabolism and can be a good indicator of renal function (Weber 1973). Creatinine levels are largely impacted by functions of body condition and muscle mass. I found creatinine levels decreased from the time of capture when compared to the 1st and 3rd workups. Low serum levels of creatinine are often associated with decreases in muscle mass, poor body condition, or young age, and are typically higher in well-conditioned animals (Schutte et al. 1981, Radin 1991). Kie et al. (1983) and DelGuidice et al. (1992) found seasonal differences in creatinine levels in white-tailed deer with winter levels being generally higher than spring and summer

levels. DelGuidice et al. (1992) attributed those differences to dehydration associated with nutritional deprivation. Säkkinen et al. (2001) observed similar seasonal trends in free-ranging reindeer (*Rangifer tarandus tarandus, Rangifer tarandus platyrhynchus*) and suggested most of the difference was associated with changes in protein and feed intake. Johnson et al. (2010) found creatinine levels in boreal caribou (*Rangifer tarandus caribou*) were lower in late winter captures compared to spring captures. Similarly, creatinine levels decreased during spring and summer sampling periods in adult male elk in Kentucky from winter levels (personal data). I believe the decreases in creatinine for all age and sex classes from the time of capture are associated with natural, seasonal changes. I also observed calf creatinine levels fall below those of adults at the 1st and 3rd workups. Those decreases are likely attributed to the lower muscle mass and age differences between adults and calves (Schutte et al. 1981, Rostal et al. 2012).

Sodium and osmolality levels decreased after the 1st and 3rd workups. Sodium levels are often indicative of hydration status. Dehydration leads to hypernatremia, whereas over hydration leads to lower serum sodium levels (Radin 1991, Bohn 2012). Osmolality is a measure of a variety of blood components including sodium and glucose. Sodium in particular exhibits nearly identical trends to osmolality by workup. De Morais et al. (1991) notes that low sodium levels will decrease osmolality levels. My findings likely indicate elk were able to adequately hydrate following the workups 3 days prior given that overhydration is associated with decreased serum osmolality and sodium levels.

Potassium is the most abundant intracellular cation and is tightly regulated by the body (Engelking 2004, Stringer et al. 2011). The membrane potential created by the

differences between potassium and the major extracellular cations such as sodium allow muscle contraction and neurotransmission (Carlson 1997). Acute stress associated with capture method and handling activities has been cited as a cause of hyperkalemia in some ungulate studies (Wilber and Robinson 1958, Kock et al. 1987, DeLiberto et al. 1989), but not others (Kocan et al. 1981, Marco and Lavin 1999). Corral trapping coupled with the contact trauma from the traps and other captured elk has been attributed to elevated potassium levels in other studies (Jago et al. 1997, Millspaugh et al. 2000). Millspaugh et al. (2000) found corral caught elk had significantly higher serum potassium levels compared to net-gunned and Clover trapped elk. Potassium levels were likely elevated at capture in this study due in part to the high percentage of elk that were corral trapped. The corral traps were monitored with motion activated trail cameras equipped with wireless Short Message Service (SMS) technology that immediately notified personnel when elk were detected in the trap and the door was closed. In many cases, especially those where antlered elk were also captured, I immediately removed the elk from the trap and transported them to the quarantine facility for initial processing, but animals may have been captured for as long as 12 hours before initial sample collection, resulting in elevated potassium levels. I also observed elevated potassium levels when comparing the 2^{nd} and 4^{th} workups to the 1^{st} and 3^{rd} workups. The large increases in extracellular potassium present in the serum likely indicate the workups imposed some physical trauma or muscle injury to the elk.

Cholesterol is a lipid manufactured primarily in the liver from excess carbohydrates and amino and fatty acids (Coblentz 1975). It aids in hormone production and digestion. Cholesterol levels were lower at each workup than that observed at

capture, but values seemed to rebound slightly between the 1st and 3rd workups. Klinger et al. (1986) observed highly variable seasonal changes in cholesterol values that were similar to those observed in our study. Seasonal changes in cholesterol may be related to dietary and metabolic differences (Coblentz 1975, Vogelsang 1977, Warren et al. 1981). Excitability resulting from capture was reported by Franzmann and Thorne (1970) and Franzmann (1972) as a likely cause of increased cholesterol levels in bighorn sheep. The stark change in cholesterol in my study could be related to both capture and dietary changes associated with quarantine. Cholesterol values at the time of capture may have been elevated due to the stress of corral trapping animals and the increased production of corticosteroids. In many cases, elk weren't handled for many hours after being caught in the trap. Cholesterol values at the 1st and 3rd workups may reflect the diet associated with quarantine. Klinger et al. (1986) and Coblentz (1975) reported cholesterol values being highest in white-tailed deer in the fall and lowest during the winter and attributed the change in cholesterol to changes in forage quality.

Alkaline phosphatase is a protein found in the body tissues that among other things helps with mineralization of bones and teeth (Golub and Battaglia 2007). Levels of ALP can be used to assess liver and bone health. Blood levels are affected by pregnancy, bone, and antler development, and vary widely among sex and age classes (Tietz 1976, Cook 2002). I observed a decrease between the time of capture and the 1st workup for adult males and an increase in calves at the 3rd workup compared to the time of capture. Kie et al. (1983) found that adult male white-tailed deer had higher ALP levels than adult females. Additionally, they noted a decrease in ALP with age. Rostal et al. (2012) observed the same decreasing trend in ALP with increased age for moose (*Alces alces*).

Cook (2002) found young, growing elk exhibited elevated levels of ALP compared to older elk. Chapple et al. (1991) found levels of ALP decreased with age in chital deer (*Axis axis*). Schroeder (1986) and Matula et al. (1977) reported elevated serum ALP levels in young black bears (*Ursus americanus*) compared to older individuals. For adult male chital deer, ALP levels varied seasonally being highest during times of active antler growth (Chapple et al. 1991), and Cook (2002) mentioned similar trends for adult male elk. The decrease I observed in ALP for adult males in quarantine followed by a rise at the start of the period of antlerogenesis is similar to what Chapple et al. (1991) reported. Calf values being elevated above adults during late spring can be attributed to the fact they are young, actively growing animals. I also observed a decrease in ALP levels at the 2nd and 4th workups compared to the 1st and 3rd workups. Marco et al. (1997) reported a similar finding in mouflon (*Ovis ammon*) after comparing at capture and post-transport values. Given the wide range of values, locations where ALP is found (liver, bone, kidneys, etc.), and the sources of variation outlined above, caution should be used in interpreting results related to ALP (Duncan and Prasse 1986, Marco et al. 1997).

Aspartate aminotransferase levels were elevated on the 2nd and 4th workups compared to the 1st and 3rd workups. Aspartate aminotransferase is known to elevate in response to severe injury/necrosis to muscle (Spraker 1993, Allison 2012, Bohn 2012). Aspartate aminotransferase is a good indicator of muscle injury with peak levels appearing at least a day after the event and returning to normal in 7-8 days for some species like horses (Spraker 1993, Allison 2012). Creatine phosphokinase by comparison peaks in 6-12 hours and returns to normal ranges within 1-2 days of the event (Spraker 1993, Allison 2012). Creatine phosphokinase is known to be a good indicator of

exertional myopathy, but due to its short half-life and the fact that 3 days went by between handling events, AST is a better gauge of exertion and muscle injury in our study. The fact that AST levels were still elevated 3 days after handling likely indicates, as did the elevated potassium levels at the 2nd and 4th workups, the workups were physically taxing on the quarantined elk. It is worth noting the values I report for the 2nd and 4th workups are likely lower than the peak values would have been 24-36 hours after the 1st and 3rd workups.

Total protein is a measure of the serum levels of albumin and globulin. As such, total protein levels closely mirror changes in albumin and globulin. Globulins consist primarily of immunoglobulins and transport proteins (Radin 1991). Both total protein and globulin levels were lower for calves than adults at all workups. Globulin levels are usually lower in younger animals (Radin 1991) compared to adults. Rostal et al. (2012) reported findings similar to mine for moose where adults had higher globulin, and as a result total protein, levels than calves. They speculated a still developing immune system was the cause for the lower globulin values.

Management Implications

Translocation of elk is likely to continue as other states try to reintroduce elk to portions of their historic range for ecological and recreational purposes. Increases in potassium and AST between paired workups as well as highly elevated body temperatures indicate elk were stressed. Despite the high levels of stress associated with workups and the lengthy quarantine period, elk survived to be translocated. Elk translocated to Virginia survived well in both years. Elk translocated to Missouri fared well in 2013, but died at an unexpected level in 2012. If the same process of capture,

quarantine, and translocation was done again, you could expect to see similar results. Unfortunately, you can't control what happens once the elk are released. The severe drought in Missouri during the summer of 2012 was an uncontrollable event that may have pushed the most stressed elk to death. Supplemental feed and water for recently released animals should be considered, especially in cases of severe drought. Managers can use the information collected from this study to make inferences on the effects handling activities have on biochemical and physiological parameters of elk. Managers can also use this information to make comparisons with their own data and examine potential differences influenced by differing seasons, capture and handling methods, geographic locations, and a host of other factors.

Table 2.1. Mixed multi-model analysis of morphological and physiological parameters of quarantined elk (*Cervus elaphus nelsoni*) in eastern Kentucky, USA during 2012 and 2013. The top 2 models, or the top model and the null model, are displayed for each parameter.

Parameter[a]	df	Parameters	Log (L)	AIC_c	*w*
Weight (kg)	11	O*A, O*S	-1485.20	2993.3	0.925
Weight (kg)	8	O*A	-1491.11	2998.7	0.061
Body Temperature (°C)	6	O, A	-448.32	908.9	1.000
Body Temperature (°C)	3	null	-493.61	993.3	0.000
Glucose (mg/dL)	9	A, O*S	-1399.42	2817.6	1.000
Glucose (mg/dL)	3	null	-1428.71	2863.5	0.000
BUN (mg/dL)	8	O*S	-744.52	1505.6	1.000
BUN (mg/dL)	3	null	-785.89	1577.9	0.000
Creatinine (mg/dL)*	8	O*A	130.02	-243.5	0.967
Creatinine (mg/dL)*	6	O, A	124.53	-236.7	0.033
Potassium (mmol/L)*	5	O	3.16	3.9	1.000
Potassium (mmol/L)*	3	null	-56.77	119.6	0.000
Calcium (mg/dL)	6	O, A	-232.50	477.3	1.000
Calcium (mg/dL)	3	null	-251.09	508.3	0.000
Magnesium (mg/dL)*	5	O	204.17	-398.1	1.000
Magnesium (mg/dL)*	3	null	166.51	-326.9	0.000
Phosphorus (mg/dL)	5	O	-453.63	917.5	1.000
Phosphorus (mg/dL)	3	null	-477.24	960.6	0.000
Cholesterol (mg/dL)	14	O*A*S	-968.28	1966.2	0.874
Cholesterol (mg/dL)	12	O*A, O*S, A*S	-972.76	1970.8	0.091
ALP (IU/L)*	14	O*A*S	-180.00	389.7	1.000
ALP (IU/L)*	3	null	-282.42	570.9	0.000
GGT (IU/L)*	5	O	-174.78	359.8	1.000
GGT (IU/L)*	3	null	-193.67	393.4	0.000
CPK (IU/L)*	6	O, A	-335.77	683.9	0.933
CPK (IU/L)*	5	O	-339.45	689.1	0.067
Total Protein (g/dL)	8	O*A	-140.57	297.7	1.000
Total Protein (g/dL)	3	null	-209.80	425.7	0.000
Albumin (g/dL)	6	O, S	39.60	-66.9	0.887
Albumin (g/dL)	5	O	36.49	-62.7	0.113
Globulin (gms%)	8	O*A	183.04	-349.5	0.997
Globulin (gms%)	6	O, A	175.19	-338.1	0.003
A:G Ratio (g/dL)	8	O*A	115.00	-213.4	0.953
A:G Ratio (g/dL)	6	O, A	109.87	207.4	0.047

[a] BUN = Blood urea nitrogen, ALP = Alkaline phosphatase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin Ratio

*Data log transformed

df=degrees of freedom, Log(L)=maximized log-likelihood function, *w*=Akaike weight

O = Occasion, A = Age, S = Sex, O*A = Interaction of Occasion and Age, etc. Models including the interaction of 2 parameters also included the parameter individually.

Table 2.2. Residual effects comparison to examine the differences between paired workups for elk (*Cervus elaphus nelsoni*) captured and quarantined as part of a translocation effort in 2012 and 2013 in eastern Kentucky, USA.

			Workup 1 v 2			Workup 3 v 4		
Parameter*	ΔAIC	df	Mean	2.5%	97.5%	Mean	2.5%	97.5%
Weight (kg)	-4.77	4	-1.35	-2.90	0.03	-4.20	-5.64	-2.65
Body Temperature (°C)	0.16	3	-0.36	-0.65	-0.09	-0.05	-0.33	0.20
Glucose (mg/dL)	1.996	3	-12.96	-21.12	-4.05	-13.39	-22.64	-4.62
BUN (mg/dL)	-13.209	4	-1.07	-1.83	-0.34	-3.24	-4.05	-2.55
Creatinine (mg/dL)	1.937	3	-0.01	-0.06	0.04	-0.02	-0.07	0.03
Chloride (mmol/L)	-10.354	4	0.56	-0.30	1.43	-1.72	-2.52	-0.90
Sodium (mmol/L)	1.977	3	-5.02	-6.53	-3.33	-5.14	-6.74	-3.59
Potassium (mmol/L)	-19.724	4	5.28	4.33	6.26	3.97	3.06	5.06
CO_2 (mmol/L)	1.71	3	1.00	0.08	1.82	0.65	-0.32	1.50
Calcium (mg/dL)	1.156	3	-1.13	-2.31	0.17	-0.31	-1.40	0.82
Magnesium (mg/dL)	1.344	3	-0.07	-0.12	-0.02	-0.10	-0.15	-0.04
Phosphorus (mg/dL)	2.000	4	-0.45	-0.72	-0.15	-0.45	-0.75	-0.08
Cholesterol (mg/dL)	1.720	3	-3.16	-4.62	-1.57	-3.77	-5.43	-2.20
ALP (IU/L)	-7.044	4	-19.77	-31.04	-8.46	-44.67	-56.90	-34.14
TBilirubin (mg/dL)	-9.136	4	0.05	0.00	0.10	0.17	0.12	0.22
DBbilirubin (mg/dL)	-2.739	4	0.04	0.02	0.06	0.07	0.05	0.09
IBilirubin (mg/dL)	-8.279	4	0.01	-0.03	0.05	0.10	0.06	0.14
AST (IU/L)	0.091	3	48.21	26.91	70.43	27.58	6.82	48.14
GGT (IU/L)	1.801	3	0.91	-2.01	3.52	1.82	-1.26	4.52
CPK (IU/L)	0.997	3	-1.62	-292.73	323.39	224.88	-60.12	524.08
Osmolality (mOsm/L)	-1.861	3	-8.32	-12.39	-4.11	-13.47	-17.54	-9.37
Total Protein (g/dL)	-2.953	4	-0.09	-0.18	0.03	-0.27	-0.38	-0.14
Albumin (g/dL)	-0.124	3	-0.11	-0.17	-0.05	-0.17	-0.23	-0.10
Globulin (gms%)	-1.198	3	0.39	0.01	0.77	-0.11	-0.51	0.26
A:G Ratio (g/dL)	-0.373	3	-0.03	-0.05	0.00	0.00	-0.02	0.02
Anion Gap	1.668	3	0.94	-2.70	4.21	-0.41	-3.68	3.04

*Elk sex and age classes were pooled for these analyses. There were 40 adults, 25 yearlings, and 42 calves.

[a]BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirubin = Direct bilirubin, IBilirubin = Indirect bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin Ratio

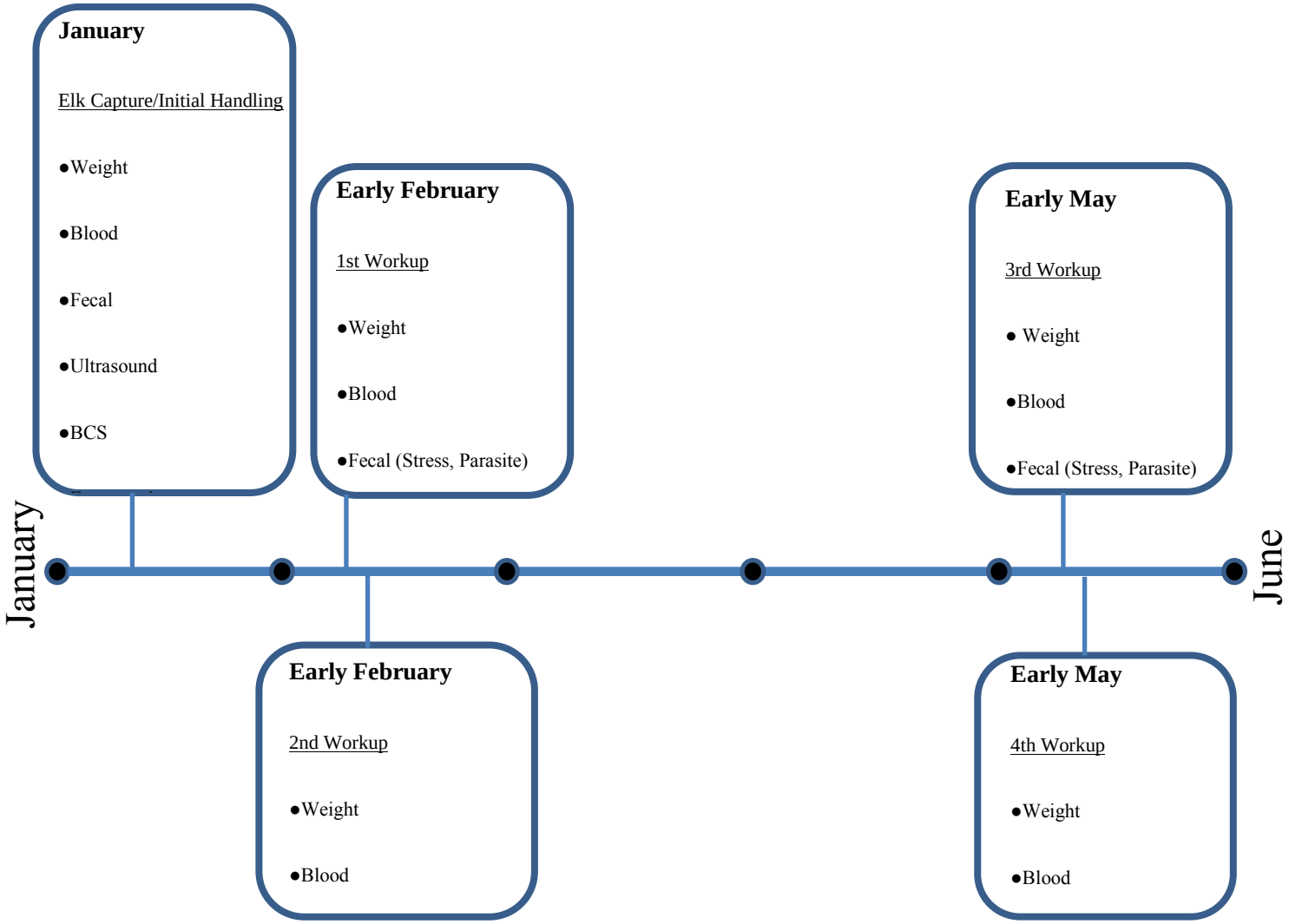

Figure 2.1. Timeline of sample collection in 2012 and 2013 from elk (*Cervus elaphus nelsoni*) captured in Kentucky for translocation to Missouri and Virginia.

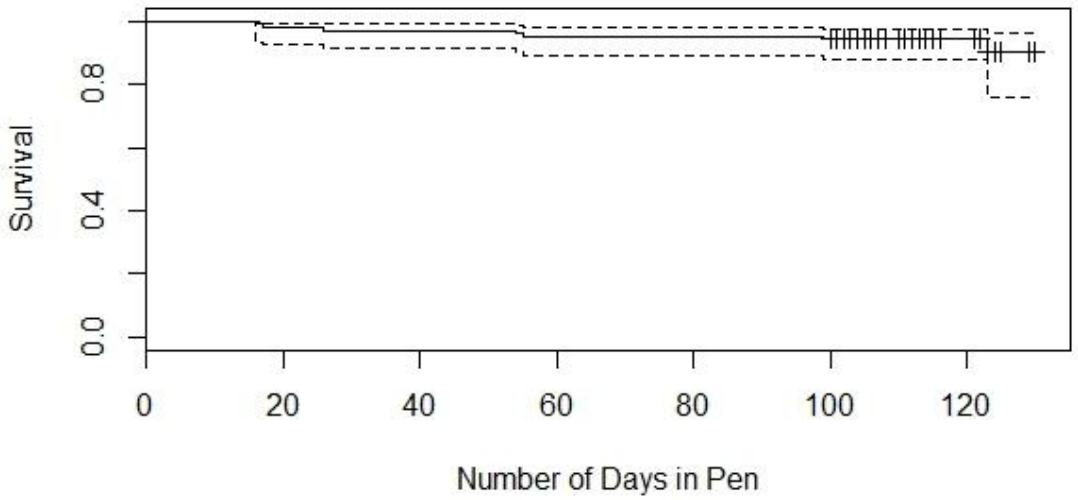

Figure 2.2. Kaplan-Meier plot of elk (*Cervus elaphus nelsoni*) survival through quarantine while in pens in Kentucky, USA in 2012 and 2013.

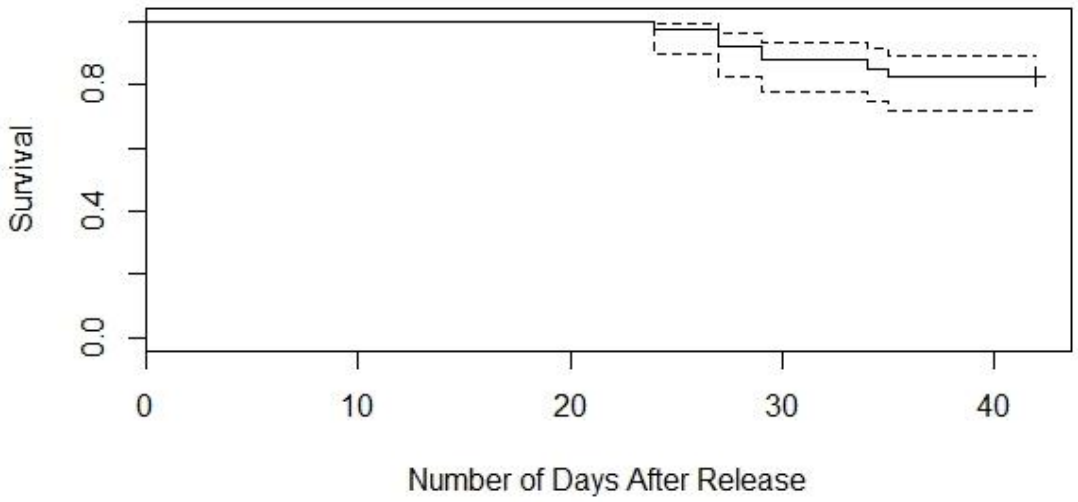

Figure 2.3. Kaplan-Meier plot of post-translocation survival of elk (*Cervus elaphus nelsoni*) released in Missouri, USA in 2012 and 2013.

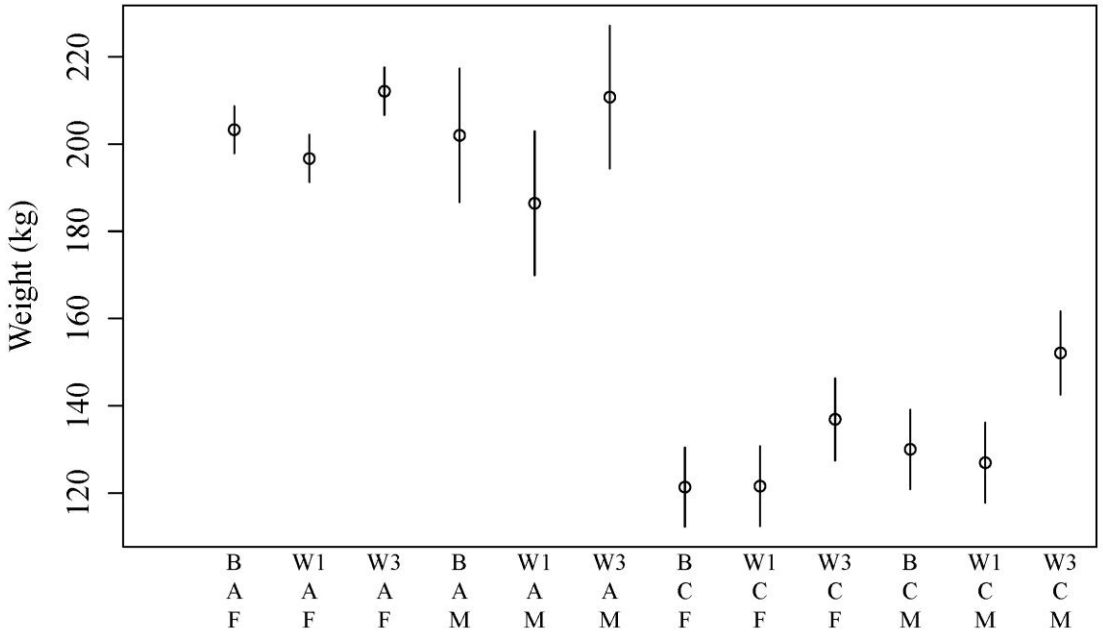

Figure 2.4. Changes in weight (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

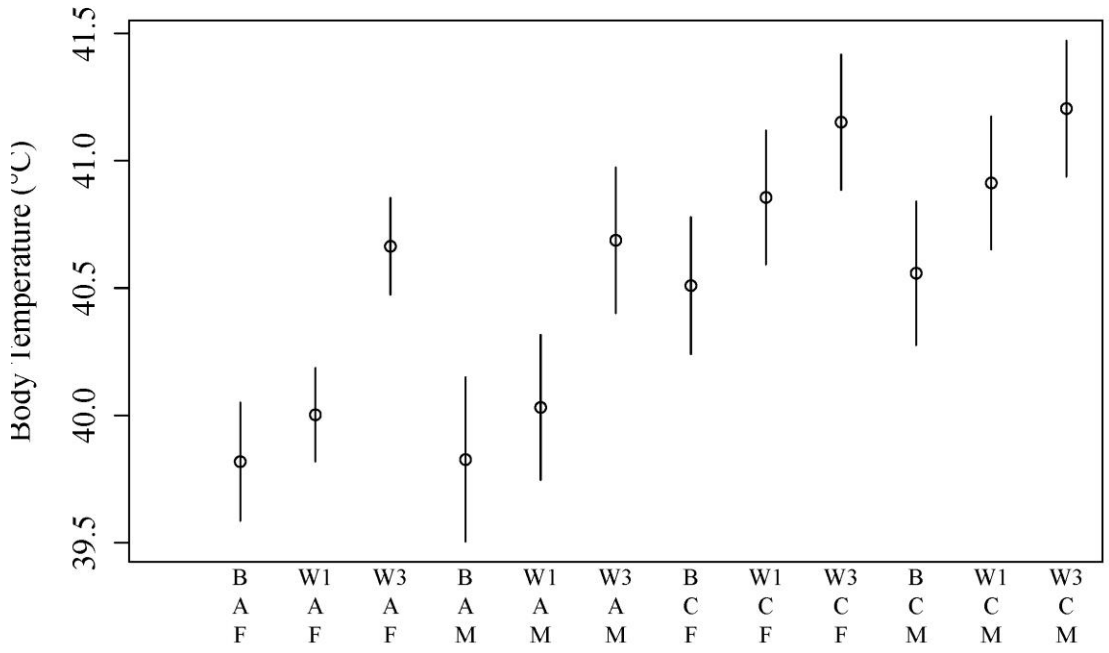

Figure 2.5. Changes in body temperature (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

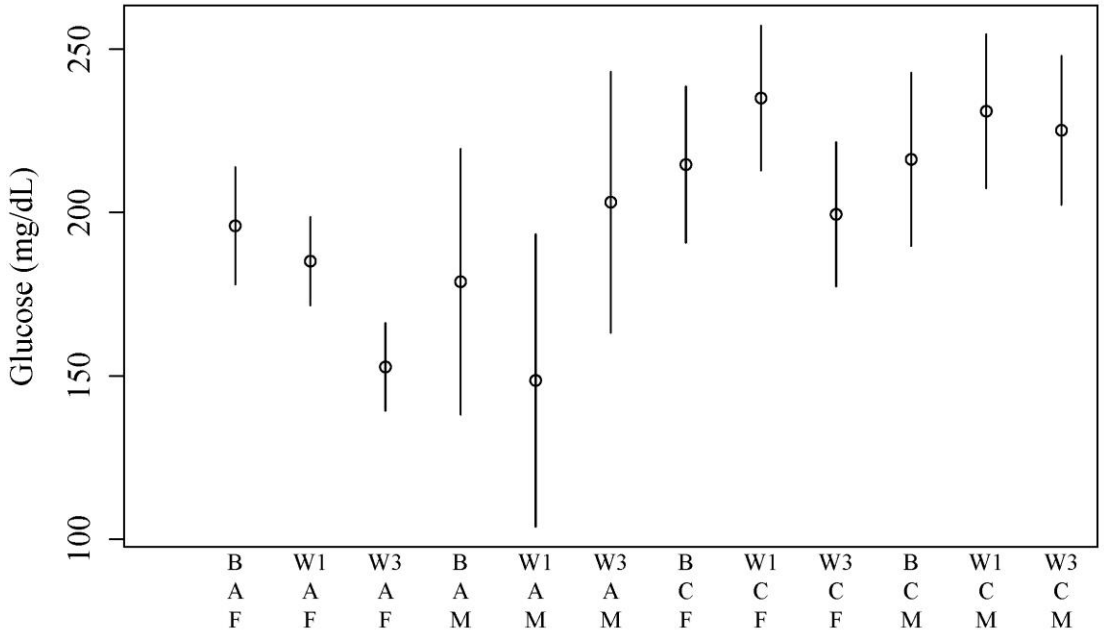

Figure 2.6. Changes in glucose (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

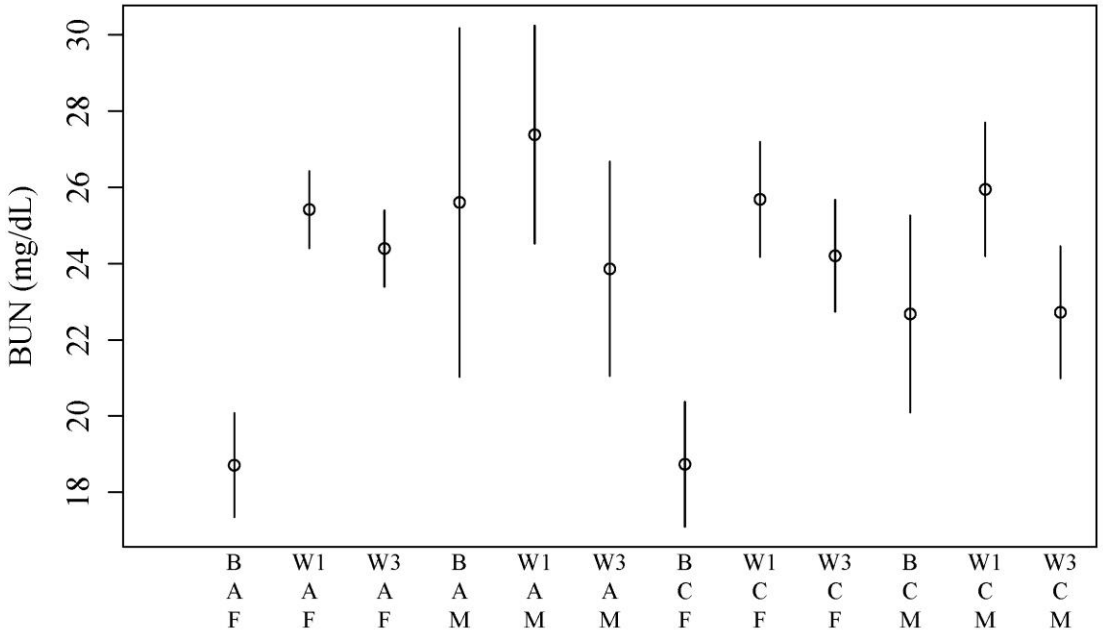

Figure 2.7. Changes in blood urea nitrogen (BUN; mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

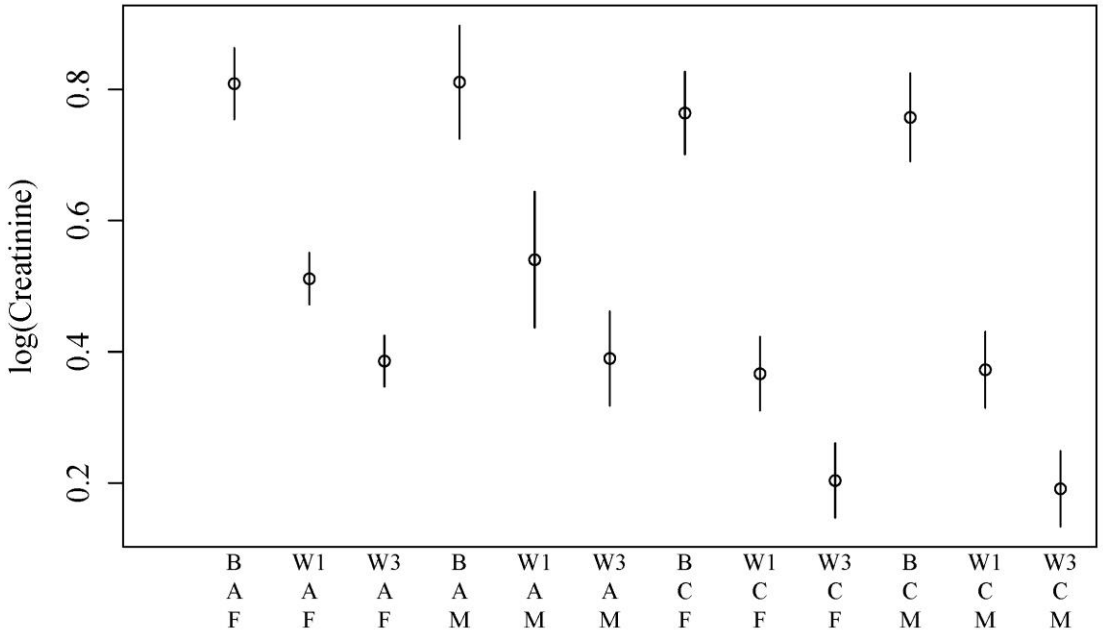

Figure 2.8. Changes in log transformed creatinine (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

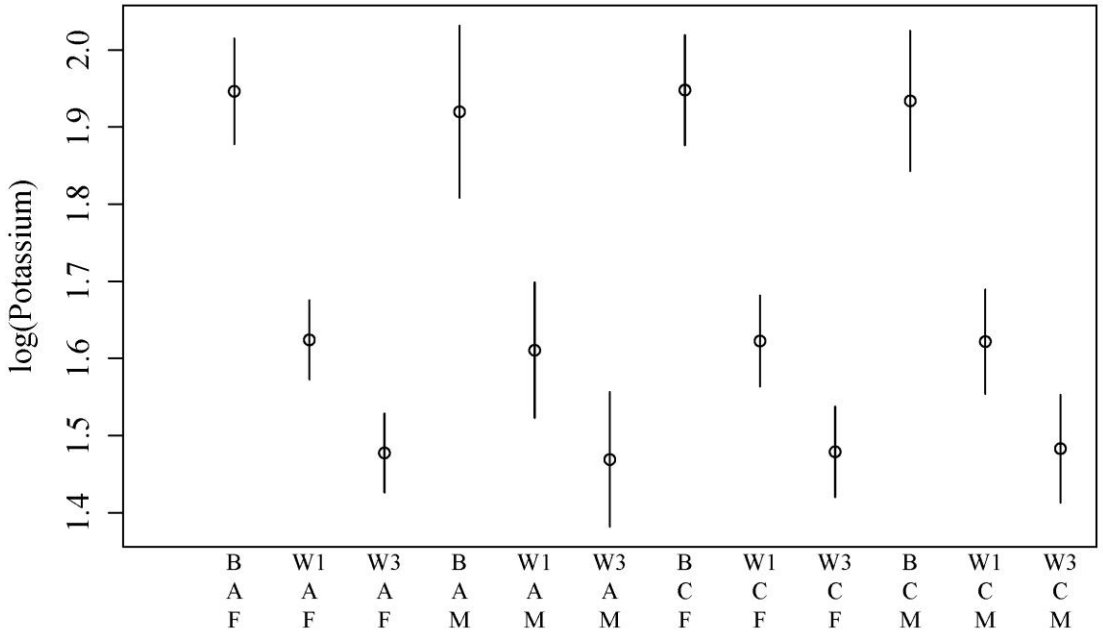

Figure 2.9. Changes in log transformed potassium (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

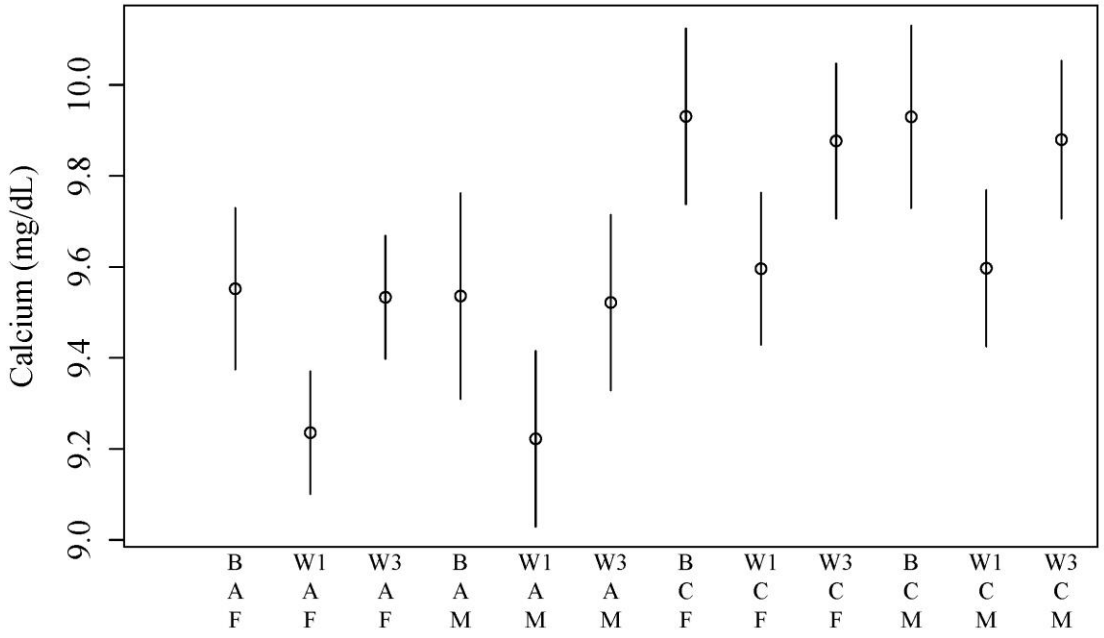

Figure 2.10. Changes in calcium (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

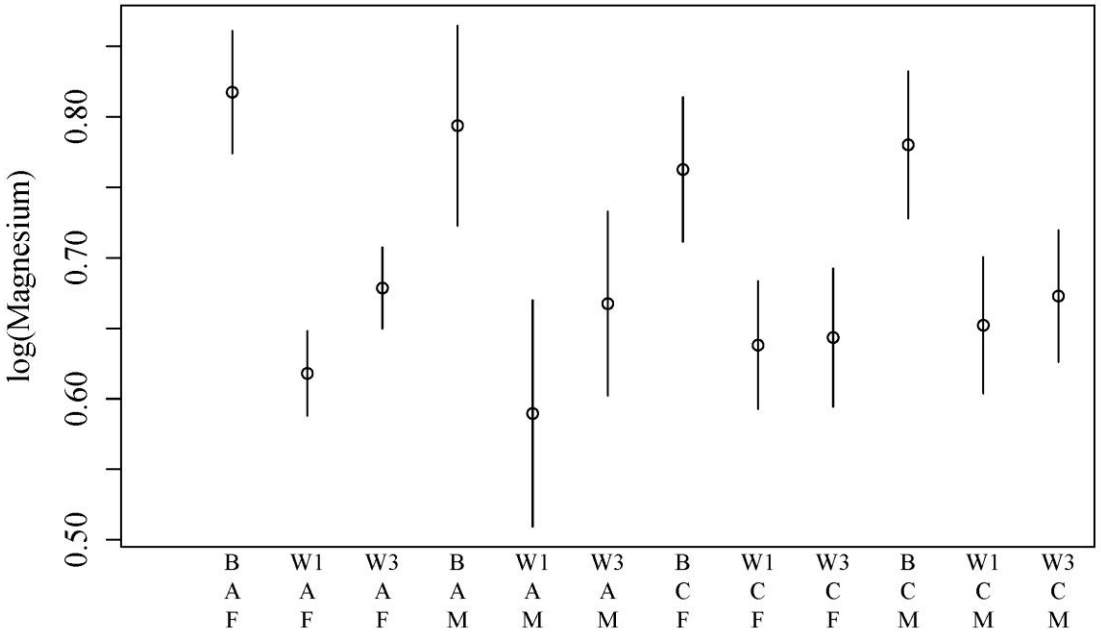

Figure 2.11. Changes in log transformed magnesium (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

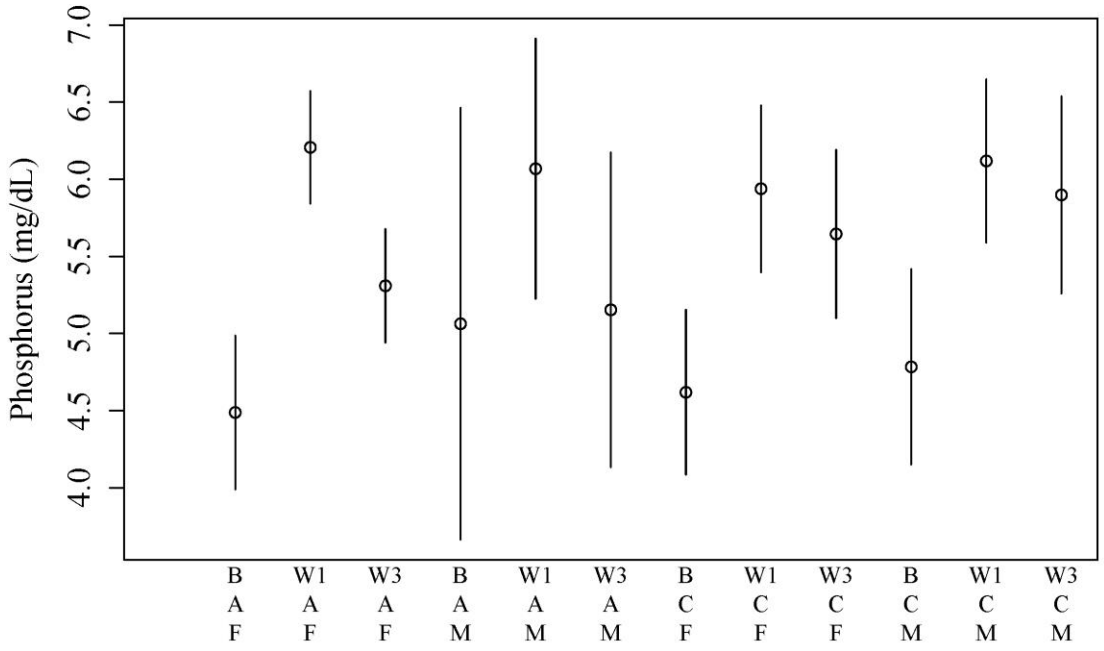

Figure 2.12. Changes in phosphorus (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

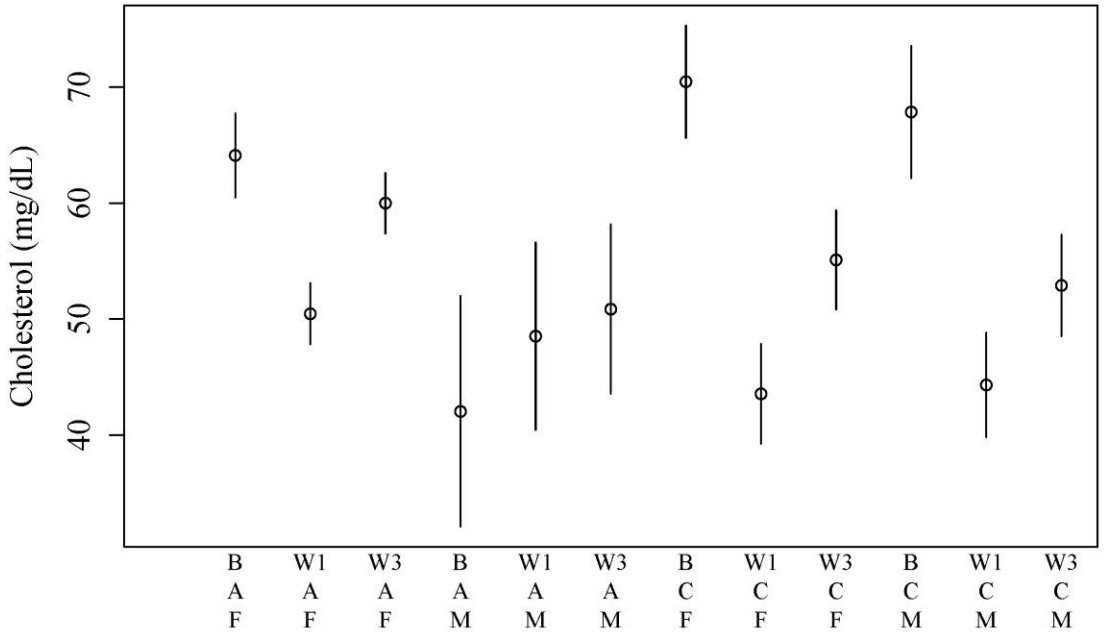

Figure 2.13. Changes in cholesterol (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

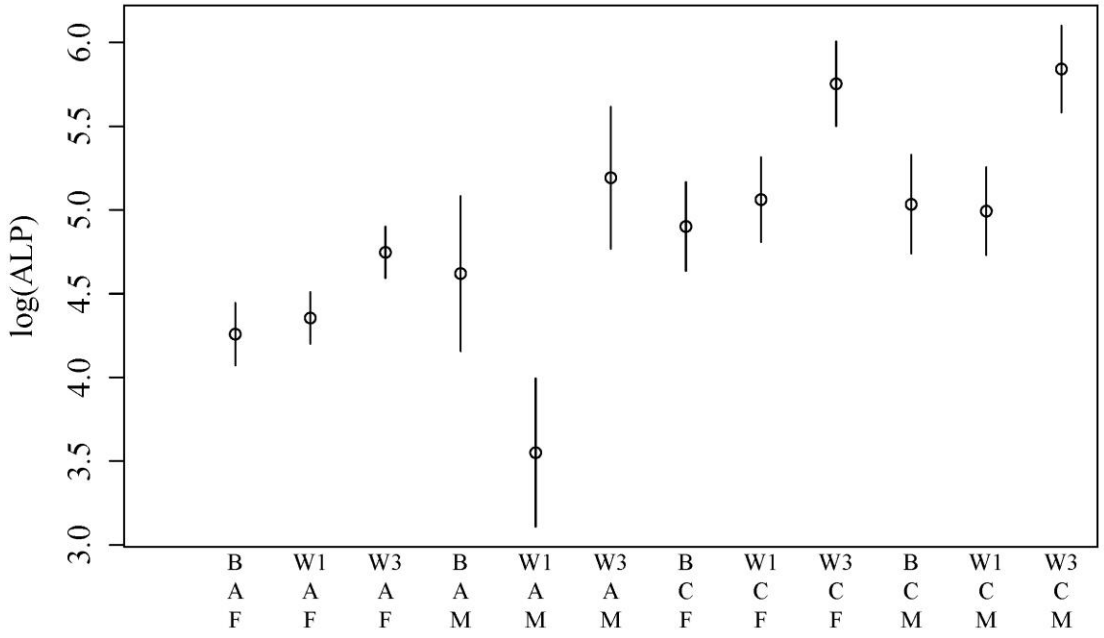

Figure 2.14. Changes in log transformed alkaline phosphatase (ALP; mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

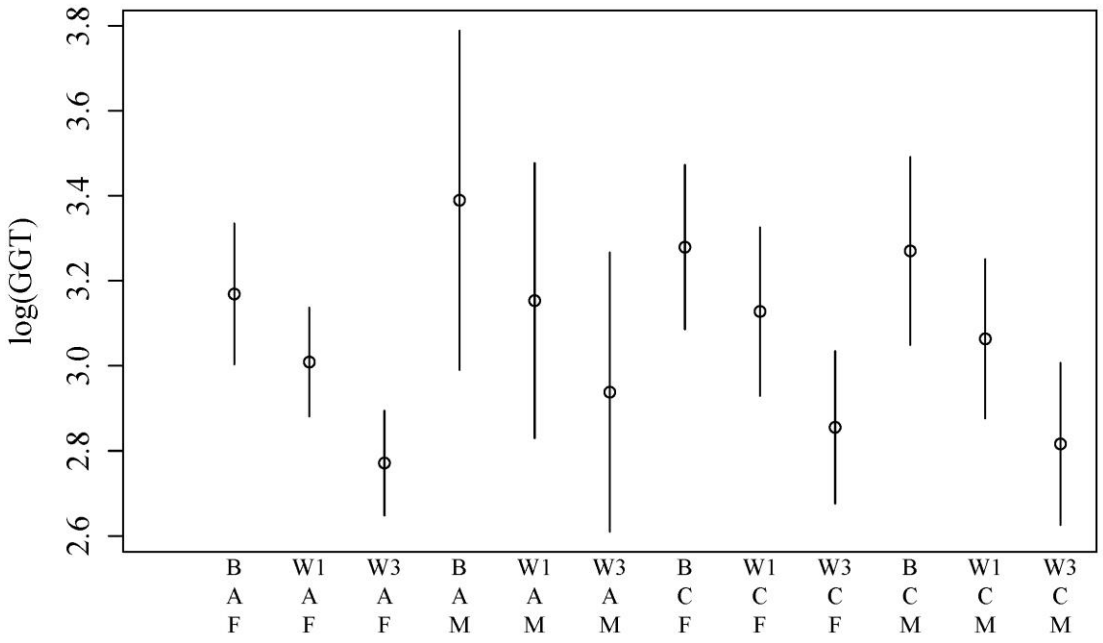

Figure 2.15. Changes in log transformed gamma-glutamyl transferase (GGT; mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

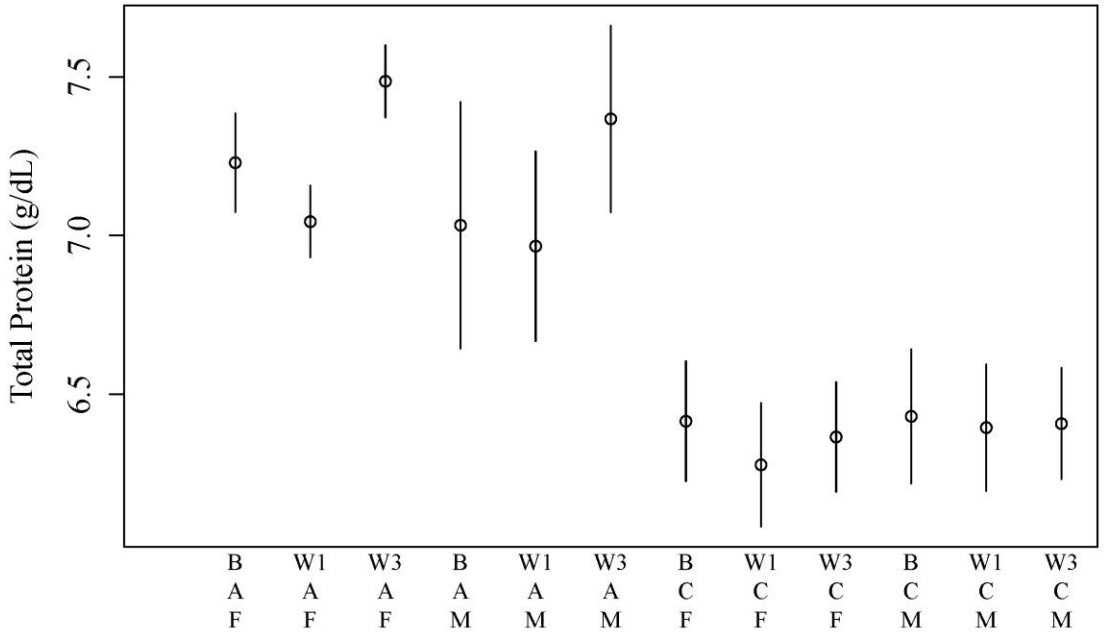

Figure 2.16. Changes in total protein (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

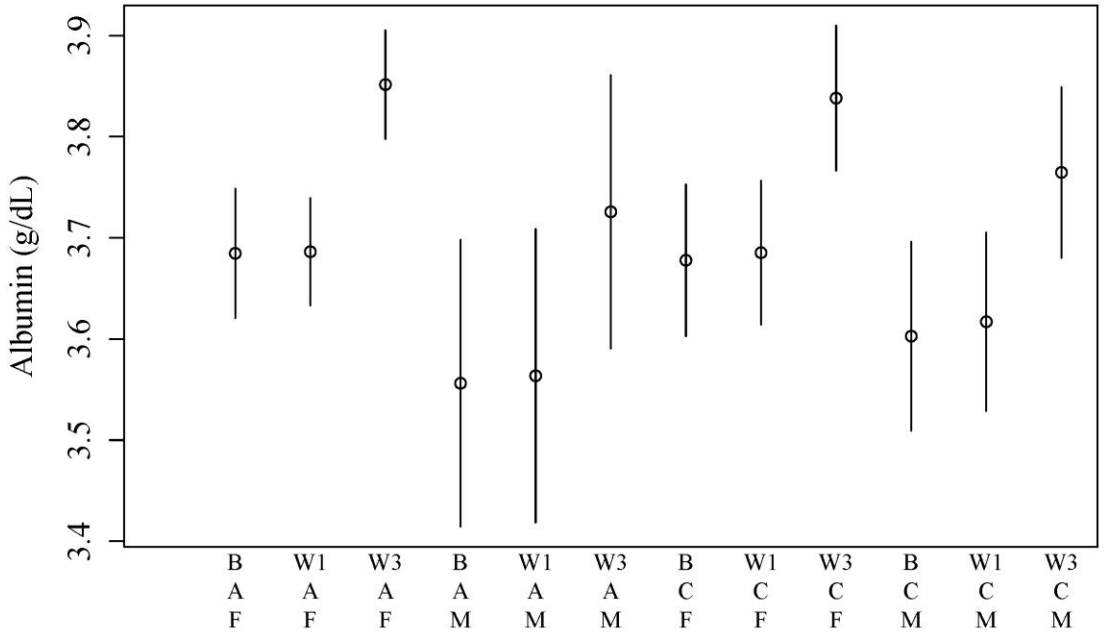

Figure 2.17. Changes in albumin (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

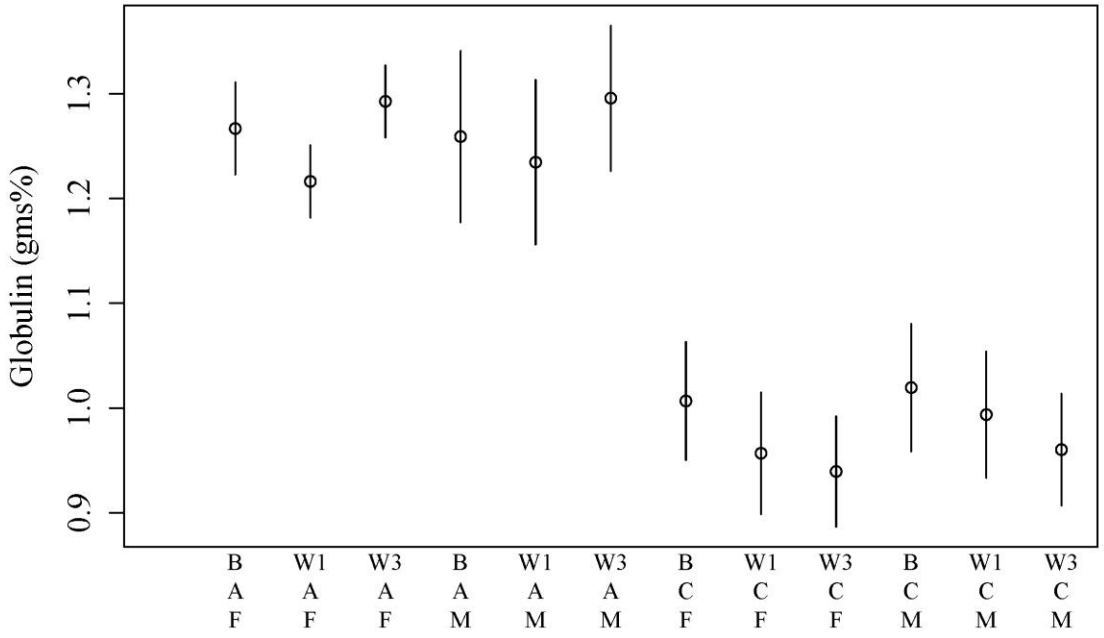

Figure 2.18. Changes in globulin (mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

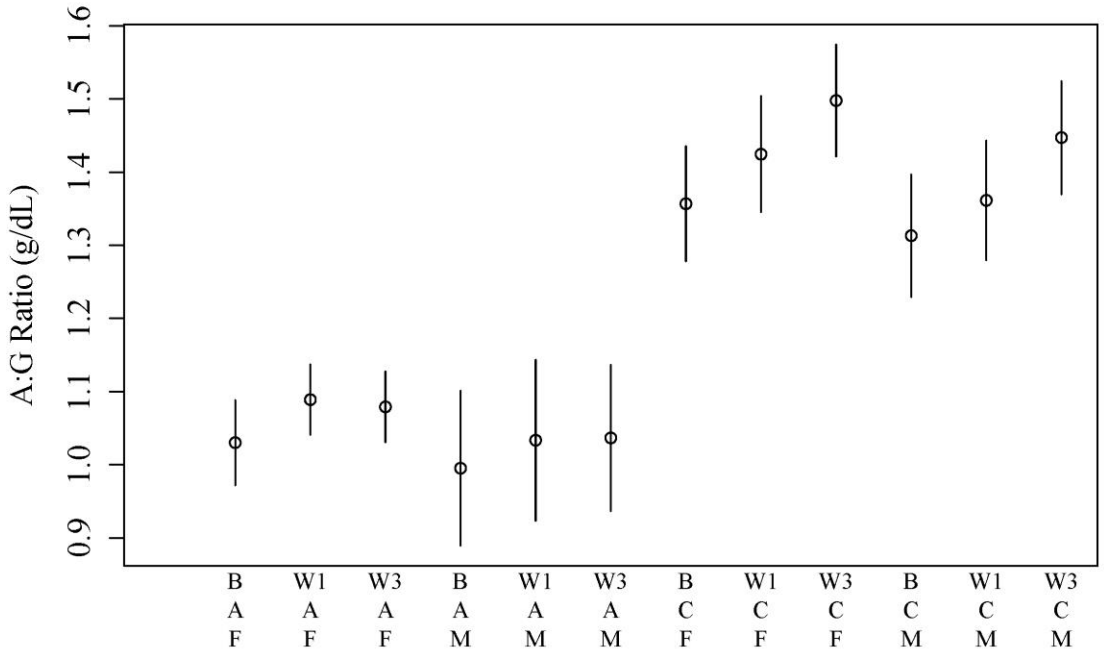

Figure 2.19. Changes in albumin:globulin ratio (A:G ratio; mean±se) by workup (B = baseline/initial workup, W1 = workup 1, W3 = workup 3), sex (F = female, M = male), and age (A = adult, C = calf) for elk (*Cervus elaphus nelsoni*) captured and quarantined in Kentucky, USA in 2012 and 2013.

APPENDICIES

Appendix A. Summary of serum chemistry values for adult female, adult male, calf, and yearling elk (*Cervus elaphus nelsoni*) captured in eastern Kentucky between 2012 and 2014.

	Adult Female					Adult Male				
Parameter[a]	No.	Min	Max	Mean	SD	No.	Min	Max	Mean	SD
Glucose (mg/dL)	75	65	315	169	43	117	20	260	148	53
BUN (mg/dL)	75	7	40	23	6	118	12	67	27	8
Creatinine (mg/dL)	75	1.35	2.77	2.17	0.32	118	0.76	4.35	1.87	0.66
Chloride (mmol/L)	75	96	115	102	4	118	10	142	97	13
Sodium (mmol/L)	75	110	158	141	6	118	77	193	133	15
Potassium (mmol/L)	75	3.8	34.5	6.5	4.9	118	3.0	40.9	10.4	8.3
CO_2 (mmol/L)	75	6.4	30.4	21.7	4.8	118	9.9	35.8	22.6	4.5
Calcium (mg/dL)	75	0.1	10.6	9.2	1.1	118	4.4	15.1	9.3	1.2
Magnesium (mg/dL)	75	0.3	2.9	2.3	0.3	118	1.1	3.5	2.3	0.3
Phosphorus (mg/dL)	75	2.4	8.5	5.4	1.4	118	2.2	9.4	5.9	1.4
Cholesterol (mg/dL)	75	34	94	59	12	118	17	83	50	14
ALP (IU/L)	75	12	529	132	103	118	29	936	176	140
TBilirubin (mg/dL)	75	0.1	0.8	0.3	0.1	118	0.1	0.5	0.2	0.1
DBbilirubin (mg/dL)	75	0.0	0.2	0.1	0.1	118	0.0	0.2	0.1	0.1
IBilirubin (mg/dL)	75	42	527	76	55	118	32	248	71	28
AST (IU/L)	75	-2	99	25	14	118	9	403	47	46
GGT (IU/L)	74	102	2930	277	344	118	54	3963	295	442
CPK (IU/L)	75	193.4	317.6	287.9	16.4	118	135.5	396.6	272.8	34.6
Osmolality (mOsm/L)	75	5.9	8.1	6.9	0.5	118	3.2	11.9	6.9	1.0
Total Protein (g/dL)	75	2.7	4.0	3.4	0.3	118	1.7	4.4	3.3	0.4
Albumin (g/dL)	75	2.7	4.7	3.5	0.4	118	1.5	7.5	3.7	0.8
Globulin (gms%)	75	0.70	1.31	0.99	0.13	118	0.39	1.33	0.92	0.16
A:G Ratio (g/dL)	75	0.1	0.7	0.2	0.1	118	0.0	0.5	0.1	0.1
Anion Gap	75	12.5	49.1	24.0	7.0	118	14.2	48.2	22.9	4.7

	Calf					Yearling				
Parameter[a]	No.	Min	Max	Mean	SD	No.	Min	Max	Mean	SD
Glucose (mg/dL)	60	67	295	189	46	37	69	341	183	54
BUN (mg/dL)	60	9	38	22	7	37	12	38	24	7
Creatinine (mg/dL)	60	1.25	2.84	2.05	0.30	37	1.59	3.47	2.20	0.33
Chloride (mmol/L)	60	94	114	101	4	37	95	109	102	4
Sodium (mmol/L)	60	129	158	143	6	37	133	152	142	5
Potassium (mmol/L)	60	3.8	18.4	6.8	3.1	37	3.8	14.0	6.3	2.6
CO_2 (mmol/L)	60	8.2	29.0	19.9	4.5	37	11.1	30.9	22.0	4.9
Calcium (mg/dL)	60	7.5	11.3	9.7	0.6	37	8.7	10.6	9.5	0.4
Magnesium (mg/dL)	60	1.7	2.8	2.2	0.2	37	1.9	2.8	2.2	0.2
Phosphorus (mg/dL)	60	2.6	7.9	5.2	1.2	37	1.7	7.4	5.3	1.4
Cholesterol (mg/dL)	60	29	94	60	15	37	33	74	54	12
ALP (IU/L)	60	24	288	142	63	37	34	642	136	108
TBilirubin (mg/dL)	60	0.1	0.8	0.3	0.2	37	0.1	1.0	0.3	0.2
DBbilirubin (mg/dL)	60	0.0	0.3	0.1	0.1	37	0.0	0.3	0.1	0.1
IBilirubin (mg/dL)	60	41	178	82	24	37	52	365	87	53
AST (IU/L)	60	16	190	33	30	37	14	166	36	33
GGT (IU/L)	60	129	7061	741	1101	37	96	16110	996	2717
CPK (IU/L)	60	262.3	320.2	292.9	12.2	37	275.2	315.0	292.4	9.5
Osmolality (mOsm/L)	60	4.4	7.7	6.3	0.6	37	6.1	7.7	6.9	0.4
Total Protein (g/dL)	60	2.4	4.0	3.5	0.3	37	3.2	4.0	3.6	0.2
Albumin (g/dL)	60	2.0	4.1	2.8	0.4	37	2.5	3.8	3.3	0.3
Globulin (gms%)	60	0.88	1.77	1.28	0.19	37	0.89	1.44	1.08	0.13
A:G Ratio (g/dL)	60	0.1	0.5	0.2	0.1	37	0.1	0.7	0.2	0.1
Anion Gap	60	15.0	50.9	29.0	6.8	37	13.8	40.6	24.9	6.6

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirubin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

Appendix B. Serum chemistry reference ranges for adult female elk (*Cervus elaphus nelsoni*) in eastern Kentucky by capture type sampled between 2012 and 2014.

	Corral							Dart						
Parameter[a]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]
Glucose (mg/dL)	66	108	288	168	44	162	CD	66	108	288	168	44	162	CD
BUN (mg/dL)	16	10	25	19	5	21	C	50	11	36	25	6	25	D
Creatinine (mg/dL)	16	2.17	2.74	2.40	0.33	2.47	C	50	1.57	2.58	2.07	0.26	2.06	D
Chloride (mmol/L)	16	98	109	105	4	105	C	50	96	111	100	3	100	D
Sodium (mmol/L)	16	136	153	146	6	146	C	50	132	149	139	5	139	D
Potassium (mmol/L)	16	4.3	11.0	7.6	3.0	6.7	C	50	4.2	9.1	6.5	5.7	5.3	D
CO_2 (mmol/L)	16	11.5	24.2	16.1	4.2	16.2	C	50	18.5	29.7	23.2	3.1	22.5	D
Calcium (mg/dL)	16	9.1	10.6	9.6	0.5	9.6	C	50	8.5	9.9	9.0	1.3	9.2	D
Magnesium (mg/dL)	66	1.9	2.8	2.3	0.3	2.3	CD	66	1.9	2.8	2.3	0.3	2.3	CD
Phosphorus (mg/dL)	16	2.4	6.5	4.2	1.5	3.9	C	50	3.4	8.3	5.8	1.1	5.8	D
Cholesterol (mg/dL)	16	57	80	68	9	65	C	50	40	85	57	11	58	D
ALP (IU/L)	16	34	173	78	54	56	C	50	32	317	140	98	107	D
TBilirubin (mg/dL)	16	0.2	0.7	0.4	0.2	0.4	C	50	0.1	0.4	0.2	0.1	0.2	D
DBbilirubin (mg/dL)	16	0.0	0.2	0.1	0.1	0.1	C	50	0.0	0.1	0.1	0.0	0.1	D
IBilirubin (mg/dL)	16	0.1	0.5	0.3	0.1	0.3	C	50	0.1	0.3	0.2	0.1	0.2	D
AST (IU/L)	66	47	121	77	59	67	CD	66	47	121	77	59	67	CD
GGT (IU/L)	66	11	54	26	14	23	CD	66	11	54	26	14	23	CD
CPK (IU/L)	16	120	736	491	665	302	C	49	107	352	192	67	172	D
Osmolality (mOsm/L)	16	278.8	313.4	296.5	10.9	294.7	C	50	270.2	309.2	282.7	16.5	285.0	D
Total Protein (g/dL)	16	6.1	7.9	7.2	0.6	7.4	C	50	6.0	7.7	6.9	0.4	6.8	D
Albumin (g/dL)	16	3.3	4.0	3.6	0.3	3.7	C	50	2.9	3.8	3.4	0.2	3.4	D
Globulin (gms%)	66	2.8	4.2	3.5	0.4	3.5	CD	66	2.8	4.2	3.5	0.4	3.5	CD
A:G Ratio (g/dL)	66	0.76	1.3	0.99	0.13	0.97	CD	66	0.76	1.3	0.99	0.13	0.97	CD
Anion Gap	16	25.4	42.9	31.9	5.6	31.4	C	50	13.3	30.0	21.3	5.3	21.2	D

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

[b] C = Corral, D = Dart

Parameters grouped together are not statistically different ($P > 0.05$)

Appendix C . Serum chemistry reference ranges for calf elk (*Cervus elaphus nelsoni*) in eastern Kentucky by capture type sampled between 2012 and 2014.

	Corral							Dart						
Parameter[a]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]
Glucose (mg/dL)	34	135	278	207	44	210	C	15	132	230	179	33	185	D
BUN (mg/dL)	49	10	32	22	6	22	CD	49	10	32	22	6	22	CD
Creatinine (mg/dL)	34	1.83	2.55	2.16	0.24	2.15	C	15	1.43	2.33	1.94	0.32	1.86	D
Chloride (mmol/L)	34	95	106	101	3	101	C	15	94	99	98	2	98	D
Sodium (mmol/L)	34	134	152	144	5	145	C	15	134	144	138	4	137	D
Potassium (mmol/L)	49	4.0	17.1	7.1	3.4	5.5	CD	49	4.0	17.1	7.1	3.4	5.5	CD
CO_2 (mmol/L)	34	11.0	24.7	18.1	4.1	19.1	C	15	21.6	29.0	23.8	4.3	23.9	D
Calcium (mg/dL)	34	9.3	11.3	10.0	0.5	10.0	C	15	9.0	10.1	9.4	0.4	9.3	D
Magnesium (mg/dL)	49	1.9	2.6	2.2	0.2	2.2	CD	49	1.9	2.6	2.2	0.2	2.2	CD
Phosphorus (mg/dL)	34	2.8	6.6	4.8	1.1	4.8	C	15	4.5	7.6	6.3	1.1	6.5	D
Cholesterol (mg/dL)	34	41	89	68	12	68	C	15	38	55	50	9	51	D
ALP (IU/L)	49	44	256	150	59	145	CD	49	44	256	150	59	145	CD
TBilirubin (mg/dL)	34	0.2	0.6	0.4	0.1	0.4	C	15	0.1	0.3	0.2	0.1	0.2	D
DBbilirubin (mg/dL)	34	0.0	0.2	0.1	0.0	0.1	C	15	0.0	0.1	0.0	0.1	0.0	D
IBilirubin (mg/dL)	34	0.1	0.5	0.3	0.1	0.3	C	15	0.1	0.2	0.2	0.0	0.2	D
AST (IU/L)	34	63	152	89	27	82	C	15	55	86	69	12	71	D
GGT (IU/L)	49	17	141	35	32	23	CD	49	17	141	35	32	23	CD
CPK (IU/L)	34	210	3960	1038	1375	559	C	15	140	431	294	292	211	D
Osmolality (mOsm/L)	34	279.3	315.2	295.6	11.7	296.8	C	15	275.8	293.7	284.8	7.3	281.8	D
Total Protein (g/dL)	34	5.8	7.1	6.5	0.4	6.5	C	15	5.2	7.1	6.2	0.7	6.3	D
Albumin (g/dL)	34	3.1	3.9	3.7	0.2	3.7	C	15	3.1	3.9	3.4	0.3	3.4	D
Globulin (gms%)	49	2.2	3.6	2.8	0.4	2.8	CD	49	2.2	3.6	2.8	0.4	2.8	CD
A:G Ratio (g/dL)	49	0.97	1.65	1.30	0.20	1.32	CD	49	0.97	1.65	1.30	0.20	1.32	CD
Anion Gap	34	26.8	42.1	32.9	5.1	32.5	C	15	15	24.5	21.9	5.3	21.2	D

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

[b] C = Corral, D = Dart

Parameters grouped together are not statistically different ($P > 0.05$)

Appendix D. Serum chemistry reference ranges for yearling elk (*Cervus elaphus nelsoni*) in eastern Kentucky by capture type sampled between 2012 and 2014.

	Corral							Dart						
Parameter[a]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]
Glucose (mg/dL)	31	123	316	191	54	172	CD	31	123	316	191	54	172	CD
BUN (mg/dL)	12	12	23	18	3	18	C	19	20	36	28	5	27	D
Creatinine (mg/dL)	31	1.70	2.52	2.17	0.26	2.23	CD	31	1.70	2.52	2.17	0.26	2.23	CD
Chloride (mmol/L)	12	101	109	104	3	104	C	19	96	103	99	2	100	D
Sodium (mmol/L)	12	137	152	146	4	147	C	19	133	142	139	3	139	D
Potassium (mmol/L)	31	4.1	13.4	6.3	2.7	5.4	CD	31	4.1	13.4	6.3	2.7	5.4	CD
CO_2 (mmol/L)	12	11.1	22.6	17.4	3.4	17.3	C	19	18.2	30.9	23.7	3.9	24.1	D
Calcium (mg/dL)	31	8.9	10.3	9.5	0.4	9.4	CD	31	8.9	10.3	9.5	0.4	9.4	CD
Magnesium (mg/dL)	31	2.0	2.5	2.3	0.2	2.3	CD	31	2.0	2.5	2.3	0.2	2.3	CD
Phosphorus (mg/dL)	31	1.9	7.1	5.2	1.4	5.6	CD	31	1.9	7.1	5.2	1.4	5.6	CD
Cholesterol (mg/dL)	12	55	74	67	6	69	C	19	33	62	47	9	46	D
ALP (IU/L)	31	50	303	145	115	115	CD	31	50	303	145	115	115	CD
TBilirubin (mg/dL)	12	0.2	1.0	0.4	0.2	0.3	C	19	0.1	0.3	0.2	0.1	0.2	D
DBilirubin (mg/dL)	12	0.0	0.3	0.1	0.1	0.1	C	19	0.0	0.1	0.0	0.1	0.0	D
IBilirubin (mg/dL)	31	0.1	0.4	0.2	0.1	0.2	CD	31	0.1	0.4	0.2	0.1	0.2	CD
AST (IU/L)	12	62	169	101	31	92	C	19	53	89	70	13	69	D
GGT (IU/L)	31	15	135	37	36	21	CD	31	15	135	37	36	21	CD
CPK (IU/L)	12	342	5726	1162	1487	668	C	19	96	549	274	159	223	D
Osmolality (mOsm/L)	12	277.8	315.0	298.2	10.1	298.1	C	19	275.2	294.5	287.3	7.0	287.7	D
Total Protein (g/dL)	31	6.4	7.5	6.9	0.3	7.0	CD	31	6.4	7.5	6.9	0.3	7.0	CD
Albumin (g/dL)	12	3.3	4	3.7	0.2	3.8	C	19	3.3	3.8	3.5	0.2	3.4	D
Globulin (gms%)	31	3.0	3.7	3.4	0.3	3.3	CD	31	3.0	3.7	3.4	0.3	3.3	CD
A:G Ratio (g/dL)	31	0.89	1.26	1.08	0.12	1.06	CD	31	0.89	1.26	1.08	0.12	1.06	CD
Anion Gap	12	26.3	40.6	31.9	4.4	31.1	C	19	13.8	26.0	21.3	4.8	20.8	D

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

[b] C = Corral, D = Dart

Parameters grouped together are not statistically different (P > 0.05)

Appendix E. Serum chemistry reference ranges for adult female, yearling, and calf elk (*Cervus elaphus nelsoni*) in eastern Kentucky comparing corral, dart, and both corral and dart capture types sampled between 2012 and 2014.

	Corral							Dart							Both						
Parameter[a]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]	No.	Low	High	Mean	SD	Median	Group[b]
Glucose (mg/dL)	62	134	316	200	52	192	C	110	69	255	168	40	165	DB	110	69	255	168	40	165	DB
BUN (mg/dL)	62	10	29	20	5	20	C	110	15	37	25	6	26	DB	110	15	37	25	6	26	DB
Creatinine (mg/dL)	62	1.70	2.68	2.23	0.28	2.24	C	84	1.55	2.58	2.06	0.28	2.05	D	26	1.54	2.77	2.15	0.45	2.09	B
Chloride (mmol/L)	88	95	114	103	4	103	CB	84	95	105	100	3	100	D	88	95	114	103	4	103	CB
Sodium (mmol/L)	88	134	155	145	5	146	CB	84	133	149	139	5	139	D	88	134	155	145	5	146	CB
Potassium (mmol/L)	62	3.8	16.2	7.8	3.5	7.1	C	110	4.3	9.1	5.9	3.9	5.2	DB	110	4.3	9.1	5.9	3.9	5.2	DB
CO_2 (mmol/L)	62	11.0	24.7	17.5	4.0	17.6	C	110	15.8	29.7	23.2	3.9	23.0	DB	110	15.8	29.7	23.2	3.9	23.0	DB
Calcium (mg/dL)	62	8.9	10.7	9.8	0.5	9.9	C	110	8.5	10.0	9.2	1.0	9.3	DB	110	8.5	10.0	9.2	1.0	9.3	DB
Magnesium (mg/dL)	172	1.9	2.8	2.2	0.3	2.2	CDB	172	1.9	2.8	2.2	0.3	2.2	CDB	172	1.9	2.8	2.2	0.3	2.2	CDB
Phosphorus (mg/dL)	62	2.4	7.1	4.6	1.4	4.6	C	84	3.7	7.9	5.9	1.1	5.8	D	26	3.5	7.2	5.4	1.0	5.5	B
Cholesterol (mg/dL)	62	53	89	68	11	68	C	110	34	75	52	11	52	DB	110	34	75	52	11	52	DB
ALP (IU/L)	172	34	306	136	92	116	CDB	172	34	306	136	92	116	CDB	172	34	306	136	92	116	CDB
TBilirubin (mg/dL)	62	0.2	0.7	0.4	0.2	0.4	C	110	0.1	0.6	0.2	0.1	0.2	DB	110	0.1	0.6	0.2	0.1	0.2	DB
DBbilirubin (mg/dL)	62	0.0	0.2	0.1	0.1	0.1	C	110	0.0	0.2	0.1	0.1	0.1	DB	110	0.0	0.2	0.1	0.1	0.1	DB
IBilirubin (mg/dL)	62	0.1	0.5	0.3	0.1	0.3	C	110	0.1	0.5	0.2	0.1	0.2	DB	110	0.1	0.5	0.2	0.1	0.2	DB
AST (IU/L)	88	53	169	88	39	79	CB	84	52	94	74	52	68	D	88	53	169	88	39	79	CB
GGT (IU/L)	172	14	102	30	25	22	CDB	172	14	102	30	25	22	CDB	172	14	102	30	25	22	CDB
CPK (IU/L)	62	195	3960	921	1264	459	C	83	107	549	229	157	205	D	26	129	991	383*	258	289	B
Osmolality (mOsm/L)	88	277.8	317.0	296.9	11.0	296.9	CB	84	270.2	303.3	284.1	13.6	285.0	D	88	277.8	317.0	296.9	11.0	296.9	CB
Total Protein (g/dL)	146	5.6	7.7	6.8	0.5	6.8	CD	146	5.6	7.7	6.8	0.5	6.8	CD	26	5.3	7.6	6.4	0.7	6.5	B
Albumin (g/dL)	62	3.1	4.0	3.7	0.2	3.7	C	110	2.9	3.8	3.4	0.3	3.4	DB	110	2.9	3.8	3.4	0.3	3.4	DB
Globulin (gms%)	88	2.2	4.0	3.1	0.5	3.1	CB	84	2.3	4.1	3.3	0.4	3.4	D	88	2.2	4.0	3.1	0.5	3.1	CB
A:G Ratio (g/dL)	62	0.89	1.65	1.21	0.22	1.18	C	84	0.76	1.43	1.04	0.16	1.00	D	26	0.89	1.33	1.10	0.16	1.09	B
Anion Gap	62	25.4	42.9	32.5	5.0	32.2	C	84	13.8	34.1	21.4	5.2	21.0	D	26	19.4	30.6	25.1	5.0	24.0	B

[a] BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirbuin = Direct Bilirubin, IBilirubin = Indirect Bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin ratio

[b] C = Corral, D = Dart, B = Both

Parameters grouped together are not statistically different ($P > 0.05$)

*Removed extreme outlier of 16,110 prior to calculation

Appendix F. Effects of darting pressure on select physiological parameters of adult male elk (*Cervus elaphus*) chemically immobilized in eastern Kentucky, USA 2012-2014.

	Unpressured			Pressured				
Parameter[a]	*n*	Mean	SD	*n*	Mean	SD	Z	*P*
Rectal temperature (°C)	74	38.5	0.7	19	39.0	0.5	3.08	0.0020
Glucose (mg/dL)	83	147	52	21	155	49	0.57	0.5653
Creatinine (mg/dL)	84	1.88	0.70	21	1.68	0.44	-0.92	0.3590
Potassium (mmol/L)	84	10.6	8.6	21	8.0	4.9	-0.69	0.4931
AST (IU/L)	84	73	31	21	64	14	-1.37	0.1706
CPK (IU/L)	83	273	441	21	233	121	0.97	0.3344

[a] AST = Aspartate aminotransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Appendix G. Effects of darting pressure on select physiological parameters of adult female elk (*Cervus elaphus*) chemically immobilized in eastern Kentucky, USA 2012-2014.

	Unpressured			Pressured				
Parameter[a]	*n*	Mean	SD	*n*	Mean	SD	Z	*P*
Rectal temperature (°C)	24	38.3	0.6	16	38.8	0.4	3.08	0.0020
Glucose (mg/dL)	25	170	45	16	161	36	-0.51	0.3058
Creatinine (mg/dL)	25	2.07	0.21	16	2.04	0.29	-0.70	0.2435
Potassium (mmol/L)	25	6.8	5.7	16	6.7	6.8	-2.60	0.0047
AST (IU/L)	25	85	91	16	72	22	0.03	0.9786
CPK (IU/L)	25	209	76	16	180	51	-0.90	0.3694

[a] AST = Aspartate aminotransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Appendix H. Effects of body condition on select physiological parameters of adult male elk (*Cervus elaphus*) captured in eastern Kentucky, USA 2012-2014.

	Bad			Good				
Parameter[a]	*n*	Mean	SD	*n*	Mean	SD	Z	*P*
Glucose (mg/dL)	9	156	30	104	148	53	0.37	0.7144
BUN (mg/dL)	9	26	9	105	27	9	-0.07	0.9413
Creatinine (mg/dL)	9	2.01	0.45	105	1.85	0.67	0.86	0.3917
Potassium (mmol/L)	9	7.5	4.8	105	10.6	8.5	-1.61	0.1066
ALP (IU/L)	9	104	35	105	184	145	-1.45	0.1470
AST (IU/L)	9	61	14	105	72	29	-1.25	0.2129
GGT (IU/L)	9	92	112	105	43	32	2.31	0.0207
CPK (IU/L)	9	136	91	105	275	398	-2.35	0.0186
Total Protein (g/dL)	9	7.4	0.9	105	6.9	1.0	1.24	0.2161
Albumin (g/dL)	9	2.8	0.4	105	3.3	0.4	-3.33	0.0009

[a] BUN = Blood urea nitrogen, ALP = Alkaline phosphatase, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Appendix I. Effects of body condition on select physiological parameters of adult female elk (*Cervus elaphus*) captured in eastern Kentucky, USA 2012-2014.

	Bad			Good				
Parameter[a]	*n*	Mean	SD	*n*	Mean	SD	Z	*P*
Glucose (mg/dL)	6	134	43	68	172	41	-2.06	0.0394
BUN (mg/dL)	6	21	6	68	24	6	-0.98	0.3255
Creatinine (mg/dL)	6	2.15	0.20	68	2.17	0.33	-0.31	0.7588
Potassium (mmol/L)	6	15.5	13.0	68	5.7	1.8	2.20	0.0277
ALP (IU/L)	6	115	101	68	134	103	-0.61	0.5392
AST (IU/L)	6	142	173	68	71	17	0.31	0.7587
GGT (IU/L)	6	20	13	68	26	14	-0.61	0.5446
CPK (IU/L)	5	197	45	68	283	356	-0.31	0.7598
Total Protein (g/dL)	6	6.6	0.3	68	7.0	0.5	-2.00	0.0457
Albumin (g/dL)	6	3.2	0.3	68	3.5	0.2	-1.43	0.1525

[a] BUN = Blood urea nitrogen, ALP = Alkaline phosphatase, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Appendix J. Effects of body condition on select physiological parameters of calf elk (*Cervus elaphus*) captured in eastern Kentucky, USA 2012-2014.

	Bad			Good				
Parameter[a]	*n*	Mean	SD	*n*	Mean	SD	Z	*P*
Glucose (mg/dL)	6	162	35	53	192	47	-1.64	0.1004
BUN (mg/dL)	6	18	4	53	23	7	-1.66	0.0975
Creatinine (mg/dL)	6	1.92	0.22	53	2.07	0.31	-1.14	0.2536
Potassium (mmol/L)	6	10.7	4.8	53	6.4	2.5	2.26	0.0239
ALP (IU/L)	6	179	67	53	138	61	1.20	0.2286
AST (IU/L)	6	75	17	53	84	24	-0.92	0.3598
GGT (IU/L)	6	33	14	53	34	31	0.98	0.3266
CPK (IU/L)	6	621	531	53	765	1145	0.34	0.7349
Total Protein (g/dL)	6	6.4	0.4	53	6.3	0.6	-0.06	0.9499
Albumin (g/dL)	6	3.5	0.2	53	3.5	0.3	-0.24	0.8104

[a] BUN = Blood urea nitrogen, ALP = Alkaline phosphatase, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Appendix K. Effects of body condition on select physiological parameters of yearling elk (*Cervus elaphus*) captured in eastern Kentucky, USA 2012-2014.

	Bad			Good				
Parameter[a]	*n*	Mean	SD	*n*	Mean	SD	Z	*P*
Glucose (mg/dL)	6	185	17	28	182	60	1.31	0.1900
BUN (mg/dL)	6	26	2	28	24	7	0.82	0.4144
Creatinine (mg/dL)	6	2.05	0.22	28	2.21	0.34	-1.18	0.2400
Potassium (mmol/L)	6	6.0	1.3	28	6.2	2.5	0.75	0.4555
ALP (IU/L)	6	134	44	28	137	118	1.04	0.2985
AST (IU/L)	6	64	10	28	92	58	-1.97	0.0492
GGT (IU/L)	6	43	25	28	29	24	1.97	0.0488
CPK (IU/L)	6	247	81	28	1214	3047	-1.78	0.0744
Total Protein (g/dL)	6	6.8	0.3	28	6.9	0.4	-0.18	0.8556
Albumin (g/dL)	6	3.5	0.2	28	3.6	0.2	-0.62	0.5371

[a] BUN = Blood urea nitrogen, ALP = Alkaline phosphatase, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase

$P \leq 0.05$ is significant

Appendix L. Comparison of biological and handling related metrics between workups 1 and 2 using paired t-tests and Wilcoxon signed-rank tests for elk (*Cervus elaphus nelsoni*) captured and quarantined as part of a translocation effort in 2012 and 2013 in eastern Kentucky, USA.

Variable	Workup	N^	AVG	SD	MIN	MAX	P-Value
Weight (kg)	1	105	167	40	91	253	
Weight (kg)	2	105	167	41	94	249	0.9828
Body Temperature (°C)	1	107	40.3	0.8	37.8	42.7	
Body Temperature (°C)	2	106	40.2	0.7	38	41.9	0.0611
Time in Facility (min)	1	106	81.8	48.6	8	215	
Time in Facility (min)	2	106	67.5	40.2	11	190	0.0212
Time in Chute (min)	1	107	4.3	3.5	2	34	
Time in Chute (min)	2	106	3.5	1.3	2	9	0.0399
Glucose (mg/dL)	1	101	202	56	71	350	
Glucose (mg/dL)	2	106	190	47	60	310	0.0825
BUN (mg/dL)	1	101	26	4	17	35	
BUN (mg/dL)	2	106	24	5	13	44	0.0496
Creatinine (mg/dL)*	1	101	1.62	0.35	0.98	3.24	
Creatinine (mg/dL)*	2	106	1.59	0.42	0.86	4.5	0.4710
Chloride (mmol/L)	1	101	99	3	92	109	
Chloride (mmol/L)	2	106	100	3	85	109	0.3513
Sodium (mmol/L)	1	101	143	2	137	148	
Sodium (mmol/L)	2	106	138	7	117	150	<0.0001
Potassium (mmol/L)*	1	101	5.1	0.9	3.5	7.9	
Potassium (mmol/L)*	2	106	10.6	5.4	4.2	23.8	<0.0001
CO_2 (mmol/L)	1	101	18	4	7.6	27.8	
CO_2 (mmol/L)	2	106	19	3	11.3	27.4	0.0459
Calcium (mg/dL)	1	101	9.4	0.5	7.8	10.7	
Calcium (mg/dL)	2	106	9.1	0.5	7.5	11.3	0.0004
Magnesium (mg/dL)*	1	101	1.9	0.2	1.2	2.4	
Magnesium (mg/dL)*	2	106	1.8	0.2	1.3	2.4	0.0033
Phosphorus (mg/dL)	1	101	6.1	1.5	2.4	9.9	
Phosphorus (mg/dL)	2	106	5.7	1.4	2.6	8.7	0.0266
Cholesterol (mg/dL)	1	101	48	10	24	75	
Cholesterol (mg/dL)	2	106	44	9	22	68	0.0189
ALP (IU/L)*	1	101	120	73	21	361	
ALP (IU/L)*	2	106	100	62	17	298	0.0520
TBilirubin (mg/dL)*	1	101	0.48	0.21	0.1	1.1	
TBilirubin (mg/dL)*	2	106	0.53	0.21	0.2	1.2	0.0693
DBbilirubin (mg/dL)*	1	101	0.14	0.07	0	0.4	
DBbilirubin (mg/dL)*	2	106	0.18	0.09	0	0.5	0.0003
IBilirubin (mg/dL)*	1	101	0.34	0.16	0.1	0.9	
IBilirubin (mg/dL)*	2	106	0.35	0.14	0	0.7	0.5909
AST (IU/L)*	1	101	96	130	34	1253	
AST (IU/L)*	2	106	141	233	34	2097	0.0002
GGT (IU/L)*	1	101	24	17	0	118	
GGT (IU/L)*	2	106	25	13	0	100	0.1231
CPK (IU/L)*	1	101	948	2575	84	20290	
CPK (IU/L)*	2	106	915	2756	93	26440	0.5950
Osmolality (mOsm/L)	1	101	293.5	14.7	193.2	305.3	
Osmolality (mOsm/L)	2	106	284.2	14.3	247	313.1	<0.0001
Total Protein (g/dL)	1	101	6.7	0.7	3.3	8.2	
Total Protein (g/dL)	2	106	6.6	0.6	3.7	7.9	0.3528
Albumin (g/dL)	1	101	3.7	0.4	2.4	6.6	
Albumin (g/dL)	2	106	3.6	0.3	2.1	4.5	0.0347
Globulin (gms%)*	1	101	3.1	0.6	2.2	5.1	
Globulin (gms%)*	2	106	3.5	2.8	2	23	0.8734
A:G Ratio (g/dL)	1	101	1.21	0.24	0.53	1.7	
A:G Ratio (g/dL)	2	106	1.18	0.23	0.5	1.8	0.4456
Anion Gap*	1	101	30.9	5.5	20.1	49.3	
Anion Gap*	2	106	29.7	4.0	22.1	43.4	0.1554

^Elk sex and age classes were pooled for these analyses. There were 40 adults, 25 yearlings, and 42 calves.

*Used Wilcoxon signed-rank test for comparison

[a]BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirubin = Direct bilirubin, IBilirubin = Indirect bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin Ratio

Appendix M. Comparison of biological and handling related metrics between workups 3 and 4 using paired t-tests and Wilcoxon signed-rank tests for elk (Cervus elaphus nelsoni) captured and quarantined as part of a translocation effort in 2012 and 2013 in eastern Kentucky, USA.

Variable	Workup	N^	AVG	SD	MIN	MAX	P-Value
Weight (kg)	3	101	186	39	116	266	
Weight (kg)	4	99	180	38	112	255	0.3317
Body Temperature (°C)	3	103	40.9	0.7	38.9	42.5	
Body Temperature (°C)	4	102	40.8	0.9	37.2	42.8	0.8746
Time in Facility (min)	3	102	87.4	51.3	14	222	
Time in Facility (min)	4	101	80.5	44.3	14	193	0.3033
Time in Chute (min)	3	103	3.8	3.0	1	19	
Time in Chute (min)	4	101	3.3	1.5	1	12	0.1082
Glucose (mg/dL)	3	103	178	62	3	362	
Glucose (mg/dL)	4	101	166	63	54	304	0.1507
BUN (mg/dL)	3	103	24	3	18	35	
BUN (mg/dL)	4	101	21	4	13	34	<0.0001
Creatinine (mg/dL)*	3	103	1.38	0.22	0.96	2.31	
Creatinine (mg/dL)*	4	101	1.36	0.19	0.9	1.97	0.5992
Chloride (mmol/L)	3	103	100	5	92	146	
Chloride (mmol/L)	4	101	99	4	86	105	0.0104
Sodium (mmol/L)	3	103	144	8	134	214	
Sodium (mmol/L)	4	101	139	8	119	151	<0.0001
Potassium (mmol/L)*	3	103	4.4	0.6	3.1	7.3	
Potassium (mmol/L)*	4	101	8.3	4.0	3.3	17.2	<0.0001
CO_2 (mmol/L)	3	103	17	5	6.8	46.5	
CO_2 (mmol/L)	4	101	18	3	10	26.1	0.2764
Calcium (mg/dL)	3	103	9.7	0.7	8	15.4	
Calcium (mg/dL)	4	101	9.4	0.6	7.7	10.6	0.0016
Magnesium (mg/dL)*	3	103	2.0	0.3	1.6	3.3	
Magnesium (mg/dL)*	4	101	1.9	0.2	1.5	2.4	0.0045
Phosphorus (mg/dL)	3	103	5.5	1.2	2.6	8.2	
Phosphorus (mg/dL)	4	101	5.0	1.3	2.4	8.8	0.0127
Cholesterol (mg/dL)	3	103	57	11	25	100	
Cholesterol (mg/dL)	4	101	53	11	27	104	0.0262
ALP (IU/L)*	3	103	237	153	23	827	
ALP (IU/L)*	4	101	194	127	22	637	0.0402
TBilirubin (mg/dL)*	3	103	0.53	0.15	0.1	1	
TBilirubin (mg/dL)*	4	101	0.70	0.33	0.2	2.5	<0.0001
DBbilirubin (mg/dL)*	3	103	0.16	0.07	0	0.3	
DBbilirubin (mg/dL)*	4	101	0.23	0.11	0	0.7	<0.0001
IBilirubin (mg/dL)*	3	103	0.37	0.11	0.1	0.8	
IBilirubin (mg/dL)*	4	101	0.47	0.24	0.1	1.8	0.0002
AST (IU/L)*	3	103	95	30	54	256	
AST (IU/L)*	4	101	121	50	58	340	<0.0001
GGT (IU/L)*	3	103	18	18	-18	176	
GGT (IU/L)*	4	101	20	11	0	82	0.0473
CPK (IU/L)*	3	103	919	1513	159	11523	
CPK (IU/L)*	4	101	1125	1206	200	8103	0.0069
Osmolality (mOsm/L)	3	103	297.7	20.6	277.4	439.7	
Osmolality (mOsm/L)	4	101	284.4	16.0	243.8	307.1	<0.0001
Total Protein (g/dL)	3	103	7.1	0.8	5.8	11.3	
Total Protein (g/dL)	4	101	6.8	0.6	5.5	8.3	0.0062
Albumin (g/dL)	3	103	3.8	0.4	1.5	5.8	
Albumin (g/dL)	4	101	3.7	0.2	3.1	4.3	0.0027
Globulin (gms%)*	3	103	3.3	0.8	2.2	5.9	
Globulin (gms%)*	4	101	3.1	0.6	1.5	5	0.2484
A:G Ratio (g/dL)	3	103	1.23	0.28	0.25	1.82	
A:G Ratio (g/dL)	4	101	1.24	0.30	0.64	2.67	0.8115
Anion Gap*	3	103	31.6	5.2	19.4	61	
Anion Gap*	4	101	31.2	4.0	22.7	44.4	0.9112

^Elk sex and age classes were pooled for these analyses. There were 40 adults, 25 yearlings, and 42 calves.

*Used Wilcoxon signed-rank test for comparison

[a]BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase, TBilirubin = Total bilirubin, Dbilirubin = Direct bilirubin, IBilirubin = Indirect bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin Ratio

Appendix N. Comparison of biological and handling related metrics by workup to capture baseline values using paired t-tests and Wilcoxon signed-rank tests for elk (*Cervus elaphus nelsoni*) captured and quarantined as part of a translocation effort in 2012 and 2013 in eastern Kentucky, USA.

Variable	Workup	N^	AVG	SD	MIN	MAX	P-Value
Weight (kg)	0	104	172	44	93	257	
Weight (kg)	1	105	167	40	91	253	0.3866
Weight (kg)	2	105	167	41	94	249	0.3795
Weight (kg)	3	101	186	39	116	266	0.0215
Weight (kg)	4	99	180	38	112	255	0.1565
Body Temperature (°C)	0	62	40.2	0.9	37.8	42.6	
Body Temperature (°C)	1	107	40.3	0.8	38.8	42.7	0.1718
Body Temperature (°C)	2	106	40.2	0.7	38.0	41.9	0.9124
Body Temperature (°C)	3	103	40.9	0.7	38.9	42.5	<0.0001
Body Temperature (°C)	4	102	40.8	0.9	37.2	42.8	<0.0001
Time in Facility (min)	0	51	23.0	14.2	6	66	
Time in Facility (min)	1	106	81.8	48.6	8	215	<0.0001
Time in Facility (min)	2	106	67.5	40.2	11	190	<0.0001
Time in Facility (min)	3	102	87.4	51.3	14	222	<0.0001
Time in Facility (min)	4	101	80.5	44.3	14	193	<0.0001
Time in Chute (min)	0	92	7.4	8.0	2	60	
Time in Chute (min)	1	107	4.3	3.5	2	34	0.0003
Time in Chute (min)	2	106	3.5	1.3	2	9	<0.0001
Time in Chute (min)	3	103	3.8	3.0	1	19	<0.0001
Time in Chute (min)	4	101	3.3	1.5	1	12	<0.0001
Rump BCS	0	54	4.0	0.6	3	5	
Rump BCS	1	100	3.7	0.6	2	5	0.0016
Rump BCS	3	97	4.1	0.6	3	5	0.3277
Withers BCS	0	54	3.9	0.7	3	5	
Withers BCS	1	100	3.6	0.8	2	5	0.0071
Withers BCS	3	97	4.0	0.7	2	5	0.3598
Ribs BCS	0	54	4.1	0.6	3	5	
Ribs BCS	1	100	3.6	0.7	2	5	<0.0001
Ribs BCS	3	97	4.2	0.6	3	5	0.9482
Rump Ultrasound (mm)	0	55	11.5	6.9	2	28	
Rump Ultrasound (mm)	1	109	14.8	6.8	1	24	0.0045
Rump Ultrasound (mm)	3	103	7.7	5.1	1	24	0.0001
Loin Ultrasound (mm)	0	54	44.3	6.2	27	57	
Loin Ultrasound (mm)	1	107	45.0	5.4	31	59	0.4259
Loin Ultrasound (mm)	3	103	47.2	5.7	25	63	0.0031

^Elk sex and age classes were pooled for these analyses. There were 40 adults, 25 yearlings, and 42 calves.

[a]BCS=Body condition score

Appendix N (continued). Comparison of biological and handling related metrics by workup to capture baseline values using paired t-tests and Wilcoxon signed-rank tests for elk (*Cervus elaphus nelsoni*) captured and quarantined as part of a translocation effort in 2012 and 2013 in eastern Kentucky, USA.

Variable	Workup	N^	AVG	SD	MIN	MAX	P-Value
Glucose (mg/dL)	0	61	200	52	107	341	
Glucose (mg/dL)	1	101	202	56	71	350	0.7614
Glucose (mg/dL)	2	106	190	47	60	310	0.2126
Glucose (mg/dL)	3	103	178	62	3	362	0.0249
Glucose (mg/dL)	4	101	166	63	54	304	0.0005
BUN (mg/dL)	0	61	20	6	9	32	
BUN (mg/dL)	1	101	26	4	17	35	<0.0001
BUN (mg/dL)	2	106	24	5	13	44	<0.0001
BUN (mg/dL)	3	103	24	3	18	35	<0.0001
BUN (mg/dL)	4	101	21	4	13	34	0.5613
Creatinine (mg/dL)*	0	61	2.22	0.29	1.35	2.84	
Creatinine (mg/dL)*	1	101	1.62	0.35	0.98	3.24	<0.0001
Creatinine (mg/dL)*	2	106	1.59	0.42	0.86	4.5	<0.0001
Creatinine (mg/dL)*	3	103	1.38	0.22	0.96	2.31	<0.0001
Creatinine (mg/dL)*	4	101	1.36	0.19	0.9	1.97	<0.0001
Chloride (mmol/L)	0	61	102	4	94	112	
Chloride (mmol/L)	1	101	99	3	92	109	<0.0001
Chloride (mmol/L)	2	106	100	3	85	109	0.0002
Chloride (mmol/L)	3	103	100	5	92	146	0.0654
Chloride (mmol/L)	4	101	99	4	86	105	<0.0001
Sodium (mmol/L)	0	61	143	7	110	158	
Sodium (mmol/L)	1	101	143	2	137	148	0.8014
Sodium (mmol/L)	2	106	138	7	117	150	<0.0001
Sodium (mmol/L)	3	103	144	8	134	214	0.3857
Sodium (mmol/L)	4	101	139	8	119	151	0.0011
Potassium (mmol/L)*	0	61	7.8	4.6	3.8	34.5	
Potassium (mmol/L)*	1	101	5.1	0.9	3.5	7.9	<0.0001
Potassium (mmol/L)*	2	106	10.6	5.4	4.2	23.8	0.0014
Potassium (mmol/L)*	3	103	4.4	0.6	3.1	7.3	<0.0001
Potassium (mmol/L)*	4	101	8.3	4.0	3.3	17.2	0.5801
CO_2 (mmol/L)	0	61	18	4	8.2	25.4	
CO_2 (mmol/L)	1	101	18	4	7.6	27.8	0.5432
CO_2 (mmol/L)	2	106	19	3	11.3	27.4	0.2422
CO_2 (mmol/L)	3	103	17	5	6.8	46.5	0.0449
CO_2 (mmol/L)	4	101	18	3	10	26.1	0.1239
Calcium (mg/dL)	0	61	9.8	0.6	8.6	11.3	
Calcium (mg/dL)	1	101	9.4	0.5	7.8	10.7	0.6654
Calcium (mg/dL)	2	106	9.1	0.5	7.5	11.3	<0.0001
Calcium (mg/dL)	3	103	9.7	0.7	8	15.4	0.4005
Calcium (mg/dL)	4	101	9.4	0.6	7.7	10.6	<0.0001
Magnesium (mg/dL)*	0	61	2.2	0.2	1.8	2.9	
Magnesium (mg/dL)*	1	101	1.9	0.2	1.2	2.4	<0.0001
Magnesium (mg/dL)*	2	106	1.8	0.2	1.3	2.4	<0.0001
Magnesium (mg/dL)*	3	103	2.0	0.3	1.6	3.3	<0.0001
Magnesium (mg/dL)*	4	101	1.9	0.2	1.5	2.4	<0.0001
Phosphorus (mg/dL)	0	61	4.6	1.4	1.7	7.2	
Phosphorus (mg/dL)	1	101	6.1	1.5	2.4	9.9	<0.0001
Phosphorus (mg/dL)	2	106	5.7	1.4	2.6	8.7	<0.0001
Phosphorus (mg/dL)	3	103	5.5	1.2	2.6	8.2	<0.0001
Phosphorus (mg/dL)	4	101	5.0	1.3	2.4	8.8	0.0520
Cholesterol (mg/dL)	0	61	66	13	38	94	
Cholesterol (mg/dL)	1	101	48	10	24	75	<0.0001
Cholesterol (mg/dL)	2	106	44	9	22	68	<0.0001
Cholesterol (mg/dL)	3	103	57	11	25	100	<0.0001
Cholesterol (mg/dL)	4	101	53	11	27	104	<0.0001
ALP (IU/L)*	0	61	140	91	34	642	
ALP (IU/L)*	1	101	120	73	21	361	0.1219
ALP (IU/L)*	2	106	100	62	17	298	0.0008
ALP (IU/L)*	3	103	237	153	23	827	<0.0001
ALP (IU/L)*	4	101	194	127	22	637	0.0083

^Elk sex and age classes were pooled for these analyses. There were 40 adults, 25 yearlings, and 42 calves.
*Used Wilcoxon signed-rank test for comparison

[a]BUN = Blood urea nitrogen, CO_2 = Carbon dioxide, ALP = Alkaline phosphatase

Appendix N (continued). Comparison of biological and handling related metrics by workup to capture baseline values using paired t-tests and Wilcoxon signed-rank tests for elk (*Cervus elaphus nelsoni*) captured and quarantined as part of a translocation effort in 2012 and 2013 in eastern Kentucky, USA.

Variable	Workup	N^	AVG	SD	MIN	MAX	P-Value
TBilirubin (mg/dL)*	0	61	0.40	0.17	0.2	1	
TBilirubin (mg/dL)*	1	101	0.48	0.21	0.1	1.1	0.0075
TBilirubin (mg/dL)*	2	106	0.53	0.21	0.2	1.2	<0.0001
TBilirubin (mg/dL)*	3	103	0.53	0.15	0.1	1	<0.0001
TBilirubin (mg/dL)*	4	101	0.70	0.33	0.2	2.5	<0.0001
DBbilirubin (mg/dL)*	0	61	0.11	0.06	0	0.3	
DBbilirubin (mg/dL)*	1	101	0.14	0.07	0	0.4	0.0263
DBbilirubin (mg/dL)*	2	106	0.18	0.09	0	0.5	<0.0001
DBbilirubin (mg/dL)*	3	103	0.16	0.07	0	0.3	<0.0001
DBbilirubin (mg/dL)*	4	101	0.23	0.11	0	0.7	<0.0001
IBilirubin (mg/dL)*	0	61	0.28	0.13	0.1	0.7	
IBilirubin (mg/dL)*	1	101	0.34	0.16	0.1	0.9	0.0137
IBilirubin (mg/dL)*	2	106	0.35	0.14	0	0.7	0.0013
IBilirubin (mg/dL)*	3	103	0.37	0.11	0.1	0.8	<0.0001
IBilirubin (mg/dL)*	4	101	0.47	0.24	0.1	1.8	<0.0001
AST (IU/L)*	0	61	85	29	41	178	
AST (IU/L)*	1	101	96	130	34	1253	0.0842
AST (IU/L)*	2	106	141	233	34	2097	0.0396
AST (IU/L)*	3	103	95	30	54	256	0.0124
AST (IU/L)*	4	101	121	50	58	340	<0.0001
GGT (IU/L)*	0	61	32	28	11	166	
GGT (IU/L)*	1	101	24	17	0	118	0.0075
GGT (IU/L)*	2	106	25	13	0	100	0.1313
GGT (IU/L)*	3	103	18	18	-18	176	<0.0001
GGT (IU/L)*	4	101	20	11	0	82	<0.0001
CPK (IU/L)*	0	61	889	1288	96	7061	
CPK (IU/L)*	1	101	948	2575	84	20290	0.0186
CPK (IU/L)*	2	106	915	2756	93	26440	0.0307
CPK (IU/L)*	3	103	919	1513	159	11523	0.0361
CPK (IU/L)*	4	101	1125	1206	200	8103	0.0002
Osmolality (mOsm/L)	0	61	293.7	13.8	228.9	317.6	
Osmolality (mOsm/L)	1	101	293.5	14.7	193.2	305.3	0.9259
Osmolality (mOsm/L)	2	106	284.2	14.3	247	313.1	<0.0001
Osmolality (mOsm/L)	3	103	297.7	20.6	277.4	439.7	0.1774
Osmolality (mOsm/L)	4	101	284.4	16.0	243.8	307.1	0.0002
Total Protein (g/dL)	0	61	6.8	0.6	5.7	8.1	
Total Protein (g/dL)	1	101	6.7	0.7	3.3	8.2	0.5509
Total Protein (g/dL)	2	106	6.6	0.6	3.7	7.9	0.1379
Total Protein (g/dL)	3	103	7.1	0.8	5.8	11.3	0.0137
Total Protein (g/dL)	4	101	6.8	0.6	5.5	8.3	0.9150
Albumin (g/dL)	0	61	3.7	0.2	3.1	4	
Albumin (g/dL)	1	101	3.7	0.4	2.4	6.6	0.8764
Albumin (g/dL)	2	106	3.6	0.3	2.1	4.5	0.0284
Albumin (g/dL)	3	103	3.8	0.4	1.5	5.8	0.0024
Albumin (g/dL)	4	101	3.7	0.2	3.1	4.3	0.5188
Globulin (gms%)*	0	61	3.1	0.5	2.2	4.7	
Globulin (gms%)*	1	101	3.1	0.6	2.2	5.1	0.8367
Globulin (gms%)*	2	106	3.5	2.8	2	23	0.9072
Globulin (gms%)*	3	103	3.3	0.8	2.2	5.9	0.4649
Globulin (gms%)*	4	101	3.1	0.6	1.5	5	0.6880
A:G Ratio (g/dL)	0	61	1.21	0.22	0.72	1.77	
A:G Ratio (g/dL)	1	101	1.21	0.24	0.53	1.7	0.9398
A:G Ratio (g/dL)	2	106	1.18	0.23	0.5	1.8	0.5461
A:G Ratio (g/dL)	3	103	1.23	0.28	0.25	1.82	0.5153
A:G Ratio (g/dL)	4	101	1.24	0.30	0.64	2.67	0.4029
Anion Gap*	0	61	30.9	5.5	21	50.9	
Anion Gap*	1	101	30.9	5.5	20.1	49.3	0.9051
Anion Gap*	2	106	31.8	22.0	22.1	253	0.2508
Anion Gap*	3	103	31.6	5.2	19.4	61	0.3010
Anion Gap*	4	101	31.2	4.0	22.7	44.4	0.3062

^Elk sex and age classes were pooled for these analyses. There were 40 adults, 25 yearlings, and 42 calves.
*Used Wilcoxon-Mann-Whitney rank-sum test for comparison

[a]TBilirubin = Total bilirubin, Dbilirubin = Direct bilirubin, IBilirubin = Indirect bilirubin, AST = Aspartate aminotransferase, GGT = Gamma-glutamyltransferase, CPK = Creatine phosphokinase, A:G Ratio = Albumin:Globulin Ratio

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