The Effects of Disease, Stress, and Distribution on Bighorn Sheep Restoration in Nebraska

by

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ABSTRACT: Twenty two Rocky Mountain Bighorn Sheep (*Ovis canadensis*) were released in the southern Panhandle of Nebraska in 2001. Since the reintroduction, population size has fluctuated between approximately 30 to 60 animals, peaking at just above 60 in 2005. The definitive aim of the reintroduction was to ensure long-term persistence of bighorn sheep in the southern panhandle of Nebraska. The objectives of this study are to assess occupied and available habitat and identify potential population limiting factors. Data that has been collected since the reintroduction by means of radio telemetry will be analyzed. Additionally, the study will assess physiological stress responses of bighorn sheep through noninvasive fecal glucocorticoid assays. Baseline stress response data will be established and potential stressors will be investigated. Physiological stress response data will be examined in light of a respiratory disease epidemic that reduced the population by 50% in early 2006.

INTRODUCTION

In March of 2001, the Nebraska Game and Parks Commission released 22 Rocky Mountain bighorn sheep into the Wildcat Hills of western Nebraska. The 22 sheep, consisting of twelve ewes, six lambs, and four rams, were captured and transported from the Pike's Peak area in Colorado and released in Cedar Canyon Wildlife Management Area (CCWMA). This release marked the first reintroduction of bighorn sheep in the southern panhandle of Nebraska. Prior to the reintroduction, the last documented sighting of bighorn sheep in Nebraska was in the early 1900s.

The first five years following the reintroduction were marked by successful growth of the population. By the end of 2005, the population had climbed to about 65 animals. Lamb production and survival rates were high and overall mortality rates were low. The population was on the rise and biologists were hopeful that a self-sustaining population would soon be established in the Wildcat Hills. However, the first few months of 2006 proved to be a catastrophic for the population. Observations of coughing sheep later proved to be a tell-tale sign of the respiratory disease outbreak that would ultimately result in a loss of about half the population.

In the spring of 2005, several sheep were observed coughing. The first observation was reported by a land owner whose property is often inhabited by rams outside of the mating season. The land owner reported that he had noticed a ram coughing, although it appeared to be otherwise healthy. About a month later, another ram was observed coughing, and soon several ewes had also developed the cough. The cough spread amongst the herd, and by fall, most of the sheep residing within CCWMA had been observed coughing. Initially, the group of bighorn sheep inhabiting private land

areas did not appear to develop the cough. However, shortly after the first rams joined the ewes at the beginning of the mating season, these ewes were also observed coughing.

It was suspected that the cough was related to the common *Pasteurella* bacteria, known to sometimes cause fatal pneumonia in bighorn sheep. On October 18, 2005, a yearling ewe was tranquilized and a throat swab was collected to be tested for infectious pathogens. *Pasteurella trehalosi* was found in the throat culture at the 2+ level, indicating moderate infection. On December 1, 2005, two more sheep were tranquilized and throat swabs were collected. Lab tests revealed that *Pasteurella trehalosi* was present in the case of a yearling ewe, and *Mannheimia haemolytica* was present in the sample collected from an adult ram.

During the winter, the coughing seemed to subside in the group of bighorn sheep within CCWMA. However, by late January the coughing escalated in the private lands herd, and by early February, the disease began to take its toll on this group of bighorn sheep. On February 8th, the carcass of an adult ewe was found, and necropsy revealed that acute pneumonia was the cause of death. Two additional mortalities of adult ewes occurred within the next few days, and these mortalities were also attributed to pneumonia. Despite efforts to treat the disease with antibiotics, twelve carcasses were found, and numerous additional mortalities were suspected.

In the end, the respiratory complex reduced the bighorn sheep population in the Wildcat Hills by about 50%. Biologists noted that all carcasses were found on private land, and no known deaths occurred within CCWMA. The sheep that stayed primarily within CCWMA appeared to fend off the disease, as coughing subsided and eventually

tapered off to a minimum. The majority of sheep inhabiting the neighboring private lands, however, did not survive the epidemic.

Understanding respiratory disease in bighorn sheep is critical to the development of a self-sustaining herd of bighorn sheep in the southern panhandle of Nebraska. At this point, the disease and its effects on the Wildcat Hills population are not well understood. There is evidence that the primary vector for transmission of the *Pasteurella* bacteria to bighorn sheep could be direct contact with domestic sheep (Miller 2001). At the time of the reintroduction in the Wildcat Hills, there were no domestic sheep in the areas surrounding the release site of the bighorn sheep. However, a herd of domestic sheep has been observed on private land about five miles from CCWMA within the last year. It is plausible that the infectious agents responsible for the bighorn dieoff were a product of contact with this herd of domestic sheep.

However, understanding the dynamics of the epidemic is complicated by the complexities involved with *Pasteurella* in bighorn sheep. The existence of *Pasteurella* in an individual is not always manifested in disease. Most wild sheep carry small amounts of the bacteria and can tolerate it in low concentrations (Miller 2001). However, there are numerous subspecies of *Pasteurella,* some of which are significantly more pathogenic than others. Furthermore, bighorn sheep are most susceptible to the harmful effects of *Pasteurella* under stressful conditions including periods of low forage quality and quantity, high predation or harassment, or harsh weather (Frank et al. 2006). Under these conditions, the immune system becomes suppressed, and individuals infected with *Pasteurella* are often more susceptible to fatal pneumonia (Festa-Bianchet 1988).

The stress factors that may have played a role in the pneumonia epidemic in the Wildcat Hills are unknown. Inclement weather, interactions with livestock, predators, human disturbances, movement patterns, and environmental factors are all variables that are worthy of investigation in light of potential stress as it relates to the pneumonia epidemic. Furthermore, tests performed on mortality sheep have revealed that many of the bighorn sheep in the Wildcat Hills herd were also infected with viruses and pathogens such as bluetongue virus, epizootic hemorrhagic disease, lungworm, and *Archanobacterium pyogenes*. Concurrent infections in bighorn sheep that carry *Pasteurella* can cause stress to the immune system, leading to outbreaks of pneumonia that result in population declines (Frank et al. 2006). These infections may have contributed to the respiratory disease epidemic in the Wildcat Hills. Of particular interest is the possibility that a potential stressor existing in the inhabited private lands but absent within CCWMA may have played a role in the outcome of the epidemic.

Further research is vital to the future of bighorn sheep in Nebraska. The establishment of a self-sustaining herd of bighorn sheep in the Wildcat Hills will require further understanding of bighorn sheep respiratory diseases. Therefore this research focuses on physiological stress response of bighorn sheep as it relates to disease. Additionally, an assessment of distribution and home range will provide further information about potential limiting factors of bighorn sheep in the Wildcat Hills of western Nebraska.

The specific objectives of the project were to: (1) develop a database of information about bighorn sheep physiological stress response, especially as it relates to respiratory disease, (2) identify potential stressors to which bighorn sheep may be

exposed in the Wildcat Hills, both inside and outside of Cedar Canyon Wildlife Management Area, (3) quantify the stress levels of reintroduced, low elevation bighorn sheep, and (4) analyze field data to examine home range and distribution patterns in correlation with habitat selection and distance from water, people, livestock, and escape cover. The results of this project will provide biologists with important insight for management of this reintroduced, low-elevation population, ultimately helping to ensure the success of bighorn sheep restoration in Nebraska.

LITERATURE REVIEW

Bighorn Sheep in the United States

It has been estimated that about 2 million bighorn sheep inhabited the mountainous terrain of the western United States during the early 1800s (Buechner 1960). Recent bighorn sheep estimates are dramatically lower, with sheep inhabiting far less of their native range. Historic decline of bighorn sheep populations has been perpetuated by disease, unregulated harvest, and habitat loss and alteration. Estimates of the current bighorn sheep population in the United States number around 50,000, with sheep occupying less than one-third of their native range (Wishart 1978, Valdez and Krausman 1999).

Attempts to restore bighorn sheep to native habitats following extirpation have been only somewhat successful. As of 1980, only 53% of 87 translocations resulted in the desired outcome of a persistent population (Leslie 1980). Evidence that population size can be indicative of persistence points to the high potential for extirpation of small, fragmented populations (Berger 1990). Effective management of these undersized, transplanted populations is vital to the persistence of wild sheep in the United States, as more than 50% of existing populations are a product of translocations (McCutchen 1981), and about two-thirds of all populations of Rocky Mountain and California bighorn sheep are comprised of less than 100 animals (Thorne et al. 1985).

Fluctuations in bighorn sheep populations are common throughout the western United States, as periods of rapid growth are often followed by severe declines (Buechner 1960, Onderka and Wishart 1984, Festa-Bianchet 1988). These fluctuations can be especially devastating to the many small populations resulting from translocations

throughout the western United States. In many instances, the inability of small populations to persist is directly related to the smallness of the population (Caughley 1994). In theory, small populations are more susceptible to disease and less likely to recover from epidemics, which ultimately results in increased vulnerability to extinction or extirpation. However, there are exceptions in which small populations persist, and therefore additional limiting factors need to be addressed in evaluating the persistence of bighorn sheep populations. Although a number of variables play a role in population fluctuations, disease is often the primary cause of drastic declines of bighorn populations.

Bighorn Sheep Diseases

Bighorn sheep are susceptible to a variety of pathogens and exhibit increased vulnerability to disease in comparison with other large North American mammals. Diseases can sometimes result in rapid local extinction of bighorn sheep or catastrophic population declines due to increased mortality and reduced lamb recruitment (Foreyt and Jessup 1982, Bunch et al. 1999). Disease, even of mild severity, has been identified as the most important cause of imperilment of bighorn sheep, having a more profound effect on population dynamics than other factors, including habitat loss and fragmentation (Singer et al. 2000). Diseases infecting bighorn sheep populations include bacterial pneumonia, chronic frontal sinusitis, bluetongue, epizootic hemorrhagic disease, ovine progressive pneumonia, caprine arthritis encephalitis, and contagious ecthyma, also known as soremouth. Parasitic infections of bighorn sheep include protozoal hemoparasite, verminous pneumonia, gastrointestinal parasites, and scabies (Jessup and Boyce 1990).

All-age dieoffs are often experienced by bighorn populations that appear to be healthy and even thriving only shortly before the onset of the disease. Populations that experience large scale, all-age dieoffs often have trouble recovering, as disease not only affects all age classes of sheep at the onset, but often results in poor lamb recruitment during the following years. Prevention of bighorn sheep epizootics is hindered by the complexity of the diseases involved. In the case of most all-age dieoffs, numerous pathogens contribute to a respiratory complex that often results in fatal pneumonia.

Pasteurella is the bacterial culprit often incriminated as the cause of respiratory disease in bighorn sheep, as well as in numerous other animals. *Pasteurella* spp. are common commensals on mucous membranes of the majority of animal species throughout the world (Biberstein, 1979). There are numerous subspecies of *Pasteurella*, and the taxonomy has undergone many changes over the years. In the case of bighorn sheep dieoffs, one or more of the following three organisms is typically involved: *Mannhemia haemolytica, Pasteurella trelahosi*, and *Pasteurella multocida*.

Pastuerella multocida was the first name given to the organisms isolated from domestic animals that were suspected as the cause of respiratory disease. These organisms were non-hemolytic and produced indole (Rosenbusch and Merchant, 1939). Organisms similar to *P. multocida* but differing in their ability to hemolyze red blood cells and their lack of ability to produce indole were determined to be atypical *Pasteurella*, and were grouped into the species known as *Pasteurella haemolytica* (Newsome and Cross 1932). It was later recognized that some organisms belonging to *P. haemolytica* have the ability to ferment arabinose but not trehalose, while others have the ability to ferment trehalose but not arabinose. This led to the identification of two

biotypes of *P. haemolytica;* biotype A (corresponding to the ability to ferment arabinose), and biotype T (corresponding to the ability to ferment trehalose) (Smith 1961). However, changes in nomenclature have been made to address discrepancies at the genus or species level as revealed by genomic DNA or ribosomal RNA studies of the organisms (Mannheim 1983, De Ley et al. 1990, and Dewhirst et al. 1992). The first change was the reassigning of organisms previously characterized as *P. haemolytica* biotype T to a new species, *P. trehalosi*, based on the fermentation of trehalose (Sneath and Stevens 1990). More recently, organisms identified as *P. haemolytica* have adopted a new genus name, and are represented by *Mannheimia haemolytica* (Angen et al. 1999). Thus these changes have resulted in three organisms of particular interest to the bighorn sheep respiratory disease complex (*Mannhiemia haemolytica, P. trehalosi*, and *P. multocida*). Because much of the existing literature was published prior to taxonomic changes, organisms will sometimes be referred to by their previous names in this review, and collectively these organisms will be referred to as *Pasteurella* spp.

Pneumonia has been reported as the cause of numerous all-age dieoffs and *Pasteurella* has allegedly played a role in mortalities throughout western North America (Onderka and Wishart 1984, Spraker et al. 1984, Ryder et al. 1992). *Pasteurella* spp. triggers lethargy and anorexia in addition to respiratory distress that often leads to fatal pneumonia resulting in large scale bighorn dieoffs (Rosen 1981). Large scale, all-age dieoffs have been observed and documented across most of the range of bighorn sheep, and severity and frequency of dieoffs has been observably higher in the northwestern United States (Onderka and Wishart 1984, Spraker et al. 1984, Ryder et al. 1992, Cassirer et al. 1996, Jorgenson et al. 1997). Growth or stabilization of bighorn sheep populations

infected with pneumonic bacteria is often hindered for several years following a dieoff due to reduced lamb survivability. Lambs that are born into populations that have experienced a recent pneumonia related dieoff typically experience low survival rates for approximately 3 to 5 years following the onset of the infection (Foreyt 1990, Coggins and Matthews 1992, Ward et al. 1992). Documented observations offer strong evidence that pneumonia associated with *Pasteurella* spp. may be a contributing factor to high lamb mortality rates (Jaworski et al. 1993).

Bighorn sheep dieoffs often follow incidents of contact with domestic sheep. Although domestic sheep are resistant to strains of wild sheep bacteria, bighorn sheep are highly susceptible to strains of *Pasteurella* spp. carried by domestic sheep (Onderka 1986). It is believed that even casual contact between bighorn sheep and domestic sheep can potentially result in respiratory distress in bighorn sheep, ultimately leading to fatal pneumonia and widespread bighorn mortalities (Onderka and Wishart 1984). Experimental studies have demonstrated that bighorn sheep usually die following contact with domestic sheep.

Of thirteen experimental fenced studies, nine resulted in the death of all bighorns following close association with domestic sheep and a 50% to 83% bighorn mortality rate was documented in the other four cases (Martin et al. 1996). There have been eighteen documented incidents of free ranging bighorn sheep dieoffs in eight states or provinces that have linked contact with domestic sheep to bighorn mortalities (Martin et al. 1996). Such dieoffs occur due to the transmission of strains of *P. haemolytica* that are nonpathogenic in domestic sheep to highly susceptible wild sheep that develop

respiratory complications as a result of the colonization of the new bacteria (Foreyt 1994).

DNA fingerprinting has been used to document the transmission of bacteria from healthy domestic sheep to bighorn sheep that died as a result of pneumonia. A study published by Foreyt et al. in 1994 revealed that the specific DNA type for *Pasteurella haemolytica* biotype A, serotype 2 originating in domestic sheep lead to the death of formerly healthy bighorns. Based on the scientific evidence available at the current time, most researchers and biologists have agreed that bighorn sheep and domestic sheep should not be managed in close proximity due to the potential for transmission of pathogenic bacteria to wild sheep and the probable outcome of a resulting bighorn dieoff.

Although it is widely known that *P. haemolytica* causes respiratory distress in bighorn sheep and generally results in eventual death by pneumonia, the process of bacterial colonization of the lung is not well understood. It has been hypothesized that *P. haemolytica* increases in number in the nose until an excess of organisms in the nose results in entry into the lungs (Grey and Thompson 1971). A healthy animal should be successful in clearance of the bacteria from the lungs, but the process may be inhibited by incidents of stress, concurrent viral infections, or environmental or climatic change (Boyce et al. 2004).

Furthermore, pathogenic strains of bacteria produce virulence factors that allow the organisms to evade the natural defense mechanisms of the host, facilitating more extensive colonization of tissues. Virulence factors of *Mannheimia haemolytica* include a leukotoxin, capsular polysaccharide, lipopolysaccharide with endotoxic activity, iron-restricted outer membrane proteins, and extracellular enzymes (Frank et al. 2006). The

leukotoxin has been identified as one of the most important virulence factors for colonization of the lungs of bighorn sheep (Srikumaran et al. 2007). The leukotoxin facilitates lung damage by decreasing phagocytic activity and causing cell death due to lysis (Clinkenbeard et al. 1989, Markham et al. 1982). It has been confirmed that the leukotoxins of both *M. haemolytica* A1 and A2 intensify damage of endotheilial cells that is typically mediated by neutrophils (Maheswaran et al. 1993). However, species specific studies have found *M. haemolytica* A1 to be nonpathogenic to domestic sheep but highly lethal to bighorn sheep, and the leukotoxin of *M. haemolytica* A1 has been identified as the primary virulence factor (Dassanayake 2007).

The respiratory disease complex in bighorn sheep is complicated by the fact that infected individuals do not always die and sometimes no harmful effects of the bacteria are observed. Because bighorn sheep infected with apparently pathogenic strains of *P. haemolytica* sometimes show no clinical signs of respiratory disease, it is believed that certain ecological or environmental conditions play a role in the all-age dieoffs (Festa-Bianchet 1988, Ryder et al. 1992).

Bighorn sheep infected with *Pasteurella* spp. may be more susceptible to bacterial colonization of the lungs if the immune system is suppressed. Factors that may result in suppression of the immune system and predisposition to pneumonia may include parasites such as lungworms (*Protostrongylus* spp.) or mites (*Psoroptes ovis*), nutritional deficiencies, harsh weather conditions, inbreeding, or density dependent stress resulting from overcrowding (Risenhoover et al. 1988, Bailey 1990, Belden et al. 1992, Jones and Worley 1994). These predisposing factors may compromise immunity of bighorn sheep, allowing for a shift from benign to lethal *Pasteurella* spp. infection or facilitating the

establishment of highly pathogenic forms that would otherwise be controlled by immune system function (Monello et al. 2001).

The role of predisposing factors and physiological stress in bacterial pneumonia of bighorn sheep is variable and not well understood, creating complexities that confound management of the disease. Bighorn sheep conservation is clearly dependent on the understanding of wildlife managers of factors influencing *Pasteurella* spp. infections, and therefore an increased understanding of physiological stress response and related immune system suppression is valuable in determining population limiting factors and assessing population persistence.

Physiological Stress Response

Short term stress, or acute stress response, is an adaptation that helps an animal maintain homeostasis in support of survival (Wingfield et al. 1995). Responses to short-term stressors redirect the behavior of an animal from its natural activities to increased foraging or momentary suspension of foraging, improved restfulness at night, and recovery once the temporary stressor is no longer present (Wingfield and Kitaysky 2002). However, when homeostasis is not realized and prolonged stress exists, the physiological response of the animal changes and the stress becomes chronic. Chronic stress can compromise the immune system of the animal, resulting in increased susceptibility to disease (Sapolsky et al. 2000, Wingfield et al 1995). Chronic stress can also decrease reproductive capacity and impair growth (Sapolsky et al 2000).

Although numerous studies of wildlife stress response are based on behavioral observations and investigations of mortalities, quantitative measures of stress may be valuable to researchers interested in the physiological response of wildlife to

environmental variables, disease exposure, and human activity. A quantitative index of bighorn sheep stress response can potentially be afforded through the measurement of fecal glucocorticoids, or hormones released in the bloodstream as a response to stress (Miller et al. 1991).

Glucocorticoids are synthesized and secreted in response to stressors perceived by the animal. Unpredictable events that may induce physiological stress responses include inclement weather, sudden changes in social status, increased predator numbers, decreased food resources, and disease (Wingfield and Kitaysky 2002). In response to a perceived stressor, the hypothalamus is activated, resulting in secretion of trophic hormones by the anterior pituitary gland, which in turn induces various target organs to secrete respective hormones (Asterita 1985). Of particular interest for purposes of measured stress response is the adrenocortocotrophic hormone (ACTH). The adrenal cortex increases synthesis and secretion of glucocorticoids in response to stimulation by ACTH (Von der Ohe and Servheen 2002). Glucocorticoids secreted in response to stress include cortisol and corticosterone, although there is variation between species in the specific glucocorticoid hormones produced and the patterns of their release (Broom and Johnson 1993).

The release of glucocorticoid hormones in response to a stressful event initiates numerous physiological reactions that are critical to survival in the presence of a stressor (Von der Ohe and Servheen 2002). However, in the instance of prolonged stress and extended periods of high glucocorticoid levels in the bloodstream, these hormones can also have a deleterious effect on the health of the animal. In instances of elevated circulating glucocorticoids over prolonged periods of time, the immune system of the

animal may be compromised, resulting in increased susceptibility to disease. Direct results of prolonged elevation of glucocorticoids may include inhibition of enzyme production, delayed processing of antigens, and quantitative reduction of immune system responses (Monjan 1981, Kiecolt-Glaser et al. 1984, Golub and Gershwin 1985).

Glucocorticoid metabolites are excreted in feces and can be measured using radioimmunoassay or enzyme immunoassay to provide an index of adrenal activity for assessment of physiological stress response. A standard assay validation is necessary to ensure that the procedure is sufficient for accurate and precise measurement of fecal glucocorticoid metabolites in the species of interest. Numerous validation experiments have concluded that physiological stress response as measured by adrenal activity can be assessed by means of fecal glucocorticoid assays (Graham and Brown 1996, Creel 1997, Goymann et al. 1999, Wasser et al. 2000, Harper and Austad 2000, Millspaugh et al. 2001, Millspaugh et al. 2002, Mateo and Cavigelli 2005, Petrauskas et al. 2006).

Commercially available kits are widely used for fecal glucocorticoid assays. One kit, the I^{125} corticosterone kit for radioimmunoassay (ICN #07-120103, ICN Biomedicals, Costa Mesa California) uses a group-specific antibody with cross-reactivities to multiple glucocorticoid metabolites excreted in the feces of a variety of species in response to adrenal activation. The ICN corticosterone antibody has been determined to be effective for measuring glucocorticoid metabolites for a diverse array of species including northern spotted owls (*Strix occidentalis caurina*, Wasser et al. 1997), domestic cats (Graham and Brown 1996), spotted hyena (*Crocuta crocuta*, Goymann et al. 1999), African wild dogs (*Lycaon pictus*, Creel et al. 1997), African elephants (*Loxodonta africana*, Foley et al. 2001), black rhinoceros (*Dicerous bicornis*, Wasser et al. 2000), cheetah (*Acinonyx*

jubatus, Wasser et al. 2000), Roosevelt and Rocky Mountain Elk (Wasser et al. 2000, Millspaugh et al. 2001), small mammals (Harper and Austad 2000), white-tailed deer (*Odocoileus virginianus*, Millspaugh et al. 2002), Stellar sea lions (*Eumetopias jubatus*, Petrauskas 2006), and Belding's ground squirrels (*Spermophilus beldingi*, Mateo and Caigelli 2005).

Fecal glucocorticoid metabolite assays provide a noninvasive alternative to traditional stress assessment methods that involve capture of wildlife for collection of blood samples to be used for glucocortcoid measurements. The noninvasive nature of fecal glucocorticoid sampling techniques eliminates the potential for increased glucocorticoid levels due to capture-related stress, thus providing a potentially more accurate means of assessing physiological stress response of wildlife (Harper and Austad 2000). However, careful consideration of numerous factors that influence glucocorticoid levels is critical in choosing a study design and interpreting results. Factors that potentially influence glucocorticoid measurements include adaptation and sensitization, sex, reproductive events, diet, prehibernatory preparations, inter-species differences, and assay methods (Von der One and Servheen 2002). Caution should be exercised in interpretation of glucocorticoid study results due to these sources of difficulty.

Few studies have been published involving bighorn sheep glucocorticoid measurements as a response to stress. One study (Goldstein et al. 2005) found that bighorn sheep glucocorticoid levels appear to reflect a cyclical pattern based on the seasons, with the highest levels measured in the summer and the lowest levels measured in the winter. This study also found no correlation between fecal larval lungworm levels and fecal glucocorticoid metabolite measure. However, such research is limited and

further investigations are necessary to assess bighorn sheep stress response through measurement of fecal glucocorticoids.

Because bighorn sheep are exceptionally susceptible to disease and may be especially sensitive to stress, research involving fecal glucocorticoid metabolite measurements may be critical to successful management of wild sheep in the future. Research that employs the use of this noninvasive, valuable tool for quantifying stress response is of great potential value for investigating the population limiting factors of small, translocated bighorn sheep populations. Management implications derived from the results of such a study could be highly valuable to the continued success of bighorn sheep restoration in Nebraska.

Habitat Selection, Home Range, and Distribution

An effective approach to ensuring the population persistence of bighorn sheep requires both habitat and disease management. Habitat management and disease management are interrelated because of human influence on wildlife populations. Human development impedes traditional movement patterns and restricts distribution, which in turn often increases contact with exotic organisms and infectious pathogens (Scott 1988). Furthermore, there is an evident relationship between the health and vigor of the animal and the condition of its environment, so research that encompasses both parameters in an effort to evaluate population persistence can be of significant value.

In general, bighorn sheep inhabit open, steep, mountainous terrain (Geist 1971). Preference for such habitat reflects the agility of bighorn sheep on steep, rocky ground as well as their keen eyesight, which allows them to detect predators from distances that often allow for escape. The habitat of bighorn sheep is naturally fragmented, occurring in

irregular patches, often with vast expanses of unsuitable terrain in between. This natural fragmentation is important to the persistence of bighorn sheep populations in that it decreases the potential for disease transmission between subherds or metapopulations, minimizing the potential for local extinction where drastic population declines are a factor (Quinn and Hastings 1987).

Bighorn sheep are habitat specialists with strong site fidelity, and they are often perceived as poor colonizers of vacant suitable habitat patches (Geist 1970, Giest 1971). It has been noted that historical changes to the landscape, resulting from human activity as well as from environmental processes, have driven bighorn sheep to become even more specialized in habitat selection over time (Shackleton et al. 1999). Nearly 95% of bighorn sheep activity is restricted to open areas within 300 meters or less of escape terrain (Smith and Flinders 1991) and it has been recognized that most foraging activity occurs with 100 meters of escape terrain (Oldemeyer et al. 1971).

Bighorn sheep maintain their home ranges based on knowledge of seasonal forage availability and preferred habitat and travel routes (Toweill and Geist 1999). This knowledge is passed down from generation to generation, as adults educate their offspring while they are young. Bighorn ewes typically remain within the maternal herd in close association with other sheep which they recognize, and most of the movement patterns, travel routes and seasonal range locations are learned during the first year of their lives (Festa-Bianchet 1986).

Numerous variables have been recognized as important determinants of bighorn sheep habitat selection and home range. Distance to escape terrain, elevation, snow depth, distance from salt, forest cover, slope, changes in slope, forage availability, plant

productivity, water, suitable lambing sites, and thermal protection are important habitat determinants (Tilton and Willard 1982, Shannon et al. 1975, Geist 1971, Ferrier and Bradley 1970). Resources are generally selected differently by season (Festa-Bianchet 1986, Shannon et al. 1975, Geist 1971,). Also important to consider is that bighorn sheep do not thrive in close association with livestock (Krausman et al. 1966, Albrechtsen and Reese 1970) or human activities (Bates and Workman 1983).

Migratory behavior is typical of bighorn sheep. Most bighorn sheep inhabiting high altitudes migrate from summer foraging grounds in the mountain tundra to the foothills for winter grazing (Geist 1971). Migration is advantageous to bighorn sheep because it facilitates use of habitat patches during peak forage quality and availability (Herbert 1973, Seip 1983). Although rams often follow complex movement patterns covering vast expanses of terrain, ewes generally utilize only 2 or 3 distinct seasonal ranges (Geist 1971). Of growing concern to researchers and biologists is the reduction in migratory movements of bighorn sheep due to factors such as human development impediments, encroaching shrub and tree growth due to fire suppression, and other variables that may not be well understood. Many bighorn sheep populations have abandoned or lost traditional migratory patterns and have become sedentary (Goodson 1980, Wakelyn 1984).

Sedentariness is typical of many static or declining populations of bighorn sheep, and has been defined as the nonmigratory and overconcentrated tendency of such herds (Risenhoover et al. 1988). Sedentariness can result in numerous problems, including an increased vulnerability to parasites, predators, and disease due to over-concentration in a small area. Furthermore, use of forage on a constant year-round basis by sedentary

populations is likely to result in inferior body condition in comparison to migratory populations with a more seasonal forage usage cycle (Berger, 1990). Morever, sedentary populations of bighorn sheep may be predisposed to pneumonia, primarily due to increased potential for deleterious lungworm infection (Bailey 1980, Wishart et al. 1980). Due to these limitations that result from sedentariness, population persistence is positively correlated with greater movement and dispersal, including seasonal migration and larger size of home range (Singer et al. 2001).

A greater than expected capacity for extra-home range movements or augmented dispersal has been documented in several studies. Extensive intermountain movements by rams and occasional intermountain movements by ewes have been documented in Arizona (Cochran and Smith 1983, Ough and deVos 1984, Krausman and Leopold 1986). In Alberta, rams have been documented up to 48 km from the site of their capture (Festa-Bianchet 1986). Research in western Montana has detected relatively long extra-home range movements for rams, up to 32.9 km, while revealing localization of ewes within their home ranges (DeCesare et al. 2006). Despite advantages such as enabled gene flow, these types of movements can also serve as a vector for disease, increasing the existing vulnerability of bighorn sheep to epizootics (Bunch et al. 1999 and DeForge et al. 1979).

METHODS

Study Area

The primary research sites for this project included three properties: Cedar Canyon Wildlife Management Area (CCWMA) located at N 41 45.930' W 103 45.927', the Hampton property located at N 41 42.374' W 103 50.190', and the Montz property located at N 41 46.716' W 103 55.207'. These three properties are situated in the southern panhandle of Nebraska in an area know as the Wildcat Hills (Figure 1). CCWMA is an 890 hectare state-owned property open to the public for hunting and recreation. The Hampton and Montz properties are privately owned ranches that are periodically grazed by cattle and encompass 3,520 hectares and 1,942 hectares respectively.

All three properties are located approximately 11 – 19 kilometers southwest of Gering, Nebraska. Although these areas are primarily within the boundaries of Scotts Bluff County, the southernmost portion of the Hampton property extends into Banner County. CCWMA was chosen for the release site of the reintroduction in 2001 based on a bighorn sheep habitat suitability assessment of the Wildcat Hills (Forbes 1999). The Hampton and Montz properties were colonized naturally by bighorn sheep following the reintroduction. These three properties were selected as primary research sites for this project based on previously collected observational bighorn sheep occupancy data.

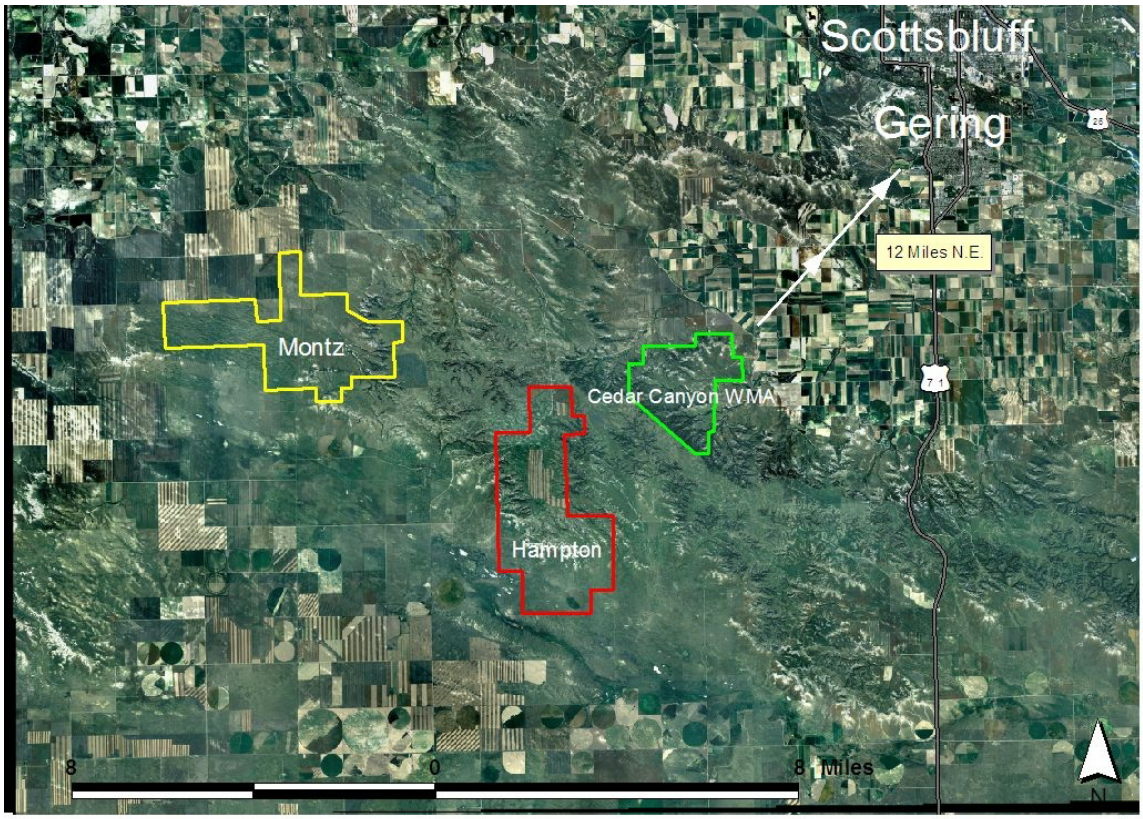


Figure 1. Map of study area including Cedar Canyon WMA, the Montz property, and the Hampton property.

Fecal Sample Collection

Fecal samples were collected opportunistically beginning in November of 2006 and ending in December of 2007. Samples were collected from sheep inhabiting CCWMA, the Hampton property, and the Montz property for a total of 285 samples. The fecal pellets were picked up using a latex glove or a freezer bag following observed defecation. To prevent disturbing of the bighorn sheep during collection, defecation was observed from a distance that did not alarm the animals, and pellets were picked up only after the sheep had moved a reasonable distance from the area on their own. Because the hormones may not be distributed evenly throughout the samples, pellets were collected from various segments of the entire sample.

The pellets were homogenized in freezer bags by thorough mixing and mashing. The freezer bags were marked with the date, time, location, and individual, and then stored in the freezer within two hours following collection. Fecal pellets were collected from ewes, rams, and lambs, and attempts were made to collect from several of the same radio-collared ewes as often as possible in order to establish baseline glucocorticoid levels for several individuals. Field notes were recorded during sample collection documenting weather and observations of any existing potential stressors (i.e. livestock in the immediate vicinity, presence of predators, human disturbances, observable changes in social structure or distribution of individuals, etc.).

Fecal Glucocorticoid Extraction and Assay Procedure

Dessication and Extraction

Immediately prior to extraction, the frozen fecal samples were thawed and homogenized by thorough mixing. Plastic containers were labeled for each sample, and approximately 1 gram of each sample was placed in the appropriate separate container. The containers were then placed in an oven at 37° C for 18 – 24 hours to complete the dessication process. Following dessication, a mortar and pestle was used to grind each sample to a fine dust. Detritus including sticks, hay, and other sizeable debris were removed from the sample and discarded.

From each of the finely ground samples, 0.2 grams of dried fecal material were placed in the bottom of appropriately labeled 15 ml extraction tubes. A solution of 90% ethanol (90:10 EtOH:distilled water) was added to the tubes in the amount of 2 ml. Tubes were placed on a shaker and shaken for 30 minutes and then centrifuged at 2000 x

g, and 1 ml of ethanol was removed from each tube. The extracts were then capped and stored at -20° C until the assay procedure.

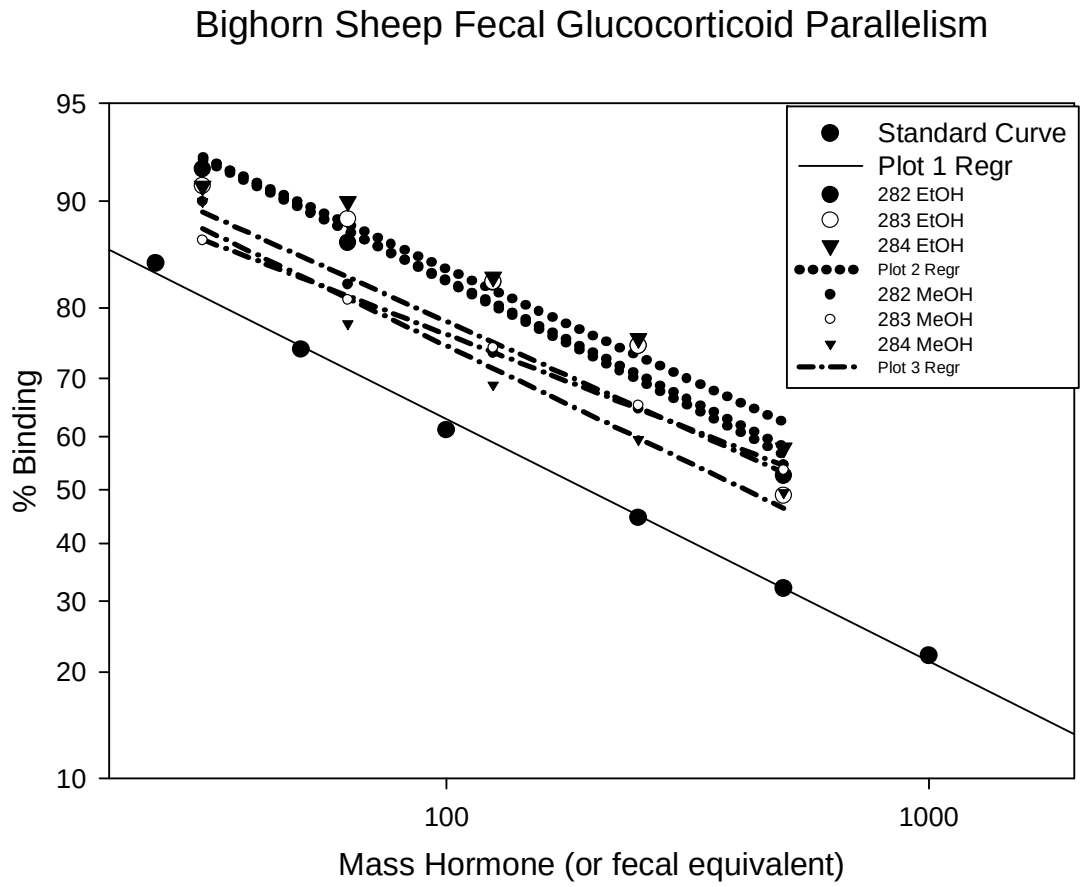
Assay Procedure

A commercially available kit was used for the assay procedure. Specifically, the I^{125} corticosterone radioimmunoassay (RIA) kit (ICN #07-120103, ICN Biomedicals, Costa Mesa, California) was used to quantify the fecal glucocorticoid metabolite concentrations. This procedure has been determined to be effective for quantifying fecal glucocorticoid metabolite extracts in a wide array of wildlife species (Wasser et al. 2000). All samples were diluted 1:4 in a phosphate-buffered saline (PBS) and assayed in duplicate following the ICN protocol for the I^{125} corticosterone RIA.

Validation

A standard assay validation was performed to ensure that the assay could accurately and precisely measure fecal glucocorticoid metabolites in bighorn sheep. Parallelism was demonstrated through preparations of serial dilutions of a pooled sample that produced a displacement curve parallel to the standard curve (Figure 2). The pooled sample was measured in each assay performed to assess between-assay reliability. Based on the duplicate sample agreement (n=374 assay determinations), the intra-assay coefficient of variability was 4.7%. The interassay coefficient of variation (n=6 assays) was 14.4 %. The range of standards was 12.5 – 500 picograms per tube.

Figure 2. Validation parallelism for fecal glucocorticoid assays.



Glucocorticoid Data Analysis

Fecal glucocorticoid metabolite concentrations were analyzed by calculating the mean and range for several different groups of samples. An Analysis of Variance (ANOVA) test was conducted to evaluate differences in glucocorticoid metabolite levels between the groups. These groups included ewes, rams, and lambs, as well as samples divided by location of collection. The glucocortiocoid concentrations of the samples collected within CCWMA and surrounding areas were compared with those collected on the Hampton and Montz properties. Because there were no sheep inhabiting the Hampton or Montz properties during December through February, samples collected during these months were removed from the CCWMA group to form an adjusted group

that was representative of samples collected over corresponding time periods. Additionally, differences across seasons were analyzed and samples collected from five adult ewes were compared. The individual ewe data included samples collected from three ewes primarily inhabiting CCWMA as well as two ewes primarily inhabiting the Montz property. The Hampton property was rarely occupied throughout the duration of this study.

Collection of Observational Data

Since the release of the bighorn sheep in March of 2001, technicians have collected data documenting the locations of bighorns through the use of telemetry. Locations of bighorn observations have been recorded based primarily on butte name or area name, and other variables such as type of habitat, temperature, sky cover, time of day, activity, sex, age class, and distance from escape terrain, people, water, and livestock have been recorded. This data was collected regularly over the past seven years, as field technicians have been responsible for monitoring the animals and recording the observational data on a consistent basis since the reintroduction.

Observational Data Analysis

Using Microsoft Excel and ArcGIS 9.2, the occupancy data was analyzed by year to illustrate changes in distribution and areas occupied over the past seven years. Bighorn observations were sorted by location using Microsoft Excel, and primary locations were determined based on the number of times the sheep were observed in the identified areas. Because locations were recorded based primarily on butte name or area name, general appropriate GPS coordinates were assigned to the primary locations of observations. These locations were plotted on a map of the study area using ArcMap,

and minimum convex polygons were created from the primary area coordinates to display the principal occupied areas. Observations outside these areas that did not frequently occur in the data set and did not fall within the minimum convex polygons were determined to be locations outside of primary areas, and these were also plotted on the map to illustrate locations of additional bighorn observations. Furthermore, a layer illustrating suitable bighorn sheep habitat available in the Wildcat Hills based on a habitat assessment performed by Iowa State University (Forbes 1999) was included in the ArcMap project, and an additional layer was created by intersecting the available habitat with the occupied habitat. This was done to exemplify habitat available in comparison with habitat occupied. The ArcMap project also included layers of roads and streams, as well as property boundaries.

In addition to the ArcMap project illustrating the locations of bighorn sheep, other data that were collected since the reintroduction in 2001 were analyzed using Microsoft Excel. Habitat selection was examined by year and overall by calculating total percentages of time spent in one of five types of habitat including rocky outcrop, heavy tree cover, light tree cover, open grassland, and shrub grassland. Documented distances from escape terrain, water, livestock, and people were also analyzed by calculating percentages of time spent at predetermined distances from these resources. Distances were broken into four categories including <25 meter, 25-50 meters, 50-100 meters, and >100 meters. Pie charts were used to illustrate percentages for habitat and distance data.

RESULTS

Fecal Glucocorticoid Metabolite Concentrations

Results of the fecal glucocorticoid metabolite assays suggest that while sex and age class do not significantly affect stress as measured by corticosterone concentration, there are significant differences across seasons and the areas inhabited by the animals. Additionally, an analysis of fecal glucocorticoid metabolite concentrations from samples collected from five adult ewes revealed no significant differences between individuals. Overall, the average concentration of corticosterone for the 285 samples collected was 27.58 ng/g of feces. Results ranged from a minimum of 7.13 ng/g to a maximum of 77.85 ng/g with a standard deviation of 13.41 (Table 1).

Table 1. Overall corticosterone concentration data.

	AVERAGE	MAX	MIN	MEDIAN	STDEV	TOTAL SAMPLES COLLECTED
OVERALL	27.58	77.85	7.13	25.23	13.41	285
RAMS	27.02	35.01	13.97	26.08	6.22	155
EWES	28.31	18.01	7.13	24.15	18.01	75
LAMBS	28.17	77.85	12.47	24.46	14.18	55

Sex and Age Class Results

Ram concentrations of corticosterone were compared with ewe concentrations of corticosterone using a two-sample *t* test assuming equal variances (Table 2). The *t* test revealed no significant differences in fecal glucocorticoid metabolite measurements between rams and ewes ($t_{228} = 0.70$, $P = .49$). The same *t* test was used to compare corticosterone concentrations of samples collected from adults and yearlings with those collected from lambs (Table 3). Results of the *t* test revealed no significant difference

between fecal glucocorticoid metabolite measurements of the two age classes ($t_{282} = 0.36$, $P = .72$).

Table 2. t-Test: two-sample assuming equal variance for ewes compared to rams.

	Ewes	*Rams*
Mean	27.01520634	28.31427711
Variance	122.9227575	286.5214389
Observations	155	75
Pooled Variance	176.0205752	
Hypothesized Mean Difference	0	
df	228	
t Stat	-0.696119265	
P(T<=t) one-tail	0.243531572	
t Critical one-tail	1.651564229	
P(T<=t) two-tail	0.487063144	
t Critical two-tail	1.970423143	

Table 3. t-Test: two-sample assuming equal variance for adults and yearlings compared to lambs.

	Adults and Yearlings	*Lambs*
Mean	27.43881638	28.17143633
Variance	175.6243998	201.0600539
Observations	230	54
Pooled Variance	180.4048596	
Hypothesized Mean Difference	0	
df	282	
t Stat	-0.360708401	
P(T<=t) one-tail	0.359293746	
t Critical one-tail	1.650274967	
P(T<=t) two-tail	0.718587492	
t Critical two-tail	1.968411839	

Seasonal Results

Fecal glucocorticoid results were compared across seasons using a single factor Analysis of Variance (ANOVA) (Table 4). The analysis revealed significant differences in corticosterone concentration across seasons (F = 61.22, F *crit* = 2.64). Measurements

were highest in the summer with an average of 35.64 ng of corticosterone/g of feces and lowest in the winter with an average of 15.23 ng/g. Samples collected in the spring averaged 34.12 ng/g, while samples collected in the fall averaged 24.91 ng/g.

Table 4. Analysis of variance output for seasons.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Winter	76	1157.416	15.22916	21.32396
Spring	69	2354.401	34.12175	189.2993
Summer	80	2850.952	35.6369	177.0747
Fall	59	1469.417	24.90537	39.23849

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20161.26	3	6720.42	61.22118	1.83E-30	2.636845
Within Groups	30736.38	280	109.7728			
Total	50897.64	283				

It should be noted that when results were broken into seasons and analyzed separately for rams and ewes, the season with the peak corticosterone measurements for the ewes was spring, with an average of 35.91 ng/g. Summer followed with an average of 30.48 ng/g. In contrast, the average summer concentration for the rams was 44.26 ng/g, followed by spring with an average of 34.05 ng/g (Table 5).

Table 5. Average corticosterone concentrations by season.

	Winter	**Spring**	**Summer**	**Fall**
Ewes	17.06	35.37	31.3	22.04
Rams	16.4	34.05	44.26	19.37
Lambs	14.01	30.18	38.4	24.03
Overall	15.23	34.12	35.64	24.91
Total Samples Collected	76	69	80	60

Results by Location

Corticosterone concentrations from samples collected within CCWMA and areas located within the immediate vicinity of the property boundaries were compared with samples collected on the Montz and Hampton properties. For comparison purposes, samples collected from CCWMA during the months of December through February were removed to form an "adjusted" CCWMA and nearby areas group to accurately represent values that correlated with the Hampton and Montz property group (Table 6). This was done because there were no sheep inhabiting the Hampton or Montz properties for the duration of December through January.

Table 6. Corticosterone concentrations by location.

	Average	**Max**	**Min**	**STDEV**	**Median**	**Total Samples Collected**
CCWMA and Nearby Areas	25.46	77.85	7.13	12.56	22.89	211
Montz and Hampton	33.60	76.74	15.58	13.99	29.4	74
Adjusted CCWMA	28.22	77.85	7.13	12.68	25.84	165

A two-sample *t* test assuming equal variances was performed (Table 7) and the Montz and Hampton group yielded significantly ($t_{236} = 2.93$, $P = .004$) higher corticosterone measurements than the adjusted CCWMA and nearby areas group. This could be a result of numerous variables that will be discussed in the sections that follow.

Table 7. t-Test for corticosterone concentrations by location.

	Adjusted CCWMA	*Montz and Hamptons*
Mean	28.22149501	33.60146118
Variance	160.885042	195.7118717
Observations	164	74
Pooled Variance	171.6577478	
Hypothesized Mean Difference	0	
df	236	
t Stat	-2.932224005	
P(T<=t) one-tail	0.001848244	
t Critical one-tail	1.65133585	
P(T<=t) two-tail	0.003696489	
t Critical two-tail	1.9700668	

Individual Adult Ewe Results

Individual fecal glucocorticoid metabolite concentrations were compared for five adult ewes. Four of the ewes were radio-collared and are referred to as ewes Y05, Y10, Y17, and Y01. The remaining ewe was not radio-collared but could easily be recognized due to a broken horn. Ewes Y05, Y10 and Y01 resided primarily with CCWMA throughout the duration of the study. The ewe with the broken horn and ewe Y17 inhabited the Montz property for approximately nine months out of the year. These ewes traveled to CCWMA during the mating season and remained in the area from December through January. With the exception of one young ram, they were the only sheep observed on the Hampton property during the study, and they remained there only for a few days before traveling back to the Montz property following the end of the mating season.

A single factor ANOVA was performed to compare corticosterone concentrations between individuals (Table 8), and results revealed no significant differences ($F = 1.23$, $F_{crit} = 2.49$). Average corticosterone measurements (Table 9) ranged from a maximum of

29.24 ng/g (ewe Y17) to a minimum of 19.86 ng/g (ewe Y01). Collection of samples from these five ewes throughout the duration of the study provides baseline corticosterone concentration data, and the following graphs illustrate the results for each of the five ewes (Figures 3 – 7).

Table 8. ANOVA output for individual ewe results.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Y05	21	576.0561898	27.43124713	220.4188768
Y10	20	564.3400597	28.21700299	154.1716249
Y17	19	555.664922	29.24552221	153.4841275
Broken Horn	13	353.5691322	27.19762555	63.09711852
Y01	12	238.3183914	19.85986595	107.632538

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	741.0334	4	185.2583391	1.230801529	0.304466	2.485885
Within Groups	12041.48	80	150.5184505			
Total	12782.51	84				

Table 9. Corticosterone concentration data for individual ewes.

	Y05	**Y10**	**Y17**	**Broken Horn**	**Y01**
Average	27.43	28.22	29.25	27.2	19.86
Min	10.06	16.12	11.3	12.95	9.06
Max	61.35	68.04	70.69	37.73	40.26
STDEV	14.85	12.42	12.39	7.94	10.37
Total Samples Collected	21	20	19	13	12

Figure 3. Y05 corticosterone concentrations.

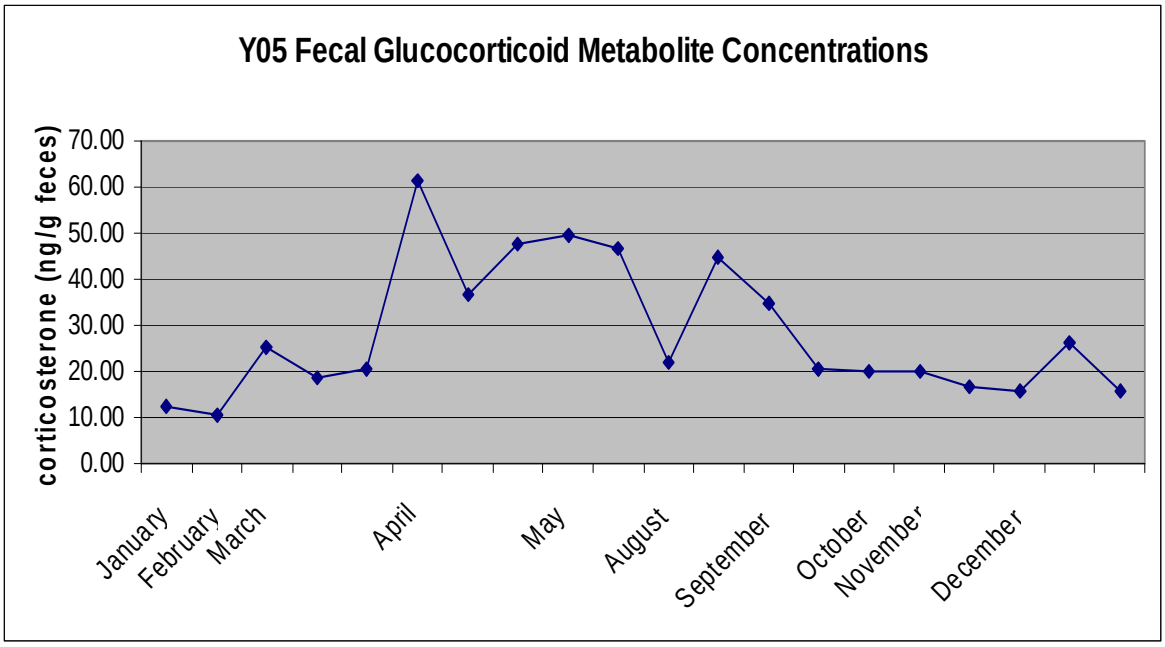


Figure 4. Y10 corticosterone concentrations.

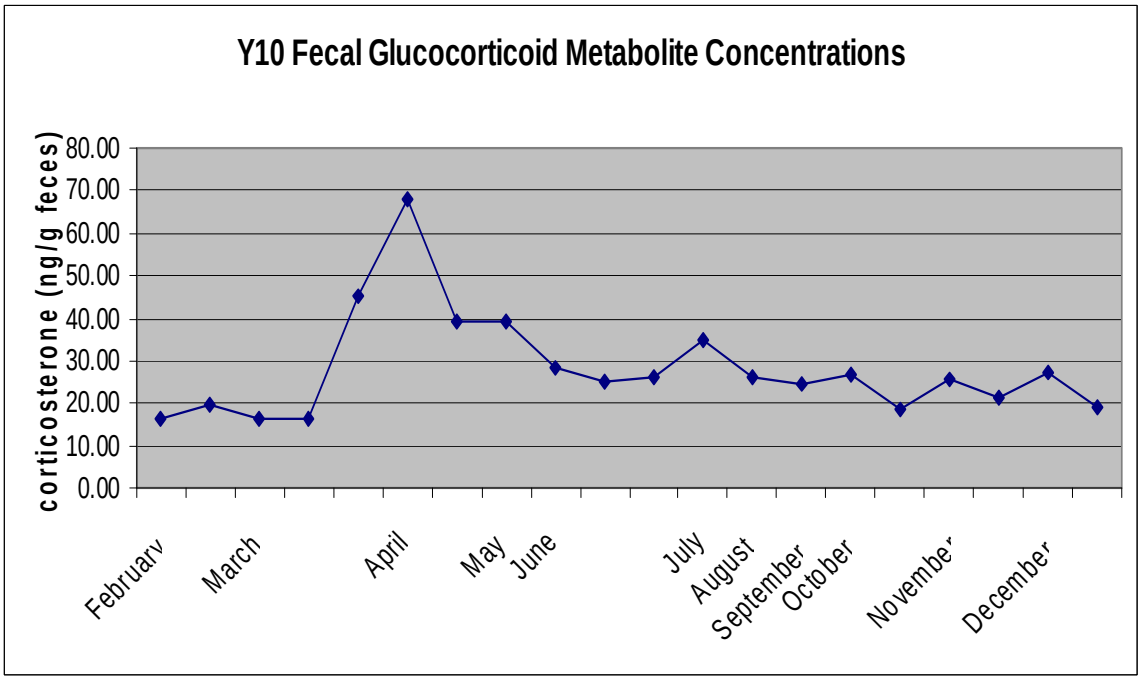


Figure 5. Y17 corticosterone concentrations.

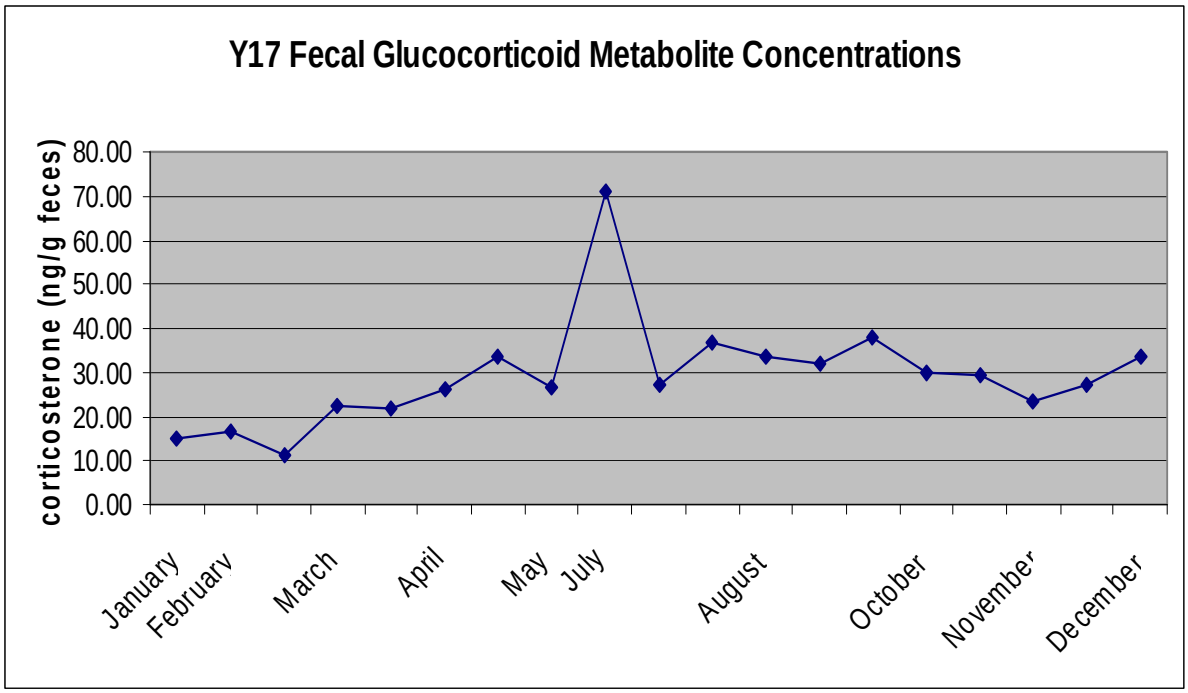


Figure 6. Corticosterone concentrations for adult ewe with broken horn.

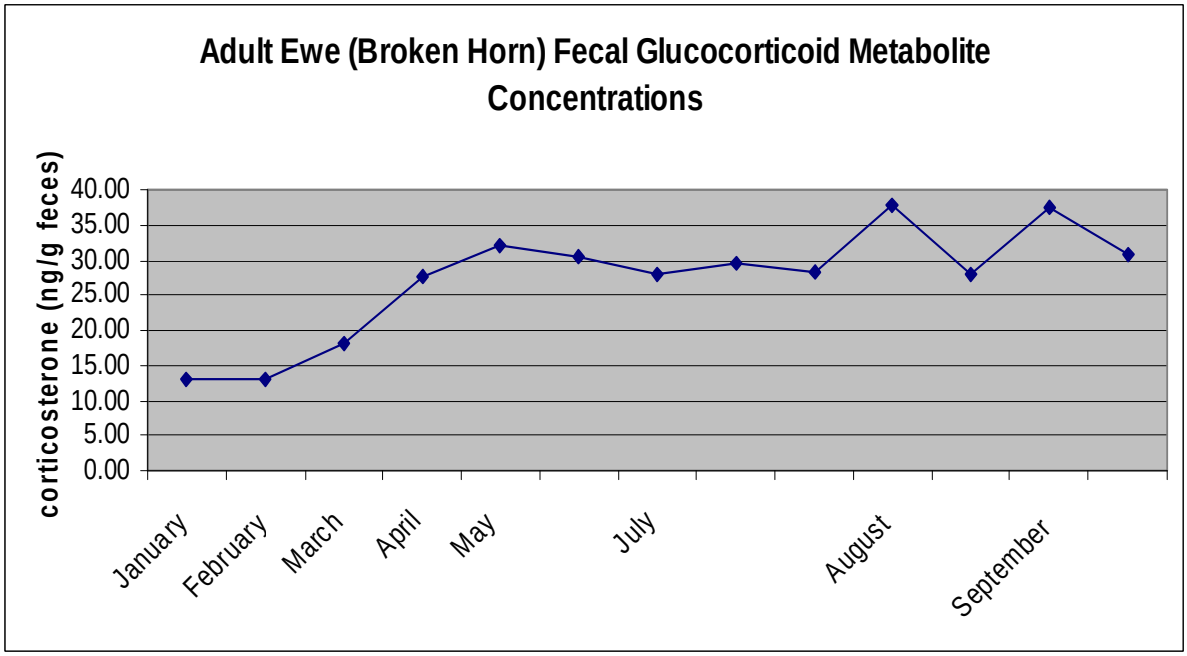
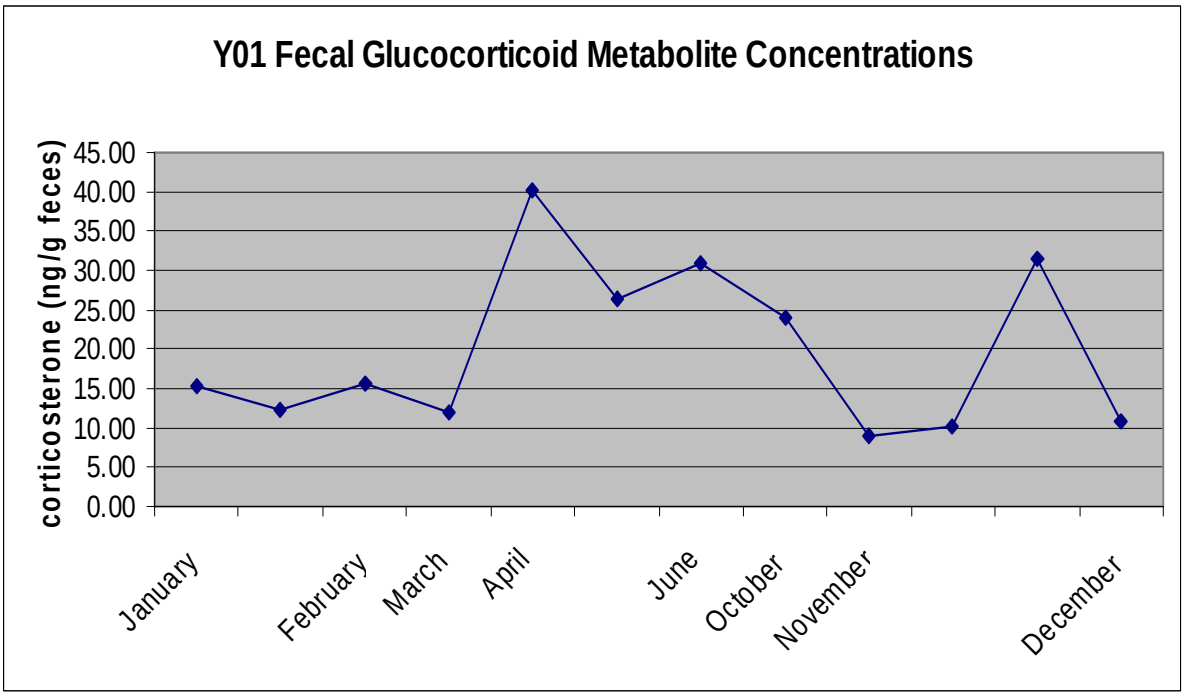


Figure 7. Y01 corticosterone concentrations.



Observational Data Results

Location and Occupancy Data

The ArcMap document illustrates changes in primary occupied areas from 2001 through 2008. In 2001, only CCWMA and areas in the immediate vicinity were occupied (Figure 8). In 2002, the Hampton property was colonized (Figure 9), and the Montz property was colonized the following year. From 2003 through the beginning of 2006, primary areas included CCWMA and the immediate vicinity, the rocky badlands on the Hampton property, and both the south and east ridge on the Montz property (Figures 10 – 13). As previously mentioned, the pneumonia related dieoff that occurred in 2006 took place on the Hampton property. Following the dieoff, the bighorn sheep no longer occupied the Hampton property for more than a few days at a time, and they never returned in substantial numbers. Furthermore, the small group of sheep that returned to

the Montz property no longer occupies the south ridge. Only the east ridge remains a primary inhabited area. Therefore primary areas occupied in 2007 and 2008 include only CCWMA and the immediate vicinity and the east ridge of the Montz property (Figures 14 and 15). Observed locations of sheep outside primary areas are also illustrated in the ArcMap document.

Figures 8 – 15 represent the spatial analysis and occupancy data from this project. The occupied available habitat is represented in red and the suitable available habitat as determined by the habitat assessment performed by Iowa State University is represented in orange. Primary locations are marked with green circles, and yellow polygons outline the primary areas inhabited. Observations outside primary areas are symbolized by orange stars. Streams are represented by the blue lines while roads are symbolized by green lines, and transparent polygons outline property boundaries with the Montz property in yellow, Hampton's in blue, the Enlow property in peach, Schaneman's in green, and CCWMA in light purple.

Figure 8. Image of ArcMap document – 2001 data frame.

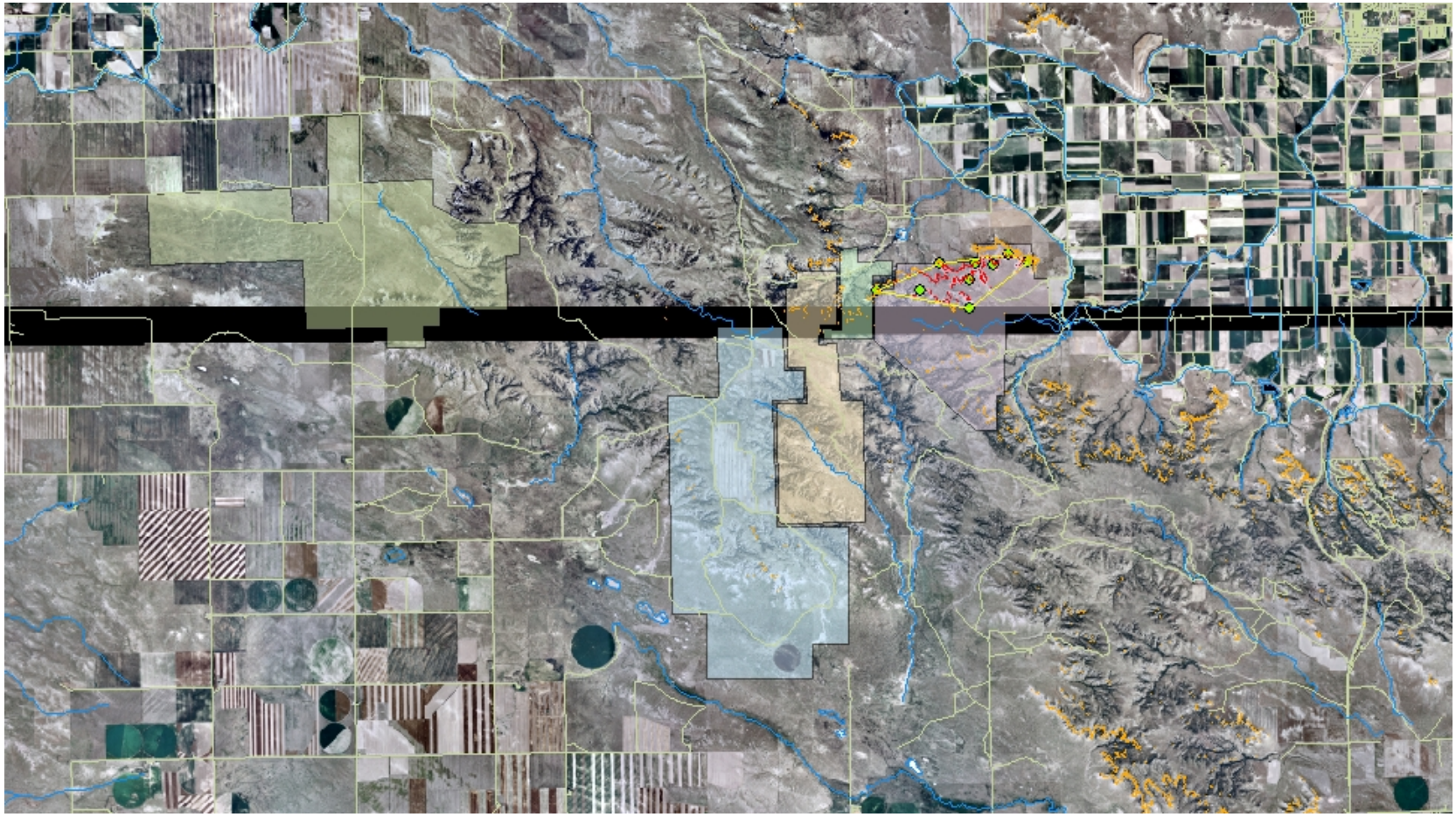


Figure 9. Image of ArcMap document – 2002 data frame.

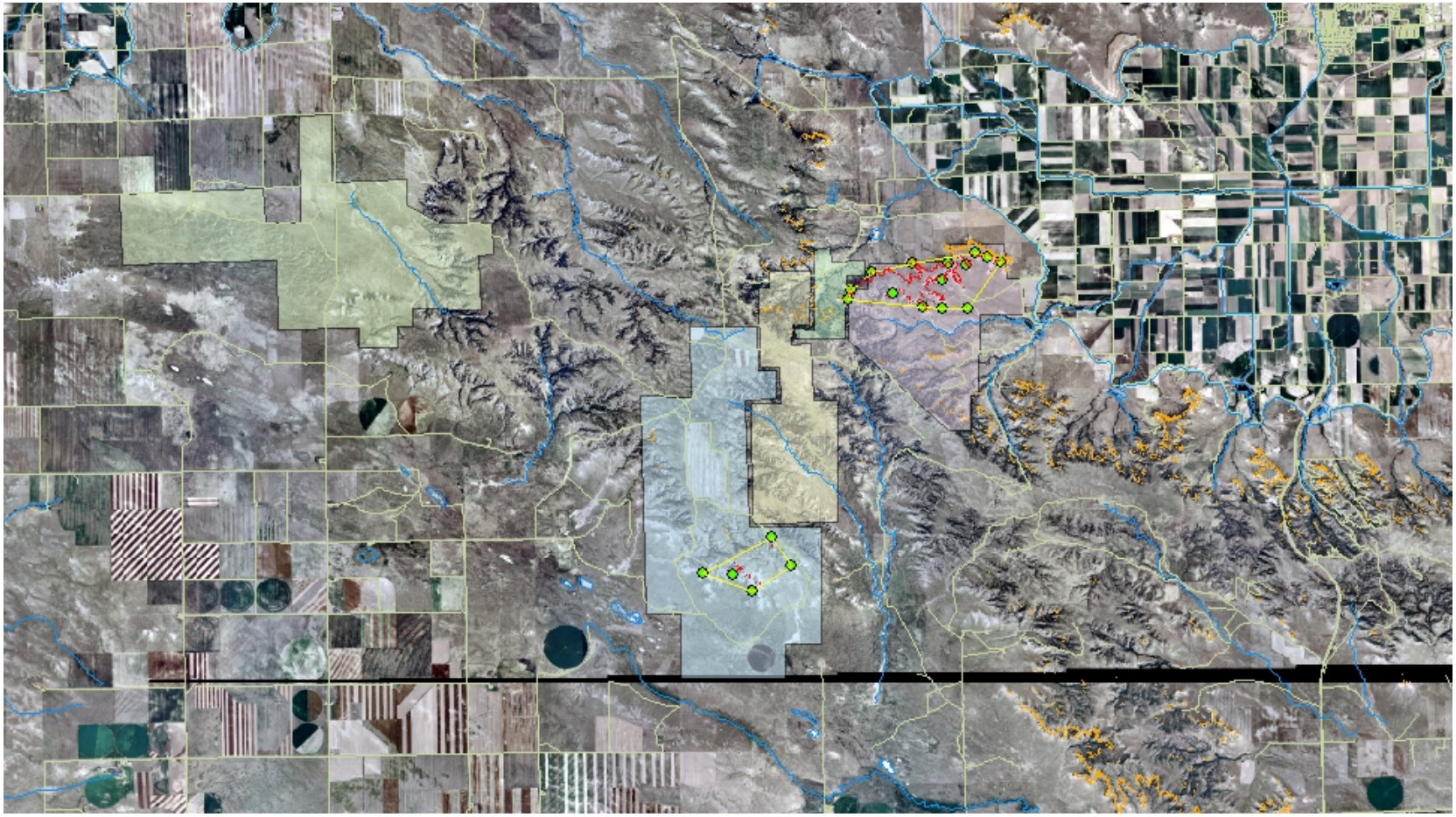


Figure 10. Image of ArcMap document – 2003 data frame.

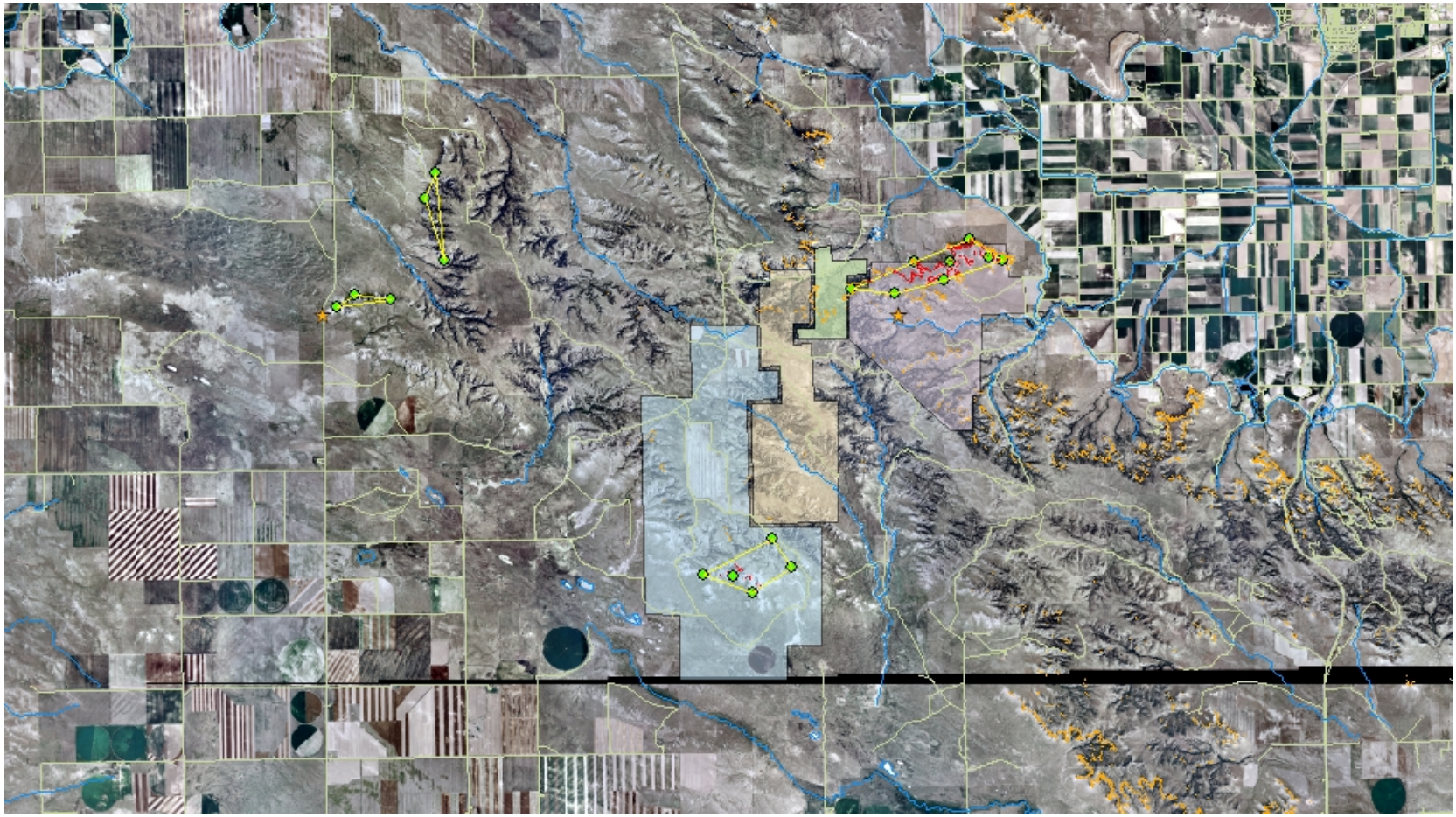


Figure 11. Image of ArcMap document – 2004 data frame.

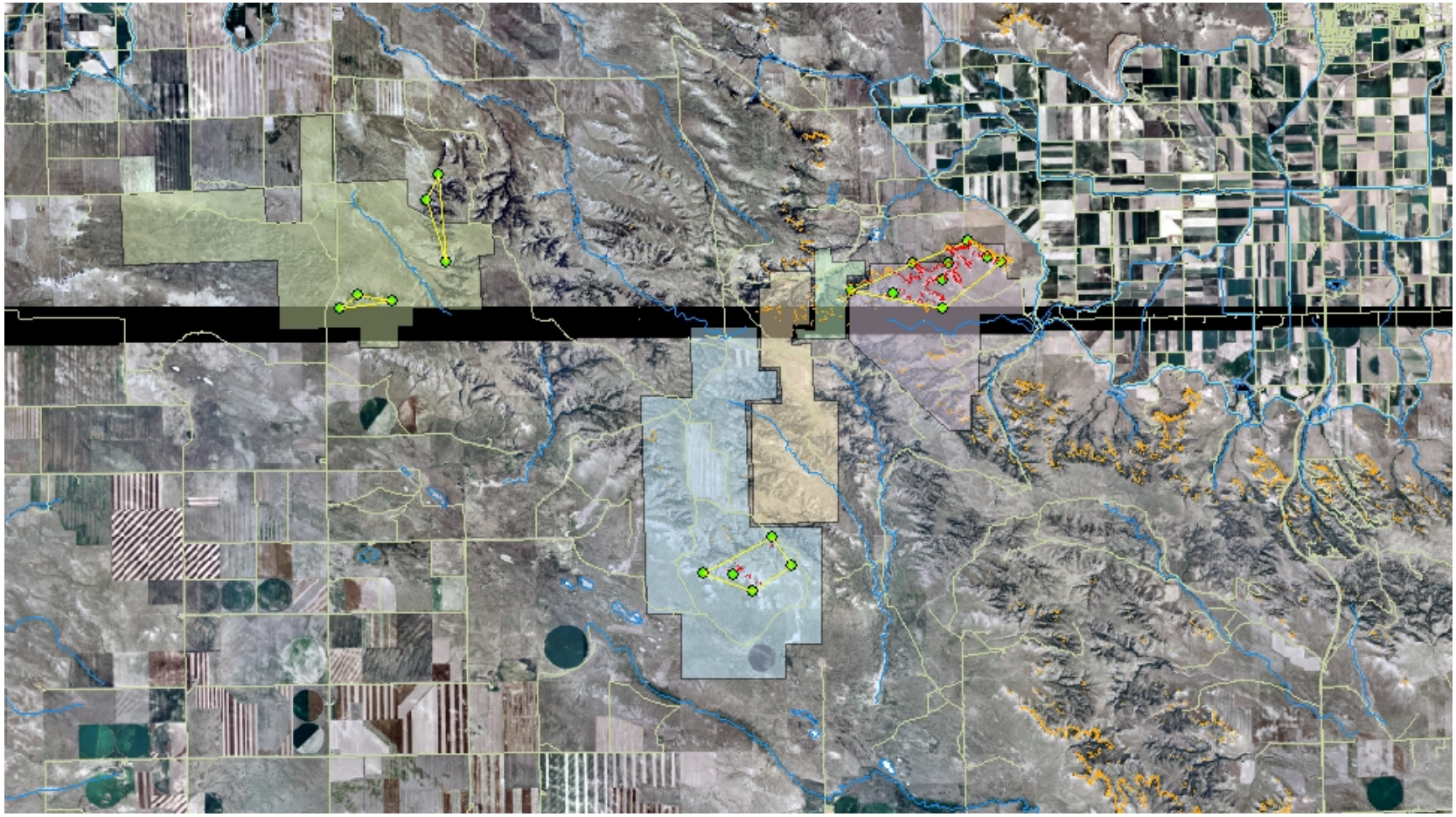


Figure 12. Image of ArcMap document – 2005 data frame.

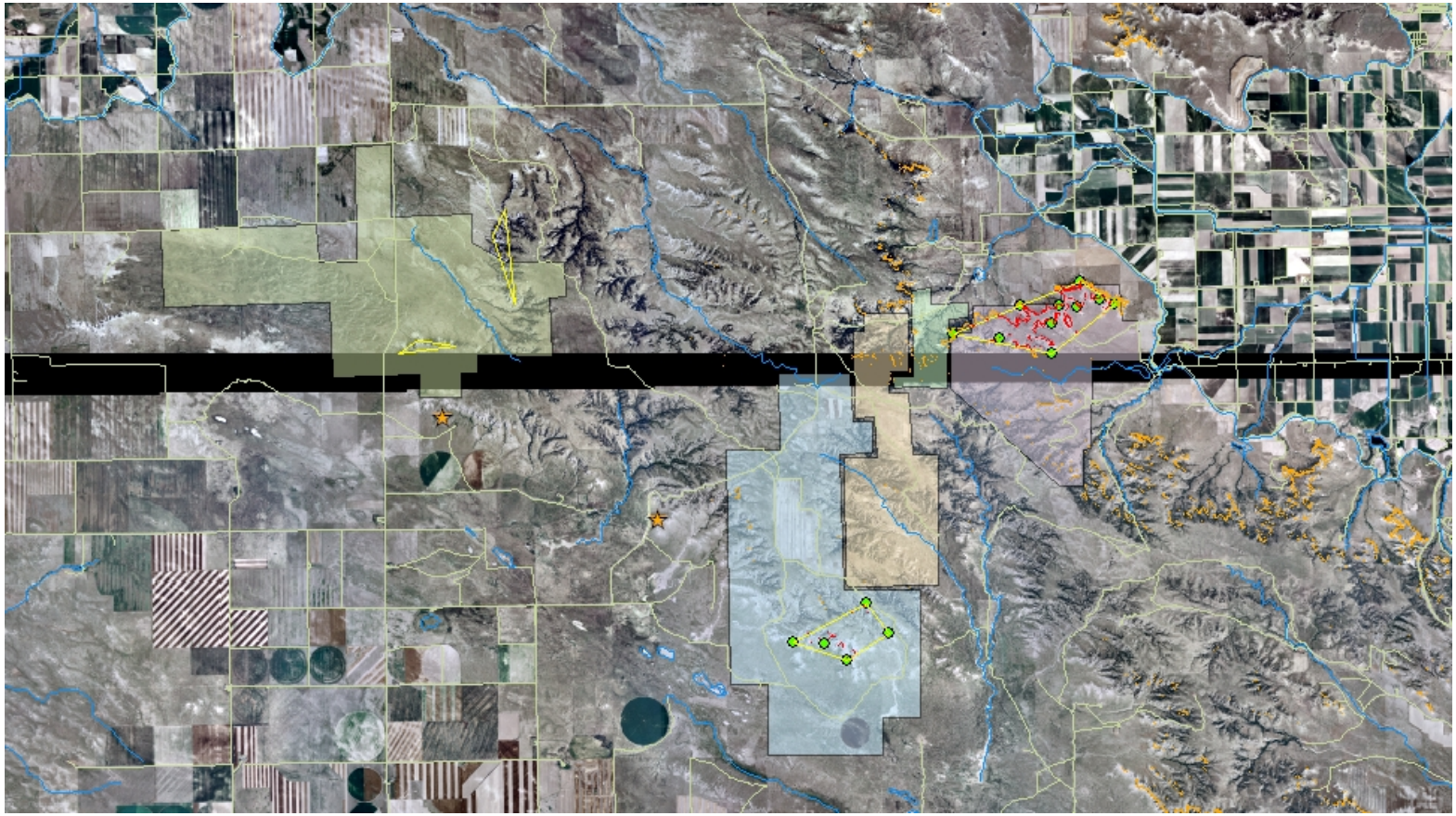


Figure 13. Image of ArcMap document – 2006 data frame.

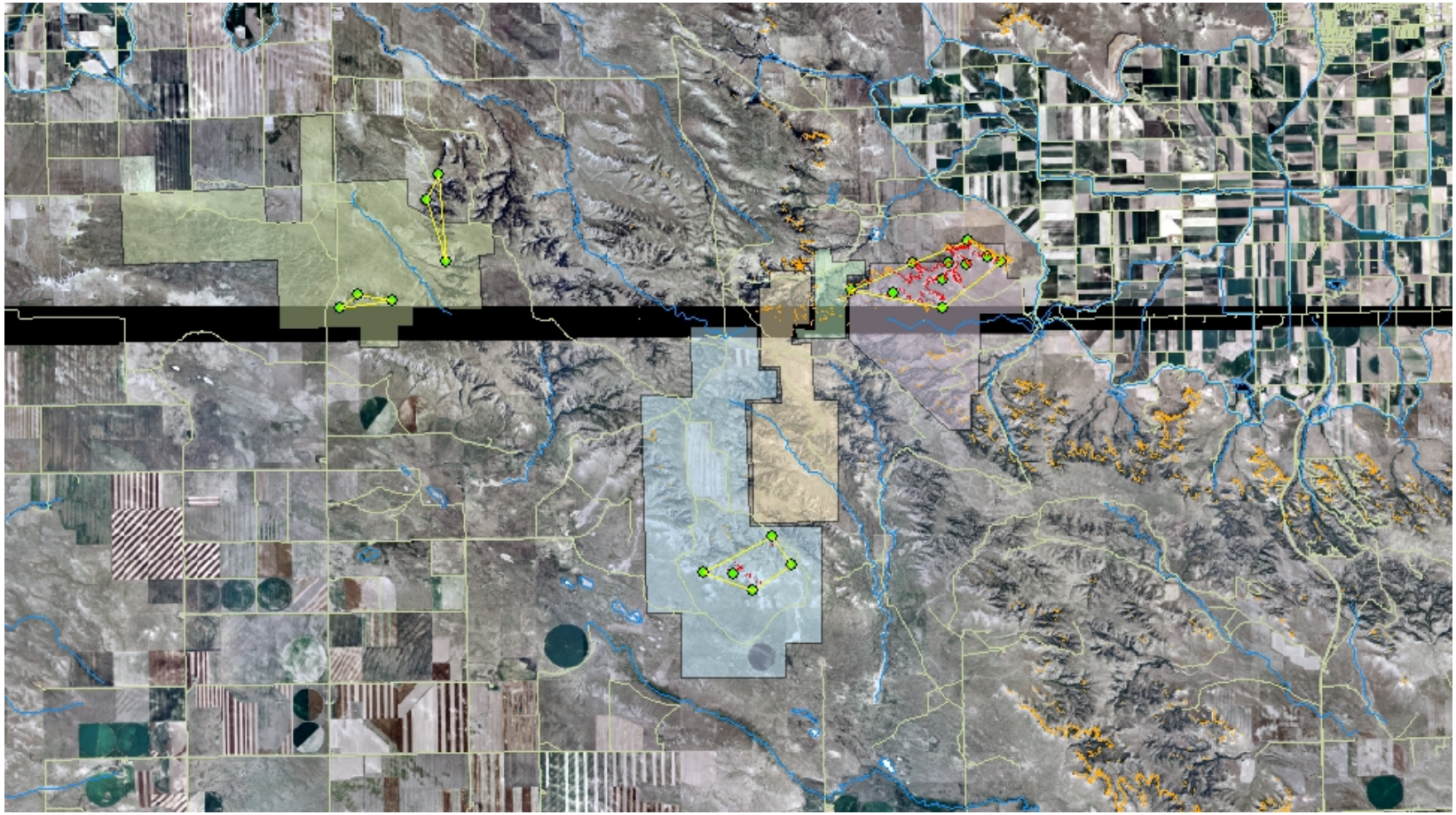


Figure 14. Image of ArcMap document – 2007 data frame.

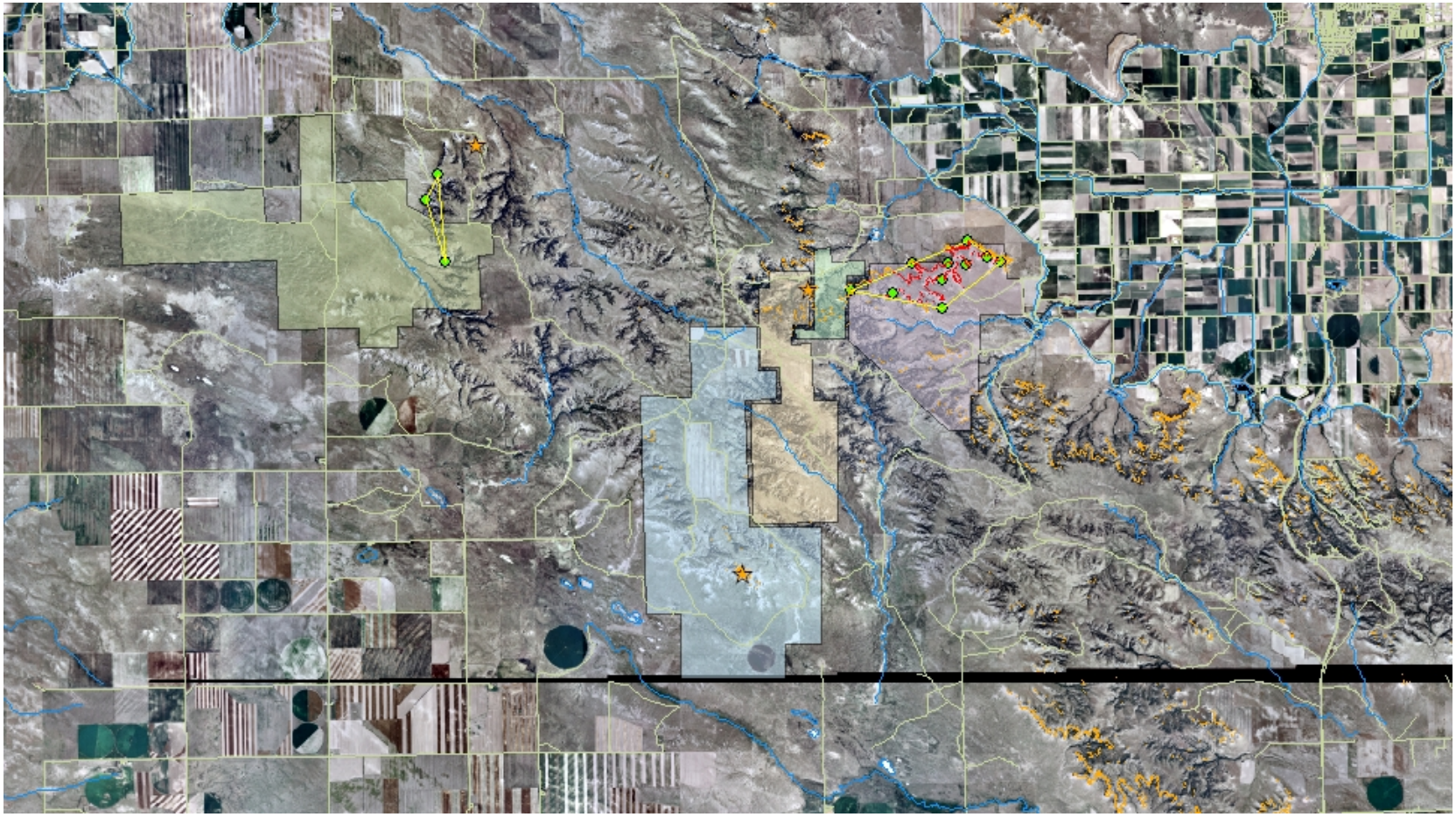
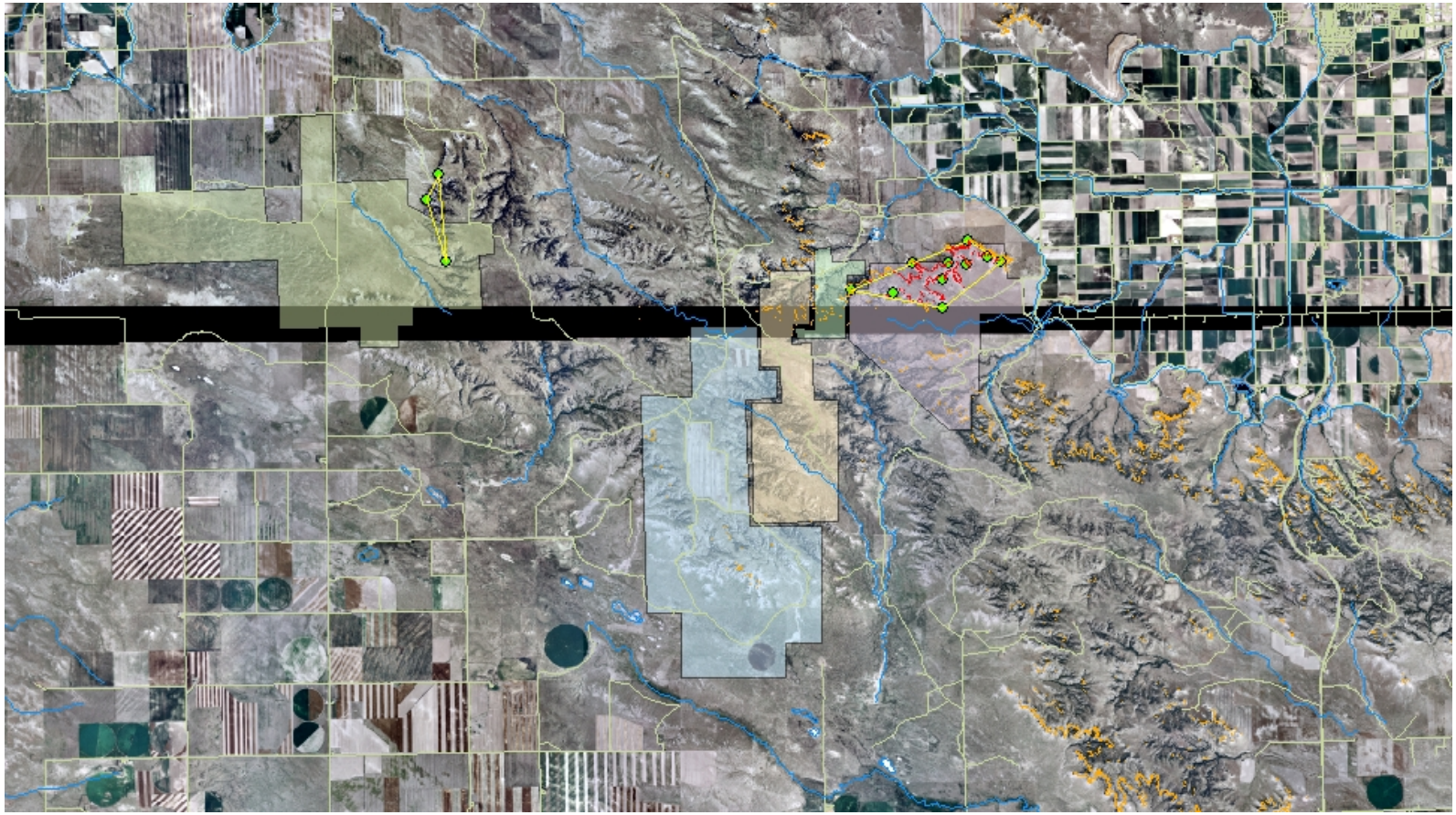


Figure 15. Image of ArcMap document – 2008 data frame.



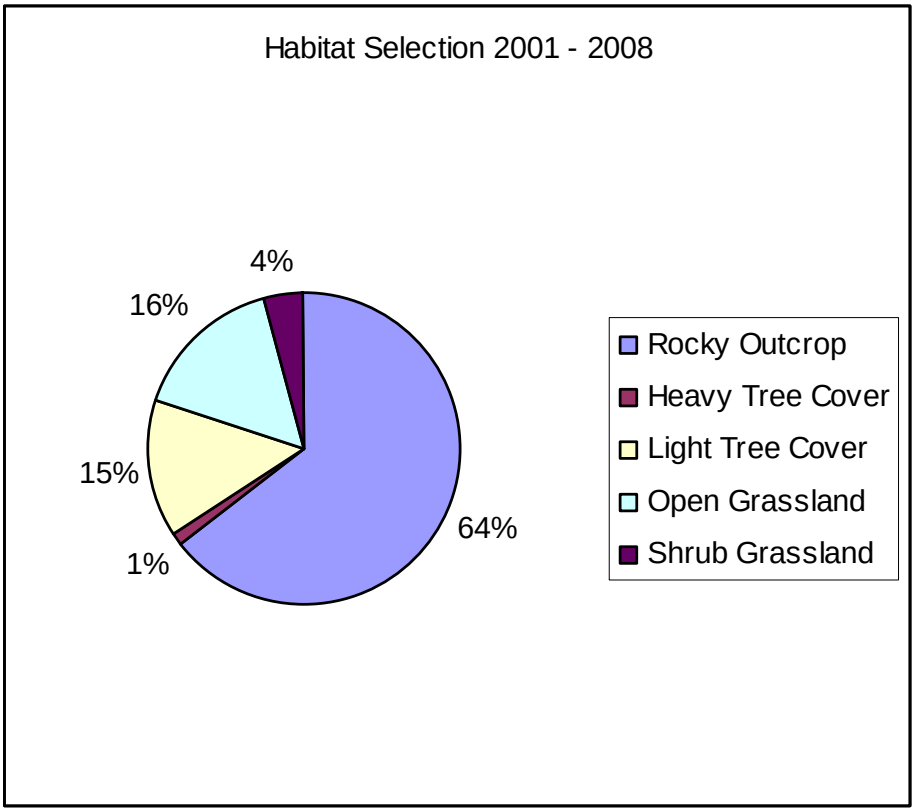
Habitat Selection and Distance Results

Based on the five categories of habitat type recorded by field technicians from 2001-2008, rocky outcrop is the preferred habitat type for bighorn sheep in the Wildcat Hills. Bighorn sheep were observed in rocky outcrop habitat 64.24% of the time. Open grasslands and light tree cover followed with percentages of 15.65 and 14.67 respectively. Bighorn sheep were observed in shrub grassland habitat only 4.24% of the time, and heavy tree cover rounded out the results with a percentage of only 1.20. These results are represented by Table 10 and Figure 16.

Table 10. 2001 – 2008 habitat selection based on number of observations.

	Habitat Selection Based on Number of Observations					
	Rocky Outcrop	Heavy Tree Cover	Light Tree Cover	Open Grassland	Shrub Grassland	Total
2001	970	26	391	272	3	1662
2002	1900	29	444	398	18	2789
2003	1711	21	234	829	0	2795
2004	487	0	97	226	5	815
2005	1246	26	159	387	93	1911
2006	2528	82	607	226	364	3807
2007	949	0	310	101	64	1424
2008	296	4	62	19	119	500
Total	10087	188	2304	2458	666	15703
% Time	**64.24**	**1.20**	**14.67**	**15.65**	**4.24**	

Figure 16. Pie chart representing habitat selection for 2001 – 2008.



Habitat selection data was also analyzed by year. From 2001 through 2008, the percentage of time that bighorn sheep were observed in rocky outcrop habitat ranged from a maximum of 67.81% in 2002 to a minimum of 58.36% in 2001. Observations of sheep in heavy tree cover were highest in 2006 (2.15%), although no observations of bighorn sheep in heavy tree cover were documented in 2004 or 2007. Light tree cover ranged from a maximum of 23.53% in 2001 to a minimum of 8.32% in 2005. In 2002, sheep were observed in open grassland habitat 29.66% of the time, but in 2008, observations in open grassland habitat were at a minimum of 3.80%. In contrast, shrub grasslands ranged from ranged from zero recorded observations in 2003 to 23.80% of observations recorded in 2008. Tables 11 – 18 and Figures 17 – 24 illustrate the changes in documented habitat selection over the past seven years.

Table 11. 2001 habitat selection data.

2001		
Habitat	**Number of Observations**	**% Time Spent in Habitat**
Rocky Outcrop	970	58.36
Heavy Tree Cover	26	1.56
Light Tree Cover	391	23.53
Open Grassland	272	16.37
Shrub Grassland	3	0.18
Total	1662	

Figure 17. Pie chart for 2001 habitat selection data.

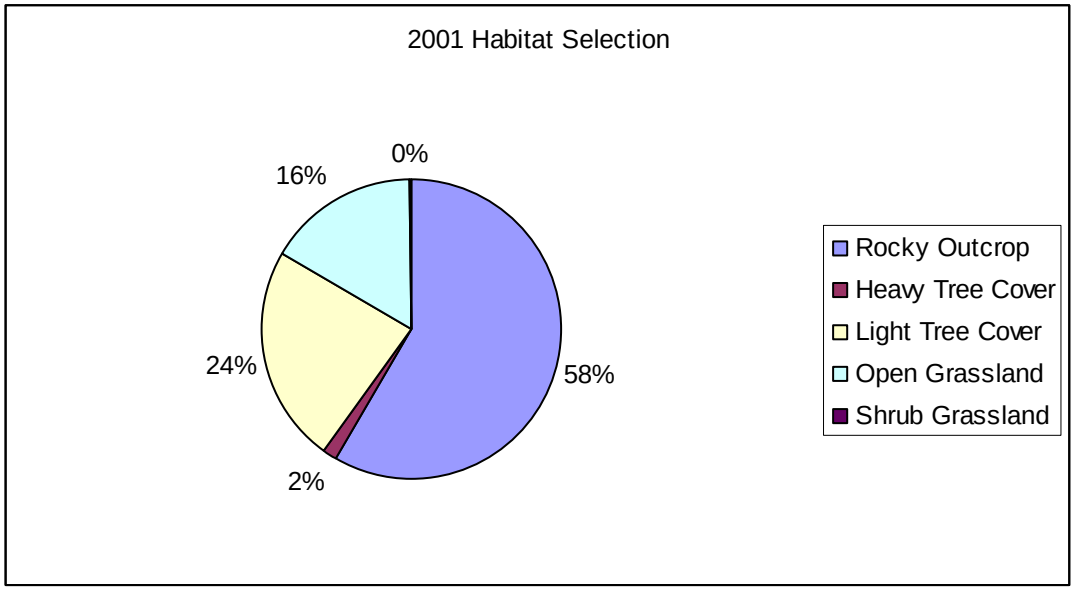


Table 12. 2002 habitat selection data.

2002		
Habitat	**Number of Observations**	**% Time Spent in Habitat**
Rocky Outcrop	1900	67.81
Heavy Tree Cover	29	1.03
Light Tree Cover	444	15.85
Open Grassland	398	14.20
Shrub Grasslands	18	0.64
Croplands	13	0.46
Total	2802	

Figure 18. Pie chart for 2002 habitat selection data.

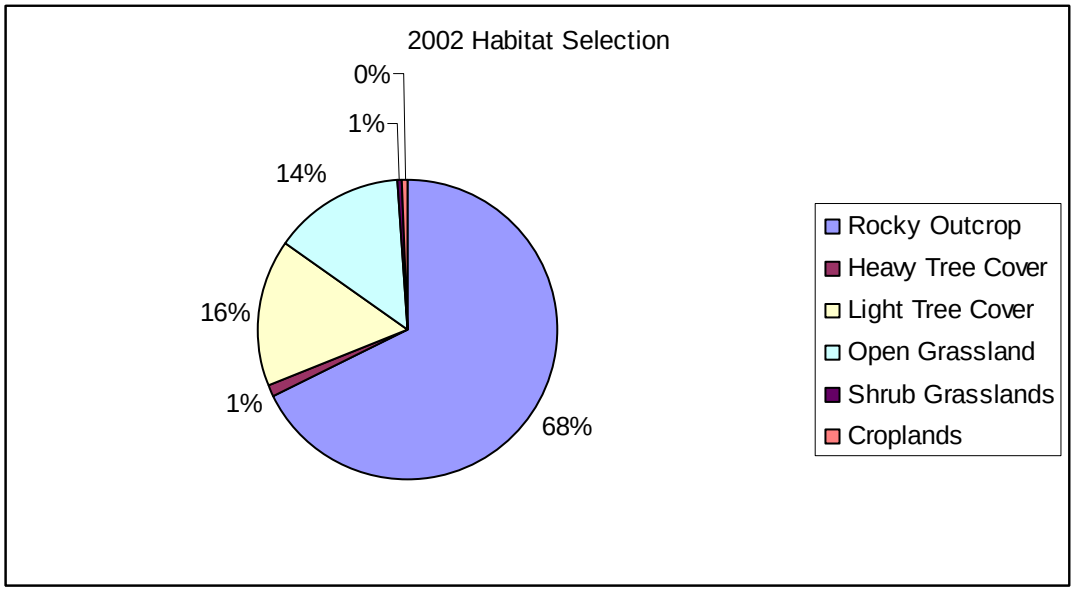


Table 13. 2003 habitat selection data.

2003		
Habitat	**Number of Observations**	**% Time Spent in Habitat**
Rocky Outcrop	1711	61.22
Heavy Tree Cover	21	0.75
Light Tree Cover	234	8.37
Open Grassland	829	29.66
Shrub Grassland	0	0.00
Total	2795	

Figure19. Pie chart for 2003 habitat selection

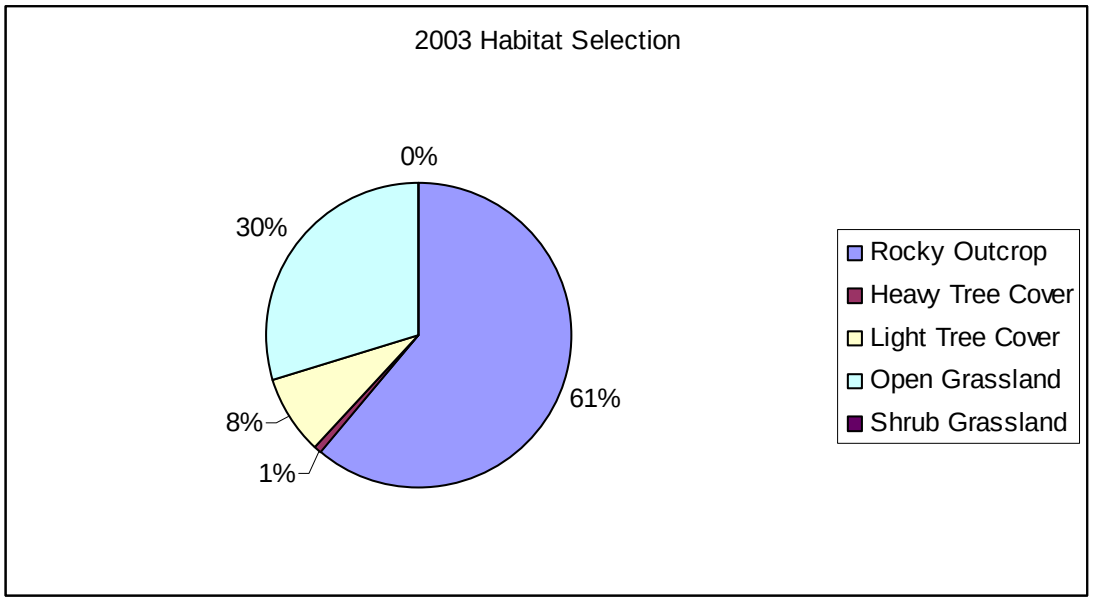


Table 14. 2004 habitat selection data.

2004		
Habitat	**Number of Observations**	**% Time Spent in Habitat**
Rocky Outcrop	487	59.75
Heavy Tree Cover	0	0.00
Light Tree Cover	97	11.90
Open Grassland	226	27.73
Shrub Grassland	5	0.61
Total	815	

Figure12. Pie chart for 2004 habitat selection data.

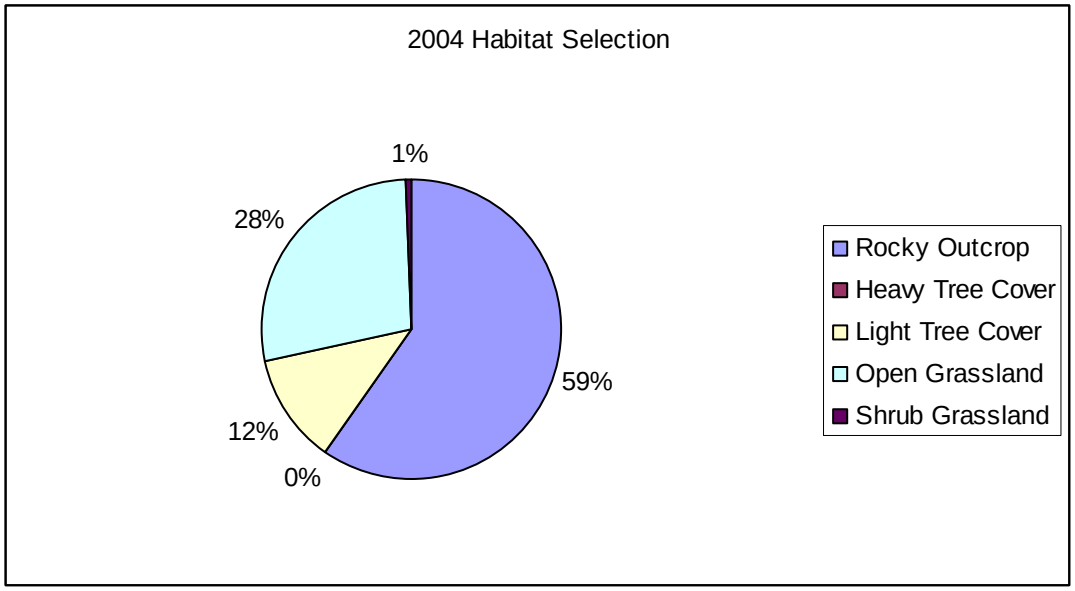


Table 15. 2005 habitat selection data.

2005		
Habitat	**Number of Observations**	**% Time Spent in Habitat**
Rocky Outcrop	1246	65.20
Heavy Tree Cover	26	1.36
Light Tree Cover	159	8.32
Open Grassland	387	20.25
Shrub Grassland	93	4.87
Total	1911	

Figure21. Pie chart for 2005 habitat selection data.

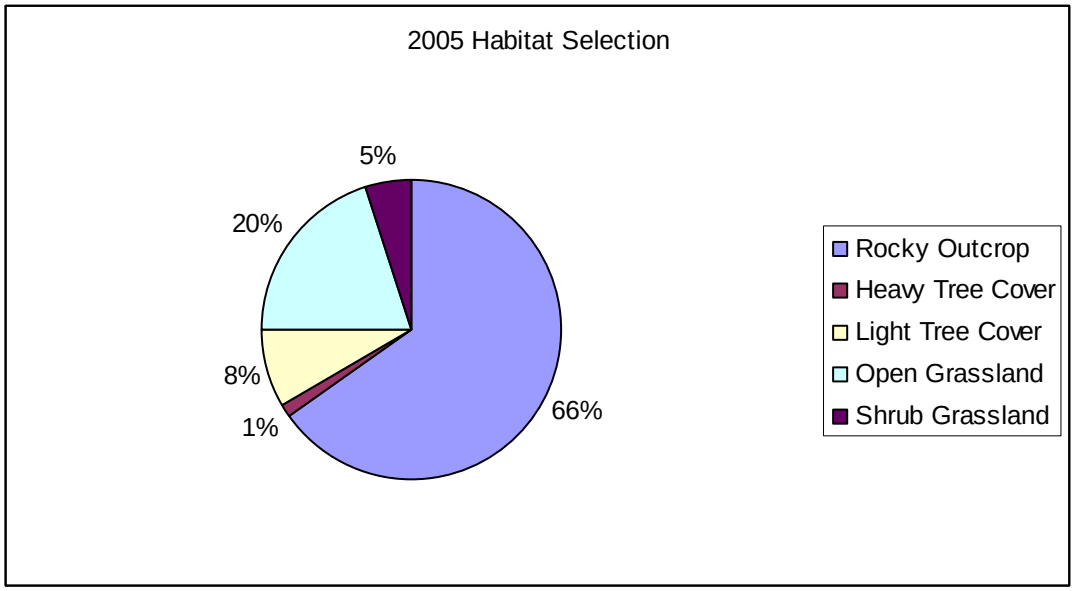


Table 16. 2006 habitat selection data.

2006		
Habitat	**Number of Observations**	**% Time Spent in Habitat**
Rocky Outcrop	2528	66.40
Heavy Tree Cover	82	2.15
Light Tree Cover	607	15.94
Open Grassland	226	5.94
Shrub Grassland	364	9.56
Total	3807	

Figure 22. Pie chart for 2006 habitat selection data.

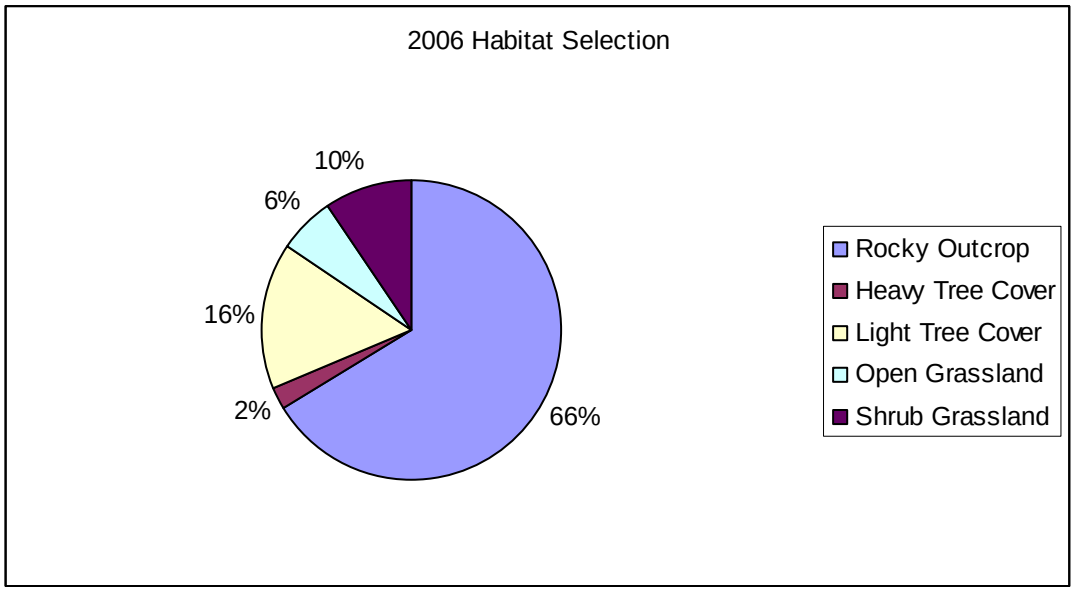


Table 17. 2007 habitat selection data.

2007		
Habitat	**Number of Observations**	**% Time Spent in Habitat**
Rocky Outcrop	949	66.69
Heavy Tree Cover	0	0.00
Light Tree Cover	310	21.78
Open Grassland	101	7.10
Shrub Grassland	63	4.43
Total	1423	

Figure23. Pie chart for 2007 habitat selection data.

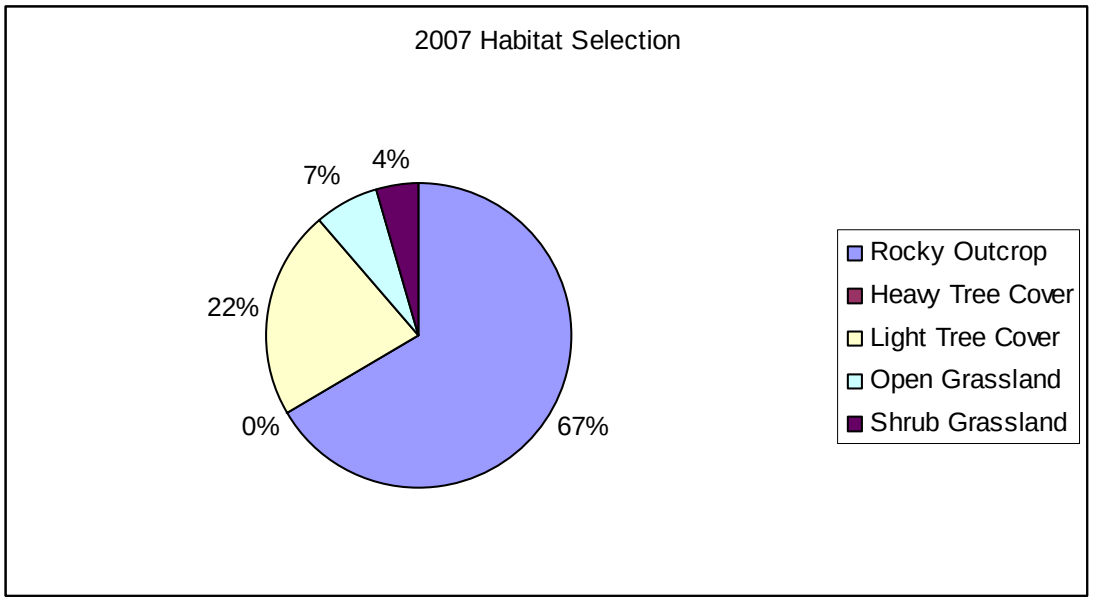
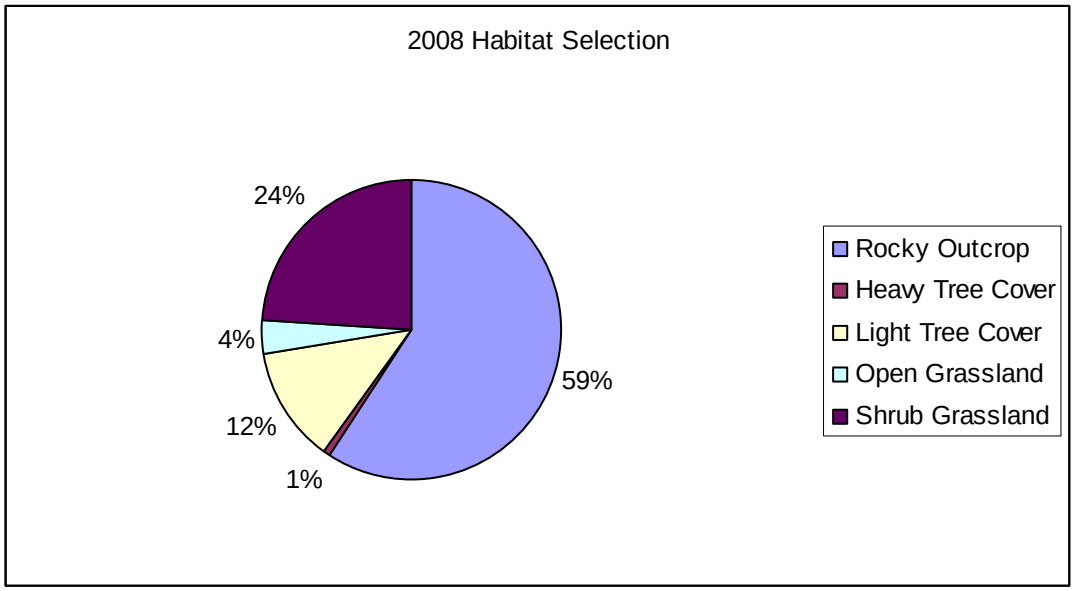


Table 18. 2008 habitat selection data.

2008		
Habitat	**Number of Observations**	**% Time Spent in Habitat**
Rocky Outcrop	296	59.20
Heavy Tree Cover	4	0.80
Light Tree Cover	62	12.40
Open Grassland	19	3.80
Shrub Grassland	119	23.80
Total	500	

Figure 24. Pie chart for 2008 habitat selection data.



Results from the distance analysis revealed that based on the four predetermined categories (<25 m, 25 – 50 m, 50 – 100 m, and >100 m), the distance from escape terrain varied widely, but the distance from water, livestock, and people remained comparatively consistent. Therefore distance from escape terrain was analyzed by year, while the other variables were analyzed in the entirety of the data set. The observed distance from water was recorded at >100 meters 99.23% of the time (Table 19), while the observed distance from livestock was documented in the >100 meters category (99.51%) of the time (Table 20). The distance from people varied slightly more, yet 84.83% of observations were documented from >100 meters away from the bighorn sheep (Table 21 and Figure 25). The distance from people data for the year of 2005 was not used because the distance from the field technician was not taken into account during 2005.

Table 19. Distance from water data based on number of observations.

	Distance from Water				
Observations	**<25 m**	**25 - 50 m**	**50 - 100 m**	**>100 m**	**Total**
2001	13	0	17	1652	1682
2002	13	0	17	2774	2804
2003	0	0	6	2823	2829
2004	0	0	11	745	756
2005	33	0	0	743	776
2006	0	0	0	3619	3619
2007	0	0	0	1330	1330
2008	0	0	0	501	501
Total	59	0	51	14187	14297
% Time	0.41	0.00	0.36	99.23	

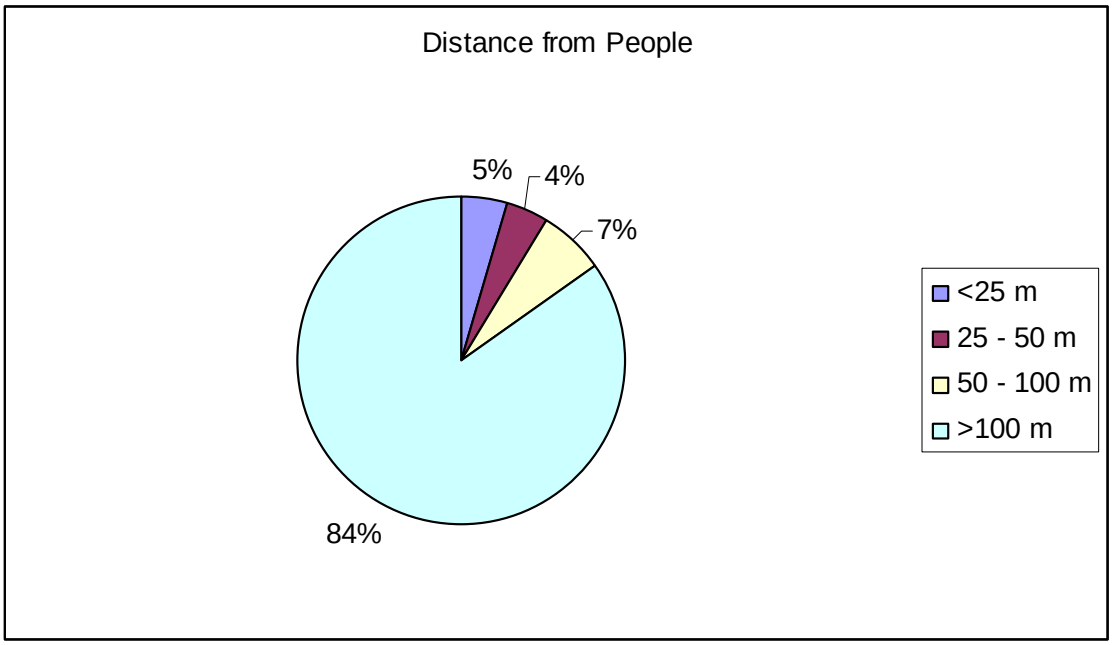
Table 20. Distance from livestock data based on number of observations.

	Distance from Livestock				
Observations	**<25 m**	**25 - 50 m**	**50 - 100 m**	**>100 m**	**Total**
2001	13	0	0	1652	1665
2002	0	0	4	2817	2821
2003	11	0	11	2800	2822
2004	0	0	0	893	893
2005	0	5	28	1029	1062
2006	0	0	0	3601	3601
2007	0	0	0	1246	1246
2008	0	0	0	501	501
Total	24	5	43	14539	14611
% Time	0.16	0.03	0.29	99.51	

Table 21. Distance from people data based on number of observations.

	Distance from People				
Observations	**<25 m**	**25 - 50 m**	**50 - 100 m**	**>100 m**	**Total**
2001	27	0	64	1537	1628
2002	10	44	59	2706	2819
2003	204	125	66	2434	2829
2004	6	19	19	711	755
2006	200	204	388	2821	3613
2007	116	123	217	829	1285
2008	50	37	60	354	501
Total	613	552	873	11392	13430
% Time	4.56	4.11	6.50	84.83	

Figure 25. Pie chart for distance from people data.



Overall, 53.34% of recorded observations documented the sheep at less than 25 meters from escape terrain. In contrast, 23.19% of recorded observations documented a distance of greater than 100 meters between the sheep and escape terrain. The percentages for the categories of 25 – 50 meters and 50 – 100 meters were 14.02% and 9.45% respectively. This data is outlined in Table 22 and Figure 26. The yearly distance data is represented by Tables 23 – 30 and Figures 27 – 24.

Table 22. Distance from escape terrain data based on number of observations.

	Distance from Escape Cover				
Observations	**<25 m**	**25 - 50 m**	**50 - 100 m**	**>100 m**	**Total**
2001	1328	24	26	1328	2706
2002	2381	181	164	95	2821
2003	1937	239	107	546	2829
2004	483	128	140	132	883
2005	684	248	255	524	1711
2006	1260	936	579	693	3468
2007	500	359	225	294	1378
2008	115	169	43	165	492
Total	8688	2284	1539	3777	16288
% Time	53.34	14.02	9.45	23.19	

Figure 26. Pie chart for distance from escape terrain data.

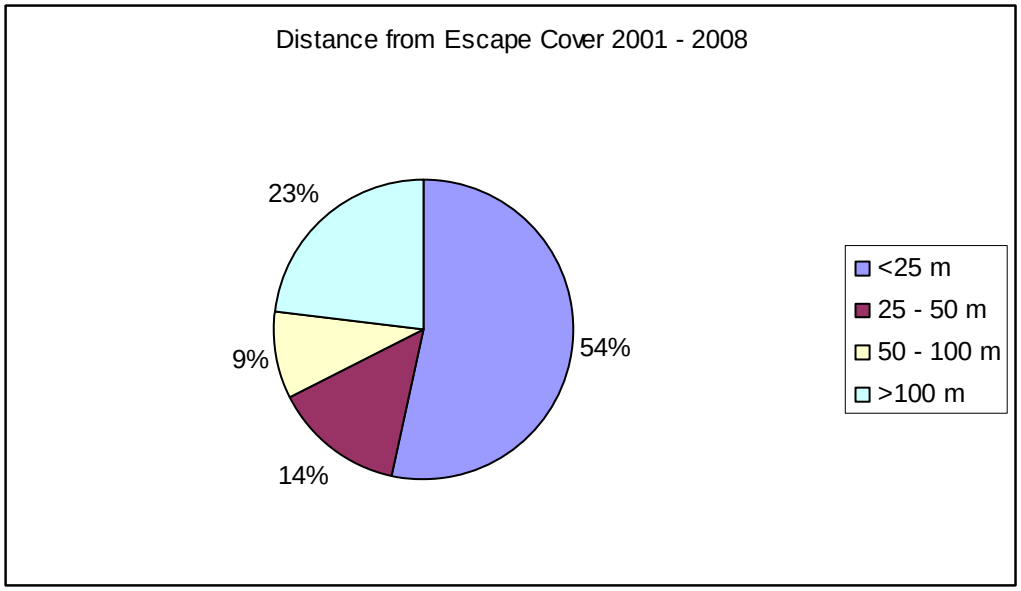


Table 23. Distance from escape terrain – 2001 data.

2001		
Distance from Escape	**Number of Observations**	**% Time**
<25 m	1328	85.02
25 - 50 m	24	1.54
50 - 100 m	26	1.66
>100 m	184	11.78
Total	1562	

Figure 27. Pie chart for distance from escape terrain – 2001 data.

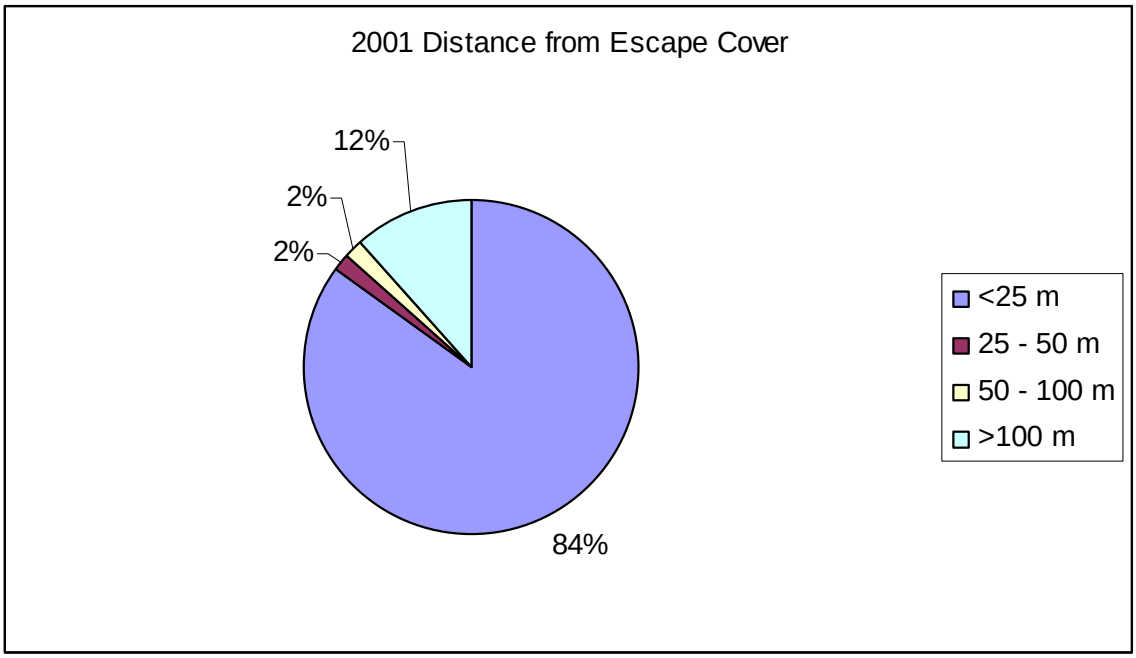


Table 24. Distance from escape terrain - 2002 data.

2002		
Distance from Escape	**Number of Observations**	**% Time**
<25 m	2381	84.40
25 - 50 m	181	6.42
50 - 100 m	164	5.81
>100 m	95	3.37
Total	2821	

Figure 28. Pie chart for distance from escape terrain – 2002 data.

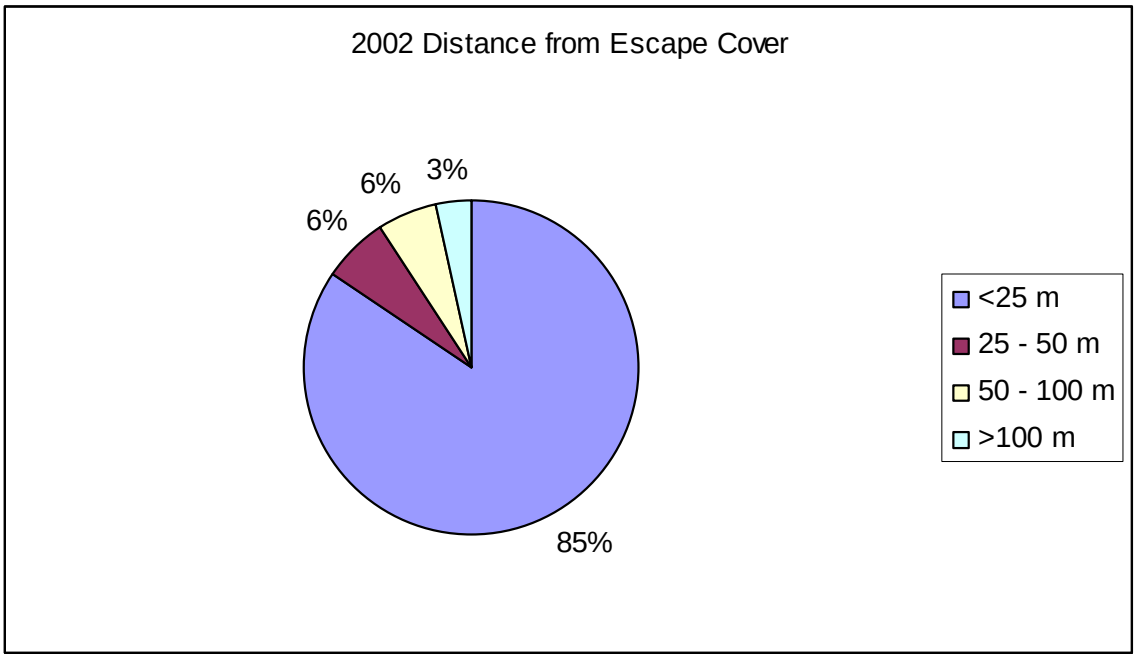


Table 25. Distance from escape terrain - 2003 data.

2003		
Distance from Escape	**Number of Observations**	**% Time**
<25 m	1937	68.47
25 - 50 m	239	8.45
50 - 100 m	107	3.78
>100 m	546	19.30
Total	2829	

Figure 29. Pie chart for distance from escape terrain – 2003 data.

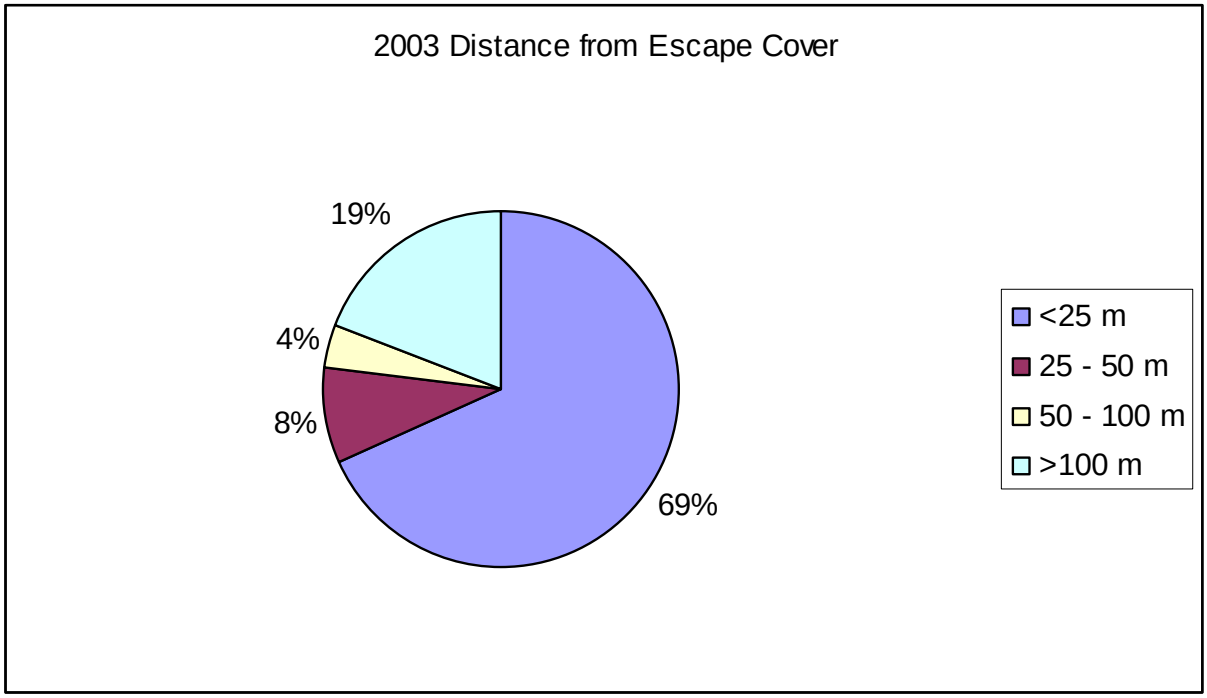


Table 26. Distance from escape terrain - 2004 data.

2004		
Distance from Escape	**Number of Observations**	**% Time**
<25 m	483	54.70
25 - 50 m	140	15.86
50 - 100 m	132	14.95
>100 m	128	14.50
Total	883	

Figure 30. Pie chart for distance from escape terrain – 2004 data.

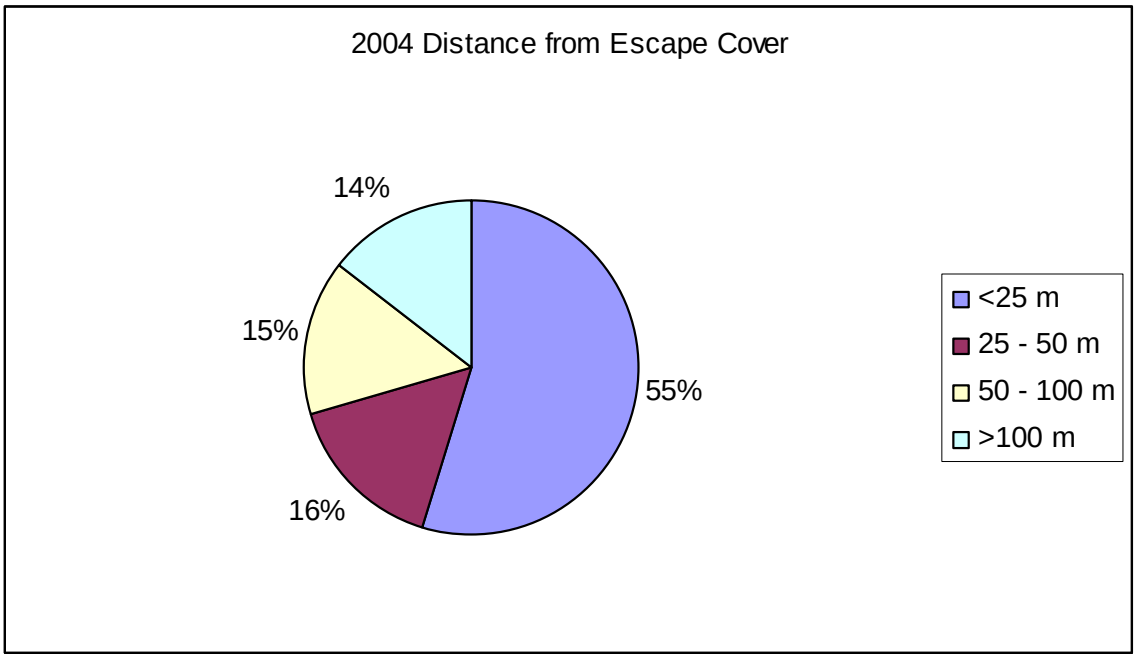


Table 27. Distance from escape terrain - 2005 data.

2005		
Distance from Escape	**Number of Observations**	**% Time**
<25 m	684	39.98
25 - 50 m	248	14.49
50 - 100 m	255	14.90
>100 m	524	30.63
Total	1711	

Figure 31. Pie chart for distance from escape terrain – 2005 data.

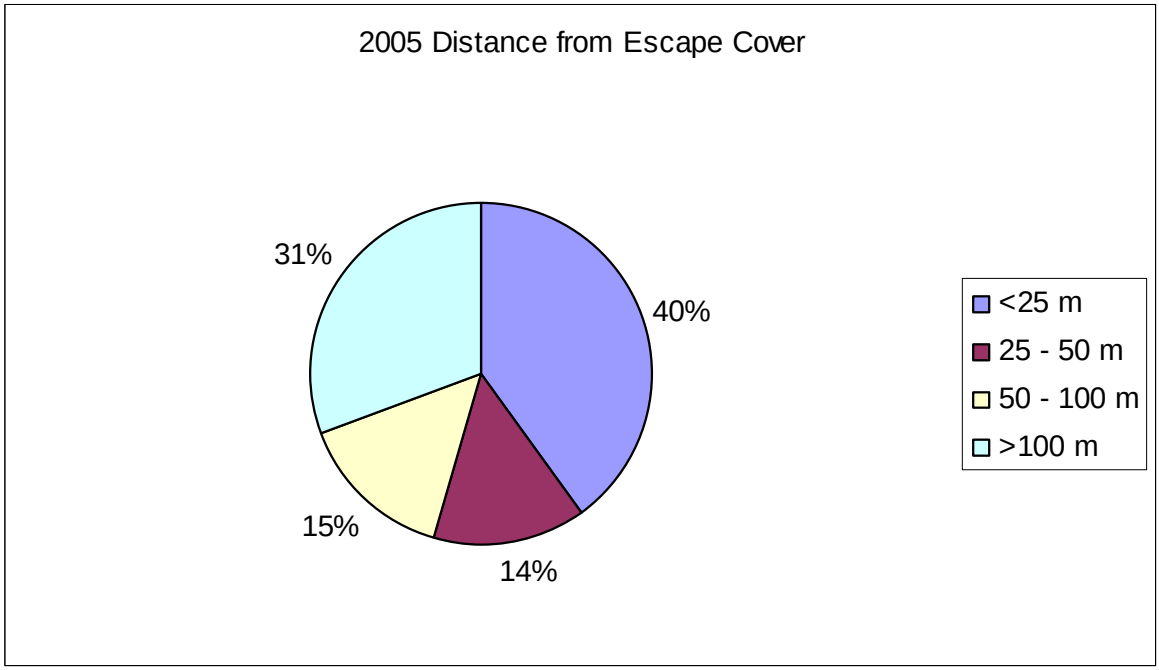


Table 28. Distance from escape terrain - 2006 data.

2006		
Distance from Escape	**Number of Observations**	**% Time**
<25 m	1260	36.33
25 - 50 m	936	26.99
50 - 100 m	579	16.70
>100 m	693	19.98
Total	3468	

Figure 32. Pie chart for distance from escape terrain – 2006 data.

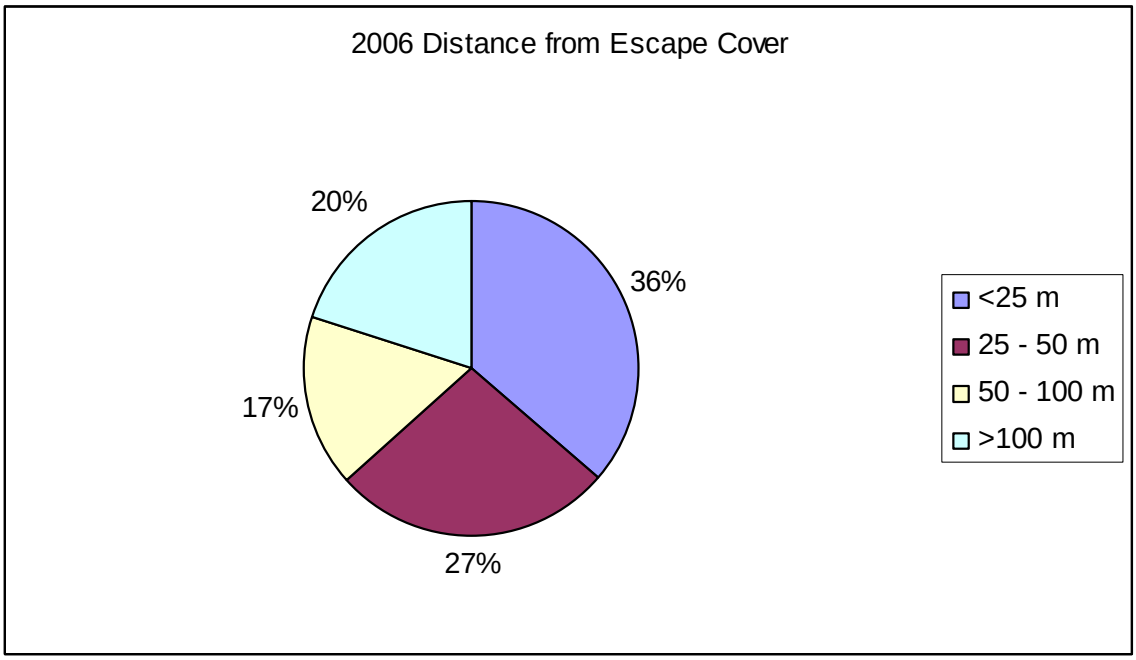


Table 29. Distance from escape terrain - 2007 data.

2007		
Distance from Escape	**Number of Observations**	**% Time**
<25 m	500	36.28
25 - 50 m	359	26.05
50 - 100 m	225	16.33
>100 m	294	21.34
Total	1378	

Figure 33. Pie chart for distance from escape terrain – 2007 data.

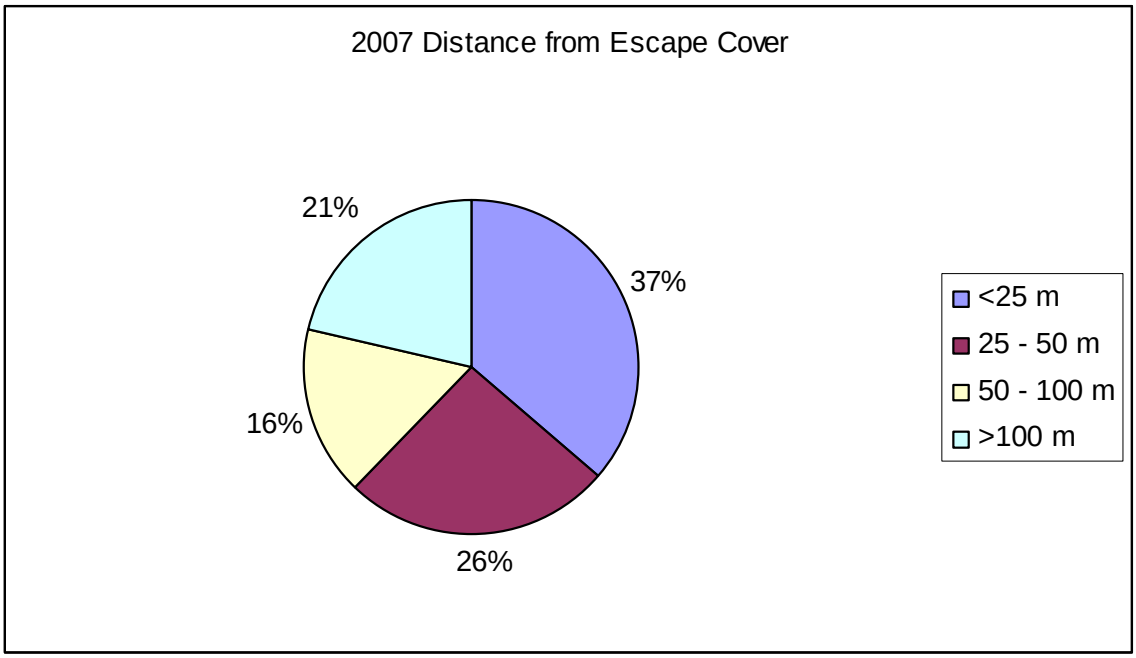
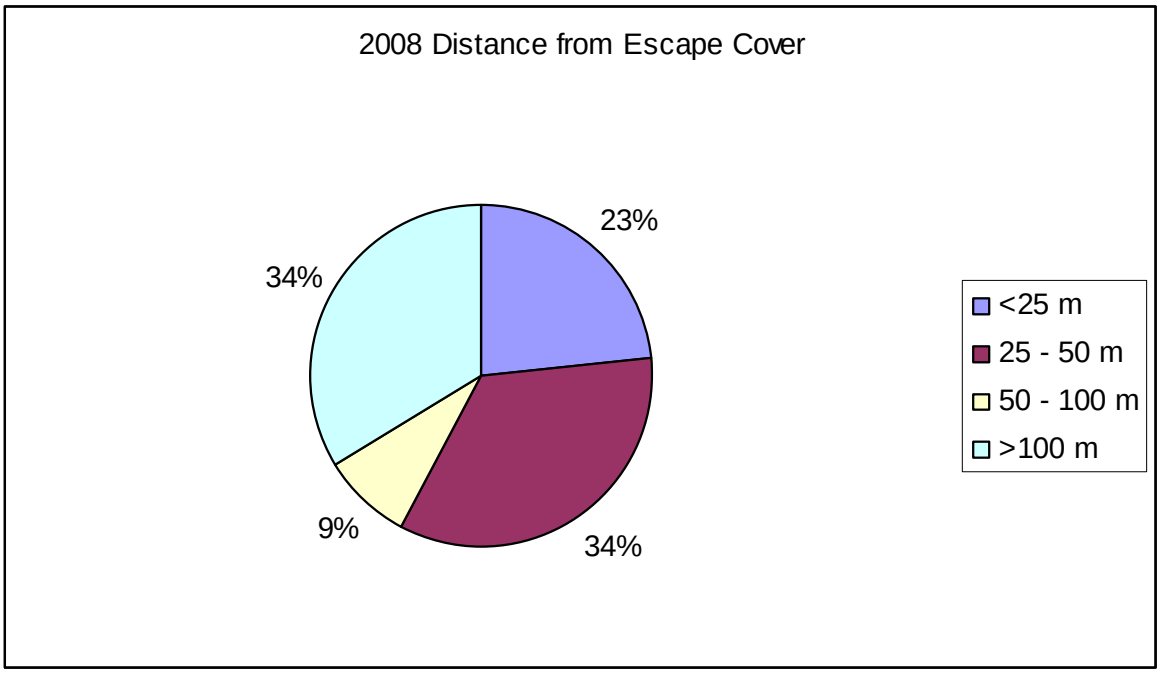


Table 30. Distance from escape terrain - 2008 data.

2008		
Distance from Escape	**Number of Observations**	**% Time**
<25 m	115	23.37
25 - 50 m	169	34.35
50 - 100 m	43	8.74
>100 m	165	33.54
Total	492	

Figure 34. Pie chart for distance from escape terrain – 2008 data.



DISCUSSION

The aim of this research project was to assess physiological stress response of bighorn sheep in the Wildcat Hills of western Nebraska, especially as it relates to the respiratory disease complex that devastated the population in early 2006. Additionally, the project focused on distribution and areas inhabited by the sheep since the reintroduction, which took place in March of 2001. The specific objectives of the project were to: (1) develop a database of information about bighorn sheep physiological stress response, especially as it relates to respiratory disease, (2) identify potential stressors to which bighorn sheep may be exposed in the Wildcat Hills, both inside and outside of Cedar Canyon Wildlife Management Area, (3) quantify the stress levels of reintroduced, low elevation bighorn sheep, and (4) analyze field data to examine home range and distribution patterns in correlation with habitat selection and distance from water, people, livestock, and escape cover.

Physiological stress response was assessed through fecal glucocorticoid metabolite assays. Arguably the most interesting results of the glucocorticoid assays revealed that bighorn sheep inhabiting the Montz and Hampton properties experience significantly increased levels of corticosterone in comparison to sheep inhabiting CCWMA and areas in the immediate vicinity. The difference could be attributed to numerous variables, and should be discussed in light of the respiratory disease epidemic of 2006. Also worthy of note is the change in primary areas inhabited following the epidemic. The ArcMap project revealed that the sheep have not occupied the Hampton property or the south ridge of the Montz property in substantial numbers or for significant

time periods since the dieoff, and this change should be considered as it may relate to the elevated corticosterone levels of sheep inhabiting these areas.

The dynamics of this large scale, all-age dieoff suggest that stress may have played a role in the ultimate outcome of the epidemic. At the time of the dieoff, the population was split primarily into two sub-herds. Rams traveled back and forth between the sub-herds, but the ewes had formed two groups that resided in different areas for much of the year. While one group resided primarily within CCWMA and areas in the immediate vicinity, the other traveled back and forth between two private properties (the Montz property and the Hampton property) and only returned to CCWMA on occasion. Through live capture and sample collection as well as necropsy work, it was determined that sheep from both sub-herds were carrying multiple subspecies of *Pasteurella.* Ultimately, however, the respiratory disease devastated the sub-herd inhabiting the Montz and Hampton properties while the CCWMA sub-herd remained stable. Overall, approximately half the population was lost in the epidemic. All of the carcasses that were found were located on the Hampton property. There were no confirmed mortalities within CCWMA resulting from the respiratory disease dieoff.

Although there were no observations of sheep inhabiting the Montz property during the epidemic, the mortalities began only a few days after the sheep traveled to the Hampton property from the Montz property. Since the large-scale dieoff, sheep have not inhabited the Hampton property in substantial numbers or for more than a few days at a time. Therefore only a few fecal samples could be collected from the Hampton property, which makes assessing potential stressors that are specific to that area especially difficult. The reason why the area is not currently inhabited remains unknown. Samples collected

from the Montz property, however, revealedl higher concentrations of corticosterone than samples collected from CCWMA, and this suggests that sheep inhabiting this particular private land area may be under increased stress.

One of the variables that could have contributed to the increased corticosterone levels is livestock. The Montz and Hampton property are both periodically grazed by cattle, while CCWMA is generally not grazed, and was never grazed throughout the duration of the study. Although numerous variables may have been contributed to the increased corticosterone levels, the grazing is the most obvious difference between CCWMA and the Montz and Hampton properties.

The existence of competition between cattle and bighorn sheep is debatable. Because bighorn sheep prefer steeper slopes in comparison to the gentle slopes typically used by cattle, ranges generally do not overlap spatially. It has been suggested that bighorn sheep prefer slopes > 30% in contrast to the ≤ 30% slopes favored by cattle during the winter (Lauer and Peek 1976). Although earlier studies did not reveal competition between cattle and bighorn sheep (Halloran and Blanchard 1950, Couey 1959, and Arellano 1961), it has been argued that bighorn sheep have not used certain gentle slopes due to the grazing of cattle on these areas (Barmore 1962).

The analysis of data collected since the reintroduction in 2001 revealed that bighorn sheep were documented at distances greater than 100 meters from livestock 99.51% of the time. From these results, it could be inferred that bighorn sheep generally avoid close contact with cattle. However, this data may not be adequate to accurately reflect the complex relationship between bighorn sheep and cattle in the Wildcat Hills. In

hindsight, the categories of <25 m, 25 – 50 m, 50 – 100 m, and >100 m, may not have been sufficient to accurately represent the variable.

Bighorn sheep are almost always observed further than 100 meters away from livestock in the Wildcat Hills, but competition cannot be ruled out based on this data. The relationship between cattle would have been more accurately represented by documenting actual or approximate distance from livestock rather than distance based on small-scale categories. Furthermore, the data does not exemplify occurrences of cattle in areas generally used by bighorn sheep or the observed utilization of resources that have been determined to be important to the sheep.

Although very few direct interactions between cattle and bighorn sheep have been documented within the Montz or Hampton properties, it is plausible that the Hampton property is no longer used by sheep due to an avoidance of cattle. It has been suggested that although bighorn sheep may not compete directly with cattle for space or resources, they often exhibit a level of social intolerance for cattle (King and Workmann 1984), and numerous studies support the argument that bighorn sheep avoid areas grazed by cattle (Barmore 1962, Albrechtsen and Reese 1970, Ferrier and Bradley 1970, Dean 1975, and Gallizioli 19977). This avoidance could also be attributed to overgrazing and a resulting lack of adequate bighorn sheep forage in grazed areas.

Based on this available information about the relationship between cattle and bighorn sheep, it could be speculated that the increased corticosterone levels found in fecal samples collected on the Montz property were at least partially influenced by the presence of cattle in the area. It was suggested that an outbreak of respiratory disease in Aravaipa Canyon, Arizona that reduced the desert bighorn population by 52% was a

result of livestock related viral disease compounded by stress related to nutrition (Mouton et al. 1991). The outcome of the epidemic in the Wildcat Hills in early 2006 may have been related to these variables in a similar manner.

However, there are numerous other variables to consider in the investigation of potential causes of elevated corticosterone levels in samples collected on the Montz property. One important consideration is the number of sheep inhabiting the Montz property in comparison to the number inhabiting CCWMA throughout the study. Throughout the duration of the study, only a small group of sheep inhabited the Montz property. For the majority of the time, this group included two adult ewes, a yearling ewe, two lambs, and several young rams that tended to come and go on a regular basis. This group was significantly smaller than the group or groups inhabiting CCWMA. Typically there were over a dozen adult ewes comprising a group at CCWMA in addition to the majority of yearlings and lambs of the population and rams that were frequently observed with the herd.

The small size of the group inhabiting the Montz property during much of the study period could be directly related to the increased corticosterone levels due to variables such as alertness and foraging efficiency. A relationship between increased foraging efficiency and increased group size at least up to five sheep has been demonstrated, and it has been determined that sheep in small groups were more likely to momentarily cease foraging activity to scan their surroundings in alertness than were sheep in larger group (Risenhoover and Bailey 1985). Similar studies revealed that sheep foraging efficiency increased with group size up to 20 animals, and solitary sheep were three times more alert than individuals in groups of 20 animals (Berger 1978 and

Simmons 1982). Despite the individual increased alertness in small groups, the combined alertness of sheep foraging in groups of 20 animals afforded nearly seven times the number of alert postures per minute, and therefore it could be said that the ability to detect predators or other threats increases with group size. Considering this correlation between group size and increased foraging efficiency and predator detection ability, it could be inferred that sheep in smaller groups naturally experience high levels of stress in comparison to individuals comprising large groups. This could contribute to an explanation for the higher levels of corticosterone in the samples collected from the Montz property compared with the CCWMA samples.

Ultimately, further research is necessary to determine the cause of the increased fecal glucocorticoid metabolite concentrations in samples collected from the Montz property. Cattle and small group size are two variables that could serve as focal points for future research projects aiming to assess stress in this bighorn sheep population. Differences in terrain, available escape cover, extent and degree of tree cover, and resources such as forage and water are other variables that could be examined with regard to differences in glucocorticoid levels across the areas.

In addition to comparisons of samples collected across different areas, fecal glucocorticoid metabolite results were grouped and compared by season. The results of this project largely support another study (Goldstein et al. 2005) which demonstrated that bighorn sheep glucocorticoid levels appear to reflect a cyclical pattern based on the seasons, with the highest levels measured in the summer and the lowest levels measured in the winter. One important consideration however, is that according to the results of this project, corticosterone levels of ewes are actually slightly higher in the spring than in

the summer months. It can be inferred that this is due to the lambing season. Ram corticosterone levels, on the other hand, were higher in summer than spring. Overall, it does appear that there is a natural fluctuation of fecal glucocorticoid metabolites based on the seasons. It is plausible that these fluctuations are more a result of normal seasonal metabolic rhythms than a result of actual seasonal changes in the degree of physiological stress experienced by the animals. Therefore caution is urged in the interpretation of the seasonal comparisons of fecal glucocorticoid metabolite measurements used in this study.

This project did not reveal significant differences in corticosterone levels of rams compared to ewes, nor did it reveal significant differences in the comparison of adults and yearling with lambs. Therefore age class and sex of bighorn sheep may have little effect on the concentration of corticosterone found in fecal samples. Ultimately, this may mean that males and females, as well as adults and lambs, all face similar stressors and respond to them in similar ways.

This project also revealed no significant difference between average corticosterone levels of five adult ewes from which samples were collected throughout the duration of the study. Further research that involves very consistent sampling from individuals over extended periods of time would be necessary to draw solid conclusions about differences in individual corticosterone levels. For purposes of this study, the individual ewe results provide preliminary baseline data illustrating corticosterone measurements for several adult ewes in this bighorn population.

The identification of potential stressors based on the assay results as related to the field notes recorded during the study proved to be difficult. Direct correlations between events documented in the field notes and elevated corticosterone levels may not exist or

may not be identifiable. Because of the variability and biological complexities in the way bighorn sheep respond to stress and the resulting inconsistencies in fecal corticosterone levels, linking single instances of elevated corticosterone to documented events may not be possible for this study. However, if the bighorn sheep in this population had appeared to be experiencing chronic stress based on corticosterone measurements, the field notes may have provided some indication of the cause by outlining processes and events occurring in the area over time. It appears, however, that stress experienced by individuals during this project was primarily acute stress. The fluctuations in corticosterone levels seem to be based on the previously discussed seasonal rhythms rather than on recorded weather patterns or occurrences of predator or other threats or disturbances in the areas.

The analysis of the data that was collected over the past seven years documenting habitat type and distance from escape terrain, water, livestock, and people did not produce any surprising results. In summary, bighorn sheep in the Wildcat Hills generally prefer rocky outcrop habitat and are typically greater than 100 meters from water, livestock, and people, although the distance of the sheep from escape terrain varies widely. This data may be of limited value due to the way in which it was collected. The data was recorded as one of five categories for habitat type (rocky outcrop, heavy tree cover, light tree cover, open grassland, and shrub grassland) and one of four categories for the distance from escape terrain, water, livestock, and people (<25 m, 25 – 50 m, 50 – 100 m, and >100 m).

There is often an overlap of the categories recorded for habitat type. For example, sheep often inhabit areas with rocky outcroppings and light tree cover. Furthermore, the

line between heavy tree cover and light tree cover is indistinct, and what one field technician may consider shrub grassland may appear to be open grassland to another technician. Since various technicians were employed by the Nebraska Game and Parks Commission to record this data based on radio telemetry observations over the years, discrepancies in the data and the data collection methods are highly likely and unavoidable.

The validity of these results is further limited because of the small-scale categorical values used to document distances from escape terrain, water, livestock, and people. The scale of the categories was not sufficient to provide valuable information about the distance of bighorn sheep from water and livestock, as sheep are almost always observed at distances of greater than 100 meters from water and livestock in the Wildcat Hills. Distance from escape terrain varied as expected, and the distance from people varied based on the distance from which the field technician made the observations. The bighorn sheep are almost always greater than 100 meters away from people other than field technicians.

Ultimately, the findings of this project raise questions about the differences in corticosterone levels experienced by sheep inhabiting the Montz property in comparison with sheep inhabiting CCWMA, as well as the reason behind the changes in primary areas inhabited that followed the epidemic. Further research aimed at identifying differences between the Montz and Hampton property and CCWMA would be of value. Understanding these differences could have implications for disease prevention and management in the Wildcat Hills of western Nebraska.

MANAGEMENT IMPLICATIONS

An understanding by wildlife managers and researchers of disease processes, stress response, and habitat selection is critical to the success of bighorn sheep restoration in the state of Nebraska. The respiratory disease epidemic of 2006 reduced one population of bighorn sheep in the Wildcat Hills to half its previous size, and stress appeared to have played a role in the disease-related decline. Since the epidemic, changes have been observed and documented in the areas inhabited by bighorn sheep, as habitat previously occupied has remained almost completely uninhabited since the mortalities.

The findings of this research project indicate that small groups of sheep inhabiting private properties that are grazed by cattle may be faced with increased physiological stress in comparison to larger groups inhabiting Wildlife Management Areas that are free of grazing. Furthermore, the results of this study suggest that following mortalities of adult ewes in the oldest age class, younger ewes have failed to re-colonize previously occupied areas. This may be a result of the often observed failure of bighorn sheep to colonize available patches of habitat or it may be related to a social intolerance of cattle or competition with livestock for resources, both of which may be resulting in avoidance of some areas. Furthermore, the changes could be related to numerous other variables that were not identified as a result of this project, such as a possible lack of important resources in the unoccupied areas or an abundance of some preferable resource in the inhabited areas.

In order to minimize disease and mitigate potential stressors, bighorn sheep management in the Wildcat Hills should aim to diminish the potential for livestock

related disease transmission and identify variables that differ between private properties with suitable habitat and Cedar Canyon Wildlife Management Area, the site of the reintroduction. Efforts should be made to document even indirect interactions between bighorn sheep and cattle, and behavioral differences of sheep in small groups compared with sheep in large groups should be noted. Careful observations of existing resources utilized in occupied habitat may provide information about the observed changes in areas inhabited by the bighorn sheep since the reintroduction.

Ultimately, further research is necessary to identify management strategies that would minimize disease and stress of bighorn sheep in the Wildcat Hills of western Nebraska. Continued documentation of bighorn sheep locations based on radio telemetry will provided further information about occupancy and the amount of available habitat that remains uncolonized by bighorn sheep in the Wildcat Hills. Additionally, documentation of information about variables including habitat type, escape terrain, livestock, water, and people can be of greater value if observations are recorded as detailed notes and accurate values, rather than general observations based on categorical values. And lastly, further collection and analysis of fecal samples for measurements of glucocorticoid metabolites would be of value to managers and researchers interested in the dynamics of this bighorn sheep population. The resulting information would be of potential value for disease management and ultimately, the propagation of bighorn sheep in the state of Nebraska.

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APPENDICES

Appendix A1. Field notes collected during fecal sample collection.

Fecal Glucocorticoid Metabolite Sample Collection Field Notes

January 25, 2007
1330 – 1430 Warm weather, 45° F or warmer
Y05 is still being chased by rams. There are six rams chasing her around today. Her lamb is with Y17's group. It appears that Y05 has not been bred yet. The rams no longer seem to be pursuing the other ewes. Y05's lamb was born later then the others last year. There have been unconfirmed reports of a mountain lion near 2nd dam. Y17 and the broken horn ewe (on Saddlehorn) seem to be more skittish than normal today. The weather is unseasonably war,

February 2, 2007
1300 Very cold, -20° F wind chill
Collected from Y05, Y01, Y10, and Y90 on the east side of Pyramid. Y24 is also with this group, but I did not see her defecate. Sheep were lying out of the wind. No rams or lambs with these four ewes today. The last few days have been bitter cold.

February 5, 2007
900, Much warmer today, close to 50° F
Collected samples from Y01, Y02, Y17, and Y10. Also in this group today were P14, Y18, Y90, Y24, P12, P13, yearling ewe, two yearling rams, and Flipper's yearling. The sheep were eating on an old bail of hay at first but then began to forage on other things and seemed uninterested in fresh hay. There were no lambs here today… I will look for them tomorrow with Y05.

February 7, 2007
Very warm again, 50° F
Collected samples from Y17, broken horn ewe, and another ewe on Saddlehorn. Y05 is laying down below on a level I can't get to on the northernmost part of Saddlehorn. There are two yearling rams with her. The lambs are spread out across the north side, separated from the ewes. I sampled from a group of three of them today. There is still a large group of rams on Flattop. I sampled from one of them today. The weather is unseasonably warm.

February 15, 2007
Very cold overnight last night (-20° F), it's warming up this afternoon (just above freezing). Collected from a yearling ram and an unknown adult ewe on Pyramid. Luke tried to dart the ram for collaring but missed. Sheep were likely stressed from our pressure today. Only young rams were here in this group today. One ewe and one ram from the Hubbard's Gap population showed up here today (R27 and R78). They are now with the other Cedar Canyon sheep.

February 2, 2007
1100, Windy and sunny, 50° F

Sampled from R27, one ram, one unknown ewe, and a lamb, which I think is Y05's lamb. The sheep are foraging in light tree cover on the east side of the Release Site. The others are on the north side of the ridge today. R78 and R27 seem to be sticking close by each other. They let me get within 50 – 100 meters of them today and they didn't move away. The weekend was warm and the temp dropped Monday when wet snow covered the ground.

February 26, 2007
920, Partly cloudy, 45° F
On the top of Submarine, I sampled from Y05 and Y18. They were lying down on top of the butte and I had to push them just a little to get the samples. There were no other sheep there, but the others were not far away. Late Friday night/early Saturday morning the wind picked up and it snowed several inches. There were gusts above 50 mph. Overall, there was not much accumulation, but the winds made for very harsh conditions on Saturday (blowing snow, blizzard-like weather).

February 27, 2007
1000, Overcast sky, 29° F
Y01, Y10, broken horn ewe, Y24, Y90, four lambs, a yearling ram, and Flipper's yearling were foraging at the bottom of Submarine. It was breezy with snow flurries this morning. Today is three days from Saturday's harsh weather. I sampled from one lamb, an unknown yearling ram, and the broken horn ewe.

March 3, 2007
1100, Very warm today, 60° F
Collected samples from Y01, Y10, unknown adult ewe, two lambs, and Flipper's yearling ram today at the top of the Release Site. This is a major change in weather because three days ago the wind blew at gust of over 50 mph and it was bitter cold. A couple of the samples collected today were softer and more clumped together than normal (Y01's and the one from Flipper's yearling).

March 8, 2007
Warm but overcast, looks like it might rain
Y17, a yearling ram, and broken horn ewe showed up at Hampton's yesterday. It was about 3 days ago that they began the trip from W Canyon. (Potential for stress from movement?) Sampled from Y17 today. Since Saturday it has been VERY warm (50 – 65° F). The weather changed significantly from Friday/Saturday to Sunday last weekend. There are no lambs with the group and the yearling ram is unmarked. Game and Parks flew over the area while I was collecting samples (possible stress from the presence of the plane?). They did not get too close and the sheep didn't seemed alarmed.

March 9, 2007
Sampled from Y17, yearling ram, and broken horn ewe at Hampton's today. Very warm again.

March 13, 2007

1400 – 1445 Warm, 76° F
Collected samples from Y05, Y10, and another unknown ewe, as well as from two lambs and a yearling ram, all on Submarine. Sheep didn't seem to mind at all that I was there today and they actually cam within <25 m of me while I sat and watched for defecation. It has been confirmed that there was a mountain lion feeding on a deer carcass north of the oil well about 2 months ago. It has been abnormally warm for this time of year, but I haven't heard any coughing and the sheep seem healthy.

March 15, 2007
Sampled from Y05, Y24, and Flipper's yearling ram at the base of Pyramid. Also here are Y10, Y90, one lamb, and Y24. Y05 is shedding her winter coat already. I got very close to her today. The lamb that is here has a visible small horn on the right side, but no visible horn on the left side. It must have broken off. The sheep are foraging on blackroot sedge. It is cooler today (about 50°) and it was cooler yesterday. Today is about 3 days after the very warm weather we had (one day it was close to 80°). Y10 seems to be leading this group around today. Sheep seem alert but came very close to me again as they did on Monday.

March 22, 2007
930 – 1030, Warm, 70° F for a high today
It has been very warm again lately and I had trouble getting samples for a few days because the sheep were on steep terrain on the north side of the ridge. There is a chance of rain tonight and this weekend. I have not heard any sheep coughing lately. Today I collected samples from Y18, Y05, a lamb, and P13 on submarine. A few others are starting to shed already. They were in light tree cover, some lying in the shade, others foraging.

March 23, 2007
Montz
Y17, broken horn ewe, and a yearling ram from Hampton's moved here yesterday. Today I found Y17 and broken horn ewe with a lamb (female, I think) at the top of the east ridge. I couldn't get any samples from them today because of their location on steep, rocky terrain. Below them and around the corner was a 2 year old ram, yearling ram, and two male lambs. There were not any lambs with the sheep at Hampton's to my knowledge, so I don't know for sure how these lambs got here. I collected samples from the 2 year old ram, yearling ram, and one of the ram lambs. It is hot today (high of 75°) and it hasn't rained at all lately. There's a chance of rain tomorrow. I heard a cough from one of the rams (I think the yearling), but it did not seem bad – just a single cough.

March 24, 2007
1200 Cooler weather, rainy
Collected from two lambs, Y24 and Y02 on submarine. Sheep were very active and appear to be enjoying the rain and cooler weather.

March 29, 2007
830 A little above freezing, snowing

I sampled from Y10, P14, and P12 on submarine. Snow started falling in big, wet flakes and the wind picked up quickly as a winter storm rolled in.

April 5, 2007
930, 30° F
Several inches of snow covered the ground this morning with more falling as I was collecting samples. High of 30° F today. I sampled from Y05, Y10, P14, and P12 on Pyramid today. The sheep were very active in the cooler weather. They were on the top level of Pyramid.

April 6, 2007
1430, 27° F, cold and snowing again
Montz – I sampled from Y17, broken horn ewe, a ram lamb, an unknown lamb (I think male), 2 year old ram, and a yearling ram. The same group of 7 were here again and I watched for several hours waiting for samples to drop and the sheep to move before collecting. I did not hear any coughing today. The sheep were very calm and allowed me to get very close without disturbing them. The rams are starting to shed.

April 13, 2007
1030, 35° F
Submarine – I had trouble getting samples this week because of lack of time. I helped with a couple burns and had a presentation to give this week. We burned Cedar Canyon down in the flats from Pyramid to Release Site yesterday. The sheep were on Pyremid when we started. Most of them moved to the north side, but Y01, Y05, and Y18 stayed put despite very thick and heavy smoke. I sampled from Y01, Y05, and Y18 today. I heard Y01 cough one time. This was the first cough I had heard at Cedar Canyon this year. Could be because of the smoke? It has been much cooler today with a lot of wind. Y05 does not look pregnant compared to Y01 and Y18 and is shedding even more. She could be pregnant, but may lamb later than the others.?

April 18, 2007
1320, 65° F, warm weather, 40 mph winds
The weather has warmed up again. I sampled from the 3 lambs, Y17, the 2 year old ram. I heard the female lamb cough several times. This was the worst coughing episode I've observed this year, but still not as bad as the cough many had for a long period of time last year. The broken horn ewe and yearling ram were also with this group, but I was unable to collect samples from them.

April 25, 2007
1130, 55° F, Sunny
Between Castle and Saddlehorn – It has been rainy lately, especially yesterday. I collected samples from Y01, Y10, Y05, and Y18, as well as one unknown sheep. The ewes are looking very pregnant. Y02 is on Pyramid and may be getting ready to lamb, but she still has a few other sheep with her right now. The rams are getting really shaggy and rough looking due to shedding.

May 1, 2007
1100, 60° F
Submarine – The weekend was very hot (89° F on Sunday) and yesterday it rained a lot. Y02 and Y05 are with the lambs and yearlings, the others are spread out along the north side, hopefully getting ready to lamb. They are acting a little strange today. They have been running around very alert down low in the flats and butting heads. I collected samples from Y05, Flipper's yearling ram, and 3 unknown lambs.

May 2, 2007
1130, Montz East Ridge
I sampled from broken horn ewe here today. I don't think she has lambed yet, but I only saw her for a quick moment before she moved off this butte. The yearling ram and one male lamb were with her for sure, and there might have been other with her that I couldn't see. It's very windy today. Y17 is not in sight although I can get her signal out on the steep rock cliff opposite the other sheep. I can't see her and don't want to walk out on the steep cliff and disturb her if she's lambing, so I will wait and come back soon.

May 3, 2007
Y24 lambed on the north side of Pyramid.

May 4, 2007
Y01 lambed at the Release Site.

May 9, 2007
Collected samples from several sheep on Pyramid.

May 14, 2007
Observed lamb with Y02 at Release Site.

May 16, 2007
930 – 1230, Montz
I collected samples from three unknown rams and the yearling ewe today. I heard one of the yearling rams cough twice today. P12 and another two year old ram are here today and must have moved from Cedar Canyon recently. There are four adult rams (3 two year olds and the usual 3 year old), two yearling rams, and the yearling ewe here today. Y17 and broken horn ewe aren't with them.

May 25, 2007
1030, about 65° F
I collected samples from Flipper's ram, P14, an unknown yearling ewe, and Y05 on submarine today. It has been much cooler the last few days (in the 60's). I don't think Y05 has had a lamb. Collecting samples has been difficult due to the lambing season. The sheep have not allowed me to get very close and even those without lambs have been on the steep terrain across the north side of the ridge with the nursery groups. Observing defecation in a place where collecting samples is possible has seemed nearly impossible over the last week or so. The sample from Flipper' s ram was very soft and clumped

together. At 1130 on Pyramid, I collected a sample from Y10 (her lamb was with her) and the unknown yearling ewe. There is a big group on the very top of Pyramid including all the ewes with lambs and most of the yearlings. Y10 and her lamb came down just low enough for me to get a sample without disturbing the group and I waited until they went back up to collect it. My main priority is to avoid causing any stress to the ewes and lambs.

May 30, 2007
930, Montz
Yesterday I observed Y17's lamb stuck in a horseshoe shaped area of rock that it could not climb out of a Montz. I watched for almost four hours (1000 – 1400) and the lamb could not climb out of the area back up to where Y17 was located. Y17 was distressed and alert as a coyote ran past the bottom of the butte and she started moving back and forth across the top of the area in which her lamb was trapped. She did not go down to her lamb – I believe because she knew she would get stuck also. We rescued the lamb this morning and I collected a sample from Y17 around 930. The lamb seems to be okay and the rescue appears to have been successful.

June 6, 2007
830, 77° F
Between Castle and Saddlehorn – I collected samples from Y10, Y01, and two unknown ewes. Last week was cooler (mid 60's mostly) but it has warmed up lately (highs in the 80's). All the sheep at Cedar Canyon have been staying on the north side of the ridge in steep, shady terrain, which has made sample collection difficult. The situation is further complicated because the ewes still have very young lambs and they flee as soon and they see me coming from across the top since I cannot come from below.

June 11, 2007
930 – 1100, 84° F
I collected samples from Y24, Y18, Y10, and unknown yearling ewe and an unknown adult ewe. I accidentally scared the sheep when I hiked up on them today and they left and went to Submarine. I saw P13 nursing a lamb – the 7th one here at Cedar Canyon must belong to her. It was very hot over the weekend (90 – 95° F for the highs). Last Thursday the wind blew at 60 mph gusts. We haven't gotten much rain at all and everything's starting to turn brown.

July 24, 2007
1100, 100° F
Montz – I collected samples from Y17 and the broken horn ewe as well as an unknown ram. A group of rams showed up here today with the ewes including a four year old, one three year old, P12, and another two year old ram. It has been so hot lately! Temps have reached triple digits for days and there's no sign of rain. The lambs look healthy and they are growing fast. All sheep are done shedding except broken horn ewe who is still a little shaggy in spots.

August 1, 2007
1300, 90° F
Pyramid – I collected samples form 3 lambs, Y05, Y18, and P13. It began to pour as I was collecting samples. Many of them were very wet when I put them in the bags. It has been slightly cooler over the past few days (85 – 95° F instead of 100° F). The lambs are growing quickly. Y02 was also in this group with her lamb. The other were back at 2nd Dam with the yearlings as well.

August 2, 2007
1300, 83° F
Montz – very south end of east ridge. I collected samples from Y17, broken horn ewe, yearling ram, unknown lamb, and yearling ewe. The rams are still there too. It rained a lot yesterday and its much cooler out today.

August 9, 2007
1000, 95° F
Montz – It has been very hot the last few days. I collected samples from 3 unknown rams today. The rams wouldn't let me get to the ewe samples. P12 was acting very territorial and was stomping his feet and standing his ground as I approached. I waited almost 2 hours for them to move, but after foraging around, they bedded back down in front of the area where the ewe samples were located.

August 15, 2007
1415, 90° F
It's a little more humid today than usual. I collected samples from Y10, unknown ewe, unknown lamb, and yearling ewe on the ridge south of 2nd Dam. The sheep have been hanging out in this area foraging on the mountain mahoganey. It has been very hot lately.

August 23, 2007
1100, 65° F
Montz – south end of the east ridge – I collected samples from Y17, broken horn ewe, 2 yearling rams, and a yearling ewe. I wasn't able to get samples from the lambs. It is much cooler today and it stormed last night – there was plenty of rain and strong winds. Yesterday the high was 84° F. All these sheep look healthy and the lambs are growing fast.

August 24, 2007
1400, 84° F
Pyramid – I collected samples from Y05, 2 unknown adult ewes, 2 unknown lambs, and a yearling ram. It is cooling down into the mid 50s overnight. The weather has been very comfortable lately. The sheep were all here on Pyramid today.

August 30, 2007
1200, 90° F
Montz – Very south end of east ridge, around the corner – I collected samples form 3 unknown rams, Y17, broken horn ewe and an unknown lamb. It was much cooler the last

couple days and now it has warmed up again. A couple more 3 year old rams showed up here today with the usual group.

September 9, 2007
900, Release Site
I collected samples from 3 unknown lambs, P13, Y24, Y18, and Y04. It rained last night following several very hot days. Only Y10 and her lamb were not here at the Release Site – they were on the north side of the ridge.

September 12, 2007
1000, 85° F, Breezy
I collected samples from 2 unknown rams, and the broken horn ewe at Montz. It was cold over the weekend (high of 60° F), but it has heated up again. I will try to collect samples to monitor for changes in stress levels that might possibly correlate with these weather changes.

September 14, 2007
1100, 60° F
Saddlehorn – I collected samples from and unknown ram lamb, unknown lamb, unknown adult ewe, Y18, Y05, and a yearling ewe. The weather has continued to fluctuate a lot lately.

September 20, 2007
1100, 85° F
2nd Dam – It's sunny and warm today. I collected samples from Y10, Y02, Y24, unknown ewe, and 2 unknown lambs. Y02's collar stopped working. The flies/gnats seem to be bothering the sheep. It has been hot during the day but cool at night.

September 26, 2007
1200, 75° F
West of Saddlehorn – collected samples form P14, Y02, Y18, and one lamb.

October 3, 2007
1445, 80° F
Montz – near the lamb rescue site – I collected samples from broken horn ewe, both lambs, unknown rams, and Y17. It has been difficult to get samples from these sheep lately due to their location on steep terrain.

October 11, 2007
11, 65° F, Partly Sunny
2nd Dam – Collected samples from P14, Y01, female lamb, Y10, male lamb, and Y24. A low-flying airplane seemed to startle the sheep. They all appear to be healthy. The weather has been mild.

October 16, 2007
730, Cold
The first freeze of the season occurred overnight. It is cold out this morning. I collected samples from Y10, unknown ewe, and Y05 on Pyramid.

October 24, 2007
1230, Montz, 70° F
I collected samples from Y17, yearling ewe, 2 lambs and an adult ram. Broken horn ewe is missing. I heard Y17 cough today but only once. I'm concerned about the broken horn ewe and the possibility of EHD, which has been affecting a lot of deer lately. It has been very warm for this time of year.

October 31, 2007
1030, Vista Trend Property, 45° F
I collected samples from a yearling ewe, a yearling ram, and an unknown lamb. The weather has remained warm for the most part. Later in the day – 1500, 60° F – Collected samples from Y05's lamb at 2nd Dam. O3 showed up here today! Couldn't get a sample from him or Y05. The rams just started showing up recently.

November 2, 2007
1330, 50° F, Crecsent
I collected samples from 2 unmarked adult rams, Y10, and a female lamb. O3 is with this group today.

November 16, 2007
1330, 65° F, W Canyon
I collected samples from some of the Montz sheep – they just came over here a couple days ago. The rams are chasing the ewes around and the sheep are very spread out. The weather continues to be unseasonably warm. I collected samples from Y10, Y17, 2 unknown adult rams, and a female lamb.

November 19, 2007
1100, at least 70° F, Very Warm!
I collected samples from Y18, unknown ewe, and Y05's female lamb. It is very warm for this time of year. I'm not sure how the strange weather will affect the sheep and the glucocorticoid levels in the samples.

November 28, 2007
1130, 33° F
Release Site – It's finally cold out. Today it's even snowing. I collected samples from O3, B10, and Y05.

December 7, 2007
1000, 25° F
It's snowy and foggy. It's also very cold. I collected samples from P12 and Y05. The sheep are very active in the cold weather and appear to enjoy the cooler temperatures.

December 13, 2007
1200, 35° F
I've started supplementing the sheep with hay because there is a lot of snow on the ground and we want to get them used to bait so that we can use it for darting and radio collaring purposes. I pulled a bail of hay on a sled today out to the base of Submarine. I'm getting a snowmobile soon to help with the baiting.

December 14, 2007
1000, 20° F
Collecting samples has been difficult because of deep snow, but I managed to collect form Y01, and Y05's lamb today at Pyramid. It is snowing and I brought more hay with me. Then end of this month will mark the end of sample collection.

Appendix A2. Complete fecal sample results.

Sample ID	CORT (ng/g feces)	Sheep ID	Sex/Age Class	Date
4	9.06	Y01	Female/Adult	11/15/06
3	8.62	P12	Male/Yearling	11/15/06
2	10.90	P14	Male/Yearling	11/15/06
5	10.33	Y01	Female/Adult	11/27/06
1	10.06	Y05	Female/Adult	11/27/06
8	7.13	Adult Ram	Male/Adult	11/27/06
6	9.55	B10	Male/Adult	11/27/06
7	9.97	Y09	Male/Adult	11/27/06
9	7.79	Y25	Male/Adult	11/27/06
34	15.00	Flipper's Yearling Ram	Male/Yearling	11/27/06
21	17.69	Unknown Lamb	Unknown/Lamb	11/27/06
17	11.32	Adult Ewe	Female/Adult	12/3/06
10	7.25	P13	Female/Yearling	12/3/06
14	10.64	Adult Ewe	Female/Adult	12/8/06
13	11.56	Adult Ram	Male/Adult	12/8/06
15	12.93	Unknown Lamb	Unknown/Lamb	12/8/06
16	15.98	Unknown Lamb	Unknown/Lamb	12/8/06
19	10.93	Y01	Female/Adult	12/19/06
18	12.47	Unknown Lamb	Unknown/Lamb	12/19/06
11	25.11	Adult Ewe	Female/Adult	12/29/06
12	35.46	Adult Ewe	Female/Adult	12/29/06
25	15.16	Y01	Female/Adult	1/10/07
24	15.01	Y02	Female/Adult	1/10/07
26	17.68	Adult Ram	Male/Adult	1/10/07
27	17.19	Yearling Ram	Male/Yearling	1/10/07
20	15.07	O4	Male/Adult	1/16/07
28	12.95	Adult Ewe - broken horn	Female/Adult	1/25/07
33	12.23	Y05	Female/Adult	1/25/07
30	14.97	Y17	Female/Adult	1/25/07
31	13.66	Adult Ram	Male/Adult	1/25/07
32	12.10	Adult Ram	Male/Adult	1/25/07
23	14.67	Unknown Lamb	Unknown/Lamb	1/25/07
29	13.13	Unknown Lamb	Unknown/Lamb	1/25/07
22	21.01	R10	Female/Adult	1/27/07
43	12.31	Y01	Female/Adult	2/2/07
41	16.19	Y10	Female/Adult	2/2/07
42	12.27	Y90	Female/Adult	2/2/07
47	15.48	Y01	Female/Adult	2/5/07
46	20.14	Y02	Female/Adult	2/5/07
45	19.52	Y10	Female/Adult	2/5/07
44	16.77	Y17	Female/Adult	2/5/07
39	17.41	Unknown Ewe	Female/Unknown	2/6/07
40	16.95	Unknown Ewe	Female/Unknown	2/6/07
38	14.20	Adult Ram	Male/Adult	2/6/07
49	14.44	Unknown Ewe	Female/Unknown	2/15/07

Appendix A2 continued. Complete fecal sample results.

Sample ID	CORT (ng/g feces)	Sheep ID	Sex/Age Class	Date
48	16.94	Yearling Ram	Male/Yearling	2/15/07
35	12.84	Y05's Lamb	Female/Lamb	2/21/07
50	15.95	Unknown Ewe	Female/Unknown	2/21/07
37	19.34	R78	Male/Adult	2/21/07
36	21.19	Yearling Ram	Male/Yearling	2/21/07
52	10.64	Y05	Female/Adult	2/26/07
51	11.30	Y17	Female/Adult	2/26/07
55	12.97	Adult Ewe - broken horn	Female/Adult	2/27/07
54	16.23	Yearling Ram	Male/Yearling	2/27/07
53	12.99	Unknown Lamb	Unknown/Lamb	2/27/07
72	11.94	Y01	Female/Adult	3/5/07
74	16.54	Y10	Female/Adult	3/5/07
70	16.89	Unknown Ewe	Female/Unknown	3/5/07
73	12.02	Flipper's Yearling Ram	Male/Yearling	3/5/07
69	13.16	Unknown Lamb	Unknown/Lamb	3/5/07
71	13.26	Unknown Lamb	Unknown/Lamb	3/5/07
75	22.40	Y17	Female/Adult	3/8/07
79	18.19	Adult Ewe - broken horn	Female/Adult	3/9/07
66	21.61	Y17	Female/Adult	3/9/07
76	15.58	Yearling Ram	Male/Yearling	3/9/07
61	25.38	Y05	Female/Adult	3/13/07
62	16.12	Y10	Female/Adult	3/13/07
64	16.59	Y05's Lamb	Female/Lamb	3/13/07
60	16.95	Unknown Ewe	Female/Unknown	3/13/07
59	17.41	Yearling Ram	Male/Yearling	3/13/07
63	15.44	Unknown Lamb	Unknown/Lamb	3/13/07
80	18.48	Y05	Female/Adult	3/15/07
78	21.65	Y24	Female/Adult	3/15/07
77	21.03	Flipper's Yearling Ram	Male/Yearling	3/15/07
58	20.56	Y05	Female/Adult	3/22/07
56	33.86	Y18	Female/Adult	3/22/07
57	24.17	P13	Female/Yearling	3/22/07
68	18.01	Unknown Lamb	Unknown/Lamb	3/22/07
67	19.01	2 year old Ram	Male/Adult	3/23/07
65	16.03	Male Lamb	Male/Lamb	3/23/07
81	18.47	Yearling Ram	Male/Yearling	3/23/07
85	26.03	Y02	Female/Adult	3/24/07
82	25.91	Y24	Female/Adult	3/24/07
83	16.62	Unknown Lamb	Unknown/Lamb	3/24/07
84	23.51	Unknown Lamb	Unknown/Lamb	3/24/07
88	45.43	Y10	Female/Adult	3/29/07
87	26.84	P12	Male/Yearling	3/29/07
86	23.36	P14	Male/Yearling	3/29/07
90	61.35	Y05	Female/Adult	4/5/07
91	68.04	Y10	Female/Adult	4/5/07

Appendix A2 continued. Complete fecal sample results.

Sample ID	CORT (ng/g feces)	Sheep ID	Sex/Age Class	Date
92	22.72	P12	Male/Yearling	4/5/07
89	33.49	P14	Male/Yearling	4/5/07
95	27.68	Adult Ewe - broken horn	Female/Adult	4/6/07
94	26.08	Y17	Female/Adult	4/6/07
96	29.36	2 year old Ram	Male/Adult	4/6/07
98	25.19	Male Lamb	Male/Lamb	4/6/07
93	27.40	Yearling Ram	Male/Yearling	4/6/07
97	23.10	Unknown Lamb	Unknown/Lamb	4/6/07
101	40.26	Y01	Female/Adult	4/13/07
99	36.53	Y05	Female/Adult	4/13/07
100	46.53	Y18	Female/Adult	4/13/07
103	33.85	Y17	Female/Adult	4/18/07
102	17.84	2 year old Ram	Male/Adult	4/18/07
104	24.42	Unknown Lamb	Unknown/Lamb	4/18/07
105	23.47	Unknown Lamb	Unknown/Lamb	4/18/07
106	18.84	Unknown Lamb	Unknown/Lamb	4/18/07
111	26.28	Y01	Female/Adult	4/25/07
107	47.67	Y05	Female/Adult	4/25/07
108	39.07	Y10	Female/Adult	4/25/07
110	37.99	Y18	Female/Adult	4/25/07
109	33.04	Unknown Ewe	Female/Unknown	4/25/07
112	49.64	Y05	Female/Adult	5/1/07
114	51.03	Flipper's Yearling Ram	Male/Yearling	5/1/07
113	45.24	Unknown Lamb	Unknown/Lamb	5/1/07
115	49.87	Unknown Lamb	Unknown/Lamb	5/1/07
116	77.85	Unknown Lamb	Unknown/Lamb	5/1/07
117	32.01	Adult Ewe - broken horn	Female/Adult	5/2/07
121	33.96	Adult Ewe	Female/Adult	5/8/07
120	24.97	Yearling Ewe	Female/Yearling	5/8/07
118	42.20	Yearling Ram	Male/Yearling	5/8/07
119	62.93	Yearling Ram	Male/Yearling	5/8/07
124	49.07	Yearling Ewe	Female/Yearling	5/16/07
122	28.27	Adult Ram	Male/Adult	5/16/07
123	24.15	Adult Ram	Male/Adult	5/16/07
125	68.00	Adult Ram	Male/Adult	5/16/07
126	46.90	Y05	Female/Adult	5/25/07
129	39.18	Y10	Female/Adult	5/25/07
130	28.81	Unknown Ewe	Female/Unknown	5/25/07
128	33.43	Flipper's Yearling Ram	Male/Yearling	5/25/07
127	60.08	P14	Male/Yearling	5/25/07
131	48.62	Unknown Ewe	Female/Unknown	5/27/07
132	26.82	Y17	Female/Adult	5/30/07
136	31.04	Y01	Female/Adult	6/6/07
133	28.34	Y10	Female/Adult	6/6/07

Appendix A2 continued. Complete fecal sample results.

Sample ID	CORT (ng/g feces)	Sheep ID	Sex/Age Class	Date
134	28.38	Unknown Ewe	Female/Unknown	6/6/07
135	34.92	Unknown Ewe	Female/Unknown	6/6/07
141	25.05	Y10	Female/Adult	6/11/07
138	19.42	Y18	Female/Adult	6/11/07
137	36.68	Y24	Female/Adult	6/11/07
139	34.13	Adult Ewe	Female/Unknown	6/11/07
140	38.79	Yearling Ewe	Female/Yearling	6/11/07
142	22.25	Yearling Ewe	Female/Yearling	6/18/07
143	24.37	Yearling Ram	Male/Yearling	6/18/07
144	21.79	Y90	Female/Adult	6/21/07
148	26.21	Y10	Female/Adult	6/26/07
147	22.37	Y18	Female/Adult	6/26/07
145	22.60	Yearling Ewe	Female/Yearling	6/26/07
146	20.98	Unknown Lamb	Male/Yearling	6/26/07
152	30.38	Adult Ewe - broken horn	Female/Adult	7/3/07
151	70.69	Y17	Female/Adult	7/3/07
153	37.88	Yearling Ewe	Female/Yearling	7/3/07
150	67.65	Yearling Ram	Male/Yearling	7/3/07
154	60.88	Yearling Ram	Male/Yearling	7/3/07
149	38.61	Unknown Lamb	Unknown/Lamb	7/3/07
155	35.19	Y90	Female/Adult	7/5/07
159	27.85	Adult Ewe - broken horn	Female/Adult	7/10/07
157	27.21	Y17	Female/Adult	7/10/07
158	36.04	Yearling Ewe	Female/Yearling	7/10/07
160	32.73	Yearling Ram	Male/Yearling	7/10/07
156	34.18	Yeraling Ram	Male/Yearling	7/10/07
161	34.89	Y10	Female/Adult	7/16/07
162	37.03	Unknown Ewe	Female/Unknown	7/16/07
163	32.55	Unknown Ewe	Female/Unknown	7/16/07
165	29.42	Adult Ewe - broken horn	Female/Adult	7/24/07
164	37.01	Y17	Female/Adult	7/24/07
166	28.54	Unknown Ram	Male/Unknown	7/24/07
172	24.88	P13	Female/Adult	8/1/07
170	21.98	Y05	Female/Adult	8/1/07
171	23.91	Y18	Female/Adult	8/1/07
167	48.93	Unknown Lamb	Unknown/Lamb	8/1/07
168	54.21	Unknown Lamb	Unknown/Lamb	8/1/07
169	48.96	Unknown Lamb	Unknown/Lamb	8/1/07
173	28.31	Adult Ewe - broken horn	Female/Adult	8/2/07
174	33.41	Y17	Female/Adult	8/2/07
176	37.83	Yearling Ewe	Female/Yearling	8/2/07
175	28.49	Yearling Ram	Male/Yearling	8/2/07

Appendix A2 continued. Complete fecal sample results.

Sample ID	CORT (ng/g feces)	Sheep ID	Sex/Age Class	Date
177	32.14	Unknown Lamb	Unknown/Lamb	8/2/07
178	76.74	Unknown Ram	Male/Unknown	8/9/07
179	29.38	Unknown Ram	Male/Unknown	8/9/07
180	74.24	Unknown Ram	Male/Unknown	8/9/07
182	26.35	Y10	Female/Adult	8/15/07
183	29.86	Unknown Ewe	Female/Unknown	8/15/07
184	28.97	Yearling Ewe	Female/Yearling	8/15/07
181	31.57	Unknown Lamb	Unknown/Lamb	8/15/07
186	37.73	Adult Ewe - broken horn	Female/Adult	8/23/07
185	32.25	Y17	Female/Adult	8/23/07
188	33.86	Yearling Ewe	Female/Yearling	8/23/07
187	76.27	Yearling Ram	Male/Yearling	8/23/07
189	45.01	Yearling Ram	Male/Yearling	8/23/07
191	31.04	Adult Ewe	Female/Adult	8/24/07
190	44.99	Y05	Female/Adult	8/24/07
195	49.57	Unknown Ewe	Female/Unknown	8/24/07
193	36.81	Yearling Ram	Male/Yearling	8/24/07
192	46.52	Unknown Lamb	Unknown/Lamb	8/24/07
194	65.61	Unknown Lamb	Unknown/Lamb	8/24/07
196	27.83	Adult Ewe - broken horn	Female/Adult	8/30/07
198	38.00	Y17	Female/Adult	8/30/07
197	45.31	Adult Ram	Male/Adult	8/30/07
200	39.50	Adult Ram	Male/Adult	8/30/07
201	37.66	Unknown Ram	Male/Unknown	8/30/07
199	38.40	Unknown Lamb	Unknown/Lamb	8/30/07
203	31.48	P13	Female/Adult	9/6/07
207	34.82	Y05	Female/Adult	9/6/07
206	42.09	Y18	Female/Adult	9/6/07
205	28.32	Y24	Female/Adult	9/6/07
202	39.06	Unknown Lamb	Unknown/Lamb	9/6/07
204	28.05	Unknown Lamb	Unknown/Lamb	9/6/07
208	43.75	Unknown Lamb	Unknown/Lamb	9/6/07
210	37.52	Adult Ewe - broken horn	Female/Adult	9/12/07
209	30.48	Unknown Ram	Male/Unknown	9/12/07
211	31.80	Unknown Ram	Male/Unknown	9/12/07
213	23.91	Adult Ewe	Female/Adult	9/14/07
217	20.64	Y05	Female/Adult	9/14/07
215	24.12	Y18	Female/Adult	9/14/07
216	21.36	Yearling Ewe	Female/Yearling	9/14/07
212	24.69	Male Lamb	Male/Lamb	9/14/07
214	26.43	Unknown Lamb	Unknown/Lamb	9/14/07
221	23.05	Adult Ewe	Female/Adult	9/20/07
219	24.37	Y02	Female/Adult	9/20/07

Appendix A2 continued. Complete fecal sample results.

Sample ID	CORT (ng/g feces)	Sheep ID	Sex/Age Class	Date
218	24.67	Y10	Female/Adult	9/20/07
220	23.55	Y24	Female/Adult	9/20/07
222	26.08	Unknown Lamb	Unknown/Lamb	9/20/07
223	21.49	Unknown Lamb	Unknown/Lamb	9/20/07
228	30.74	Adult Ewe - broken horn	Female/Adult	9/26/07
226	31.60	Y02	Female/Adult	9/26/07
225	35.01	Y18	Female/Adult	9/26/07
227	27.96	P14	Male/Adult	9/26/07
224	30.88	Unknown Lamb	Unknown/Lamb	9/26/07
232	29.70	Y17	Female/Adult	10/3/07
231	28.24	Unknown Ram	Male/Unknown	10/3/07
229	23.73	Unknown Lamb	Unknown/Lamb	10/3/07
230	26.79	Unknown Lamb	Unknown/Lamb	10/3/07
234	23.97	Y01	Female/Adult	10/11/07
236	26.58	Y10	Female/Adult	10/11/07
238	21.80	Y24	Female/Adult	10/11/07
235	24.50	Female Lamb	Female/Lamb	10/11/07
233	21.82	P14	Male/Adult	10/11/07
237	33.89	Male Lamb	Male/Lamb	10/11/07
241	19.90	Y05	Female/Adult	10/16/07
239	18.41	Y10	Female/Adult	10/16/07
240	26.96	Unknown Ewe	Female/Unknown	10/16/07
246	29.23	Y17	Female/Adult	10/24/07
244	28.10	Yearling Ewe	Female/Yearling	10/24/07
243	31.62	Adult Ram	Male/Adult	10/24/07
242	24.25	Unknown Lamb	Unknown/Lamb	10/24/07
245	43.18	Unknown Lamb	Unknown/Lamb	10/24/07
247	20.11	Y05's Female Lamb	Female/Lamb	10/31/07
248	26.35	Yearling Ewe	Female/Yearling	10/31/07
249	36.90	Yearling Ram	Male/Yearling	10/31/07
250	24.91	Unknown Lamb	Unknown/Lamb	10/31/07
253	25.77	Y10	Female/Adult	11/2/07
254	19.92	Female Lamb	Female/Lamb	11/2/07
251	21.96	Adult Ram	Male/Adult	11/2/07
252	35.86	Adult Ram	Male/Adult	11/2/07
255	23.72	Y17	Female/Adult	11/7/07
256	21.73	Yearling Ram	Male/Yearling	11/7/07
257	20.14	Y05	Female/Adult	11/13/07
258	26.31	Female Lamb	Female/Lamb	11/13/07
259	21.45	Y10	Female/Adult	11/16/07
262	27.12	Y17	Female/Adult	11/16/07
263	No Sample	Female Lamb	Female/Lamb	11/16/07
260	25.98	Adult Ram	Male/Adult	11/16/07
261	19.58	Adult Ram	Male/Adult	11/16/07
266	25.96	Y18	Female/Adult	11/19/07
265	20.91	Y05's Female Lamb	Female/Lamb	11/19/07

Appendix 2A continued. Complete fecal sample results.

Sample ID	CORT (ng/g feces)	Sheep ID	Sex/Age Class	Date
264	21.40	Unknown Ewe	Female/Unknown	11/19/07
269	16.63	Y05	Female/Adult	11/28/07
268	16.28	B10	Male/Adult	11/28/07
267	25.28	O3	Male/Adult	11/28/07
270	13.97	Adult Ewe	Female/Adult	12/3/07
272	15.53	Y05	Female/Adult	12/3/07
271	13.14	B11	Male/Adult	12/3/07
274	26.36	Y05	Female/Adult	12/7/07
273	16.43	P12	Male/Adult	12/7/07
275	33.53	Y17	Female/Adult	12/13/07
276	31.54	Y01	Female/Adult	12/14/07
277	31.73	Y05's Female Lamb	Female/Lamb	12/14/07
279	27.22	Y10	Female/Adult	12/18/07
278	22.38	Male Lamb	Male/Lamb	12/18/07
280	26.86	R79	Male/Adult	12/19/07
281	15.62	Y05	Female/Adult	12/20/07
283	14.63	Y18	Female/Adult	12/20/07
282	17.36	Adult Ram	Male/Adult	12/20/07
284	16.80	R79	Male/Adult	12/21/07
285	19.29	Y10	Female/Adult	12/29/07
Average	**27.58**			
Median	**25.23**			
Standard Deviation	**13.41082878**			
Max	**77.85**			
Min	**7.13**			
Variance	**179.8503285**			

Appendix A3. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9988**						
			Slope	**-0.5317**						
			Int	**1.9536**						
1	NSB	973	971.50							
2	NSB	970								
3	0	22820	22753.50							
4	0	22687								
5	12.5	19426	19270.00	84.01	1.66	1.07	11.79			
6	12.5	19114								
7	25	17139	17028.50	73.72	1.03	1.41	25.42			
8	25	16918								
9	50	14098	14212.50	60.79	0.44	1.72	52.53			
10	50	14327								
11	125	10138	10150.00	42.14	-0.32	2.12	132.49			
12	125	10162								
13	250	7605	7652.50	30.67	-0.82	2.39	243.90			
14	250	7700								
15	500	5421	5391.50	20.29	-1.37	2.68	479.82			
16	500	5362								
17	Pool	12591	12591.00	53.34	0.13	1.88	76.27	30.51	**27.30**	16.59
18	Pool	13625	13625.00	58.09	0.33	1.78	60.25	24.10		
19	1	17242	17242.00	74.70	1.08	1.38	23.88	9.55	**10.06**	7.19
20	1	16893	16893.00	73.09	1.00	1.42	26.43	10.57		
21	2	16705	16705.00	72.23	0.96	1.45	27.88	11.15	**10.90**	3.24
22	2	16867	16867.00	72.98	0.99	1.43	26.63	10.65		
23	3	17874	17874.00	77.60	1.24	1.29	19.63	7.85	**8.62**	12.57
24	3	17301	17301.00	74.97	1.10	1.37	23.46	9.38		
25	4	17183	17183.00	74.43	1.07	1.39	24.30	9.72	**9.06**	10.33
26	4	17664	17664.00	76.63	1.19	1.32	20.99	8.40		
27	5	16991	16991.00	73.54	1.02	1.41	25.70	10.28	**10.33**	0.73
28	5	16955	16955.00	73.38	1.01	1.41	25.97	10.39		
29	6	17410	17410.00	75.47	1.12	1.36	22.70	9.08	**9.55**	7.02
30	6	17076	17076.00	73.93	1.04	1.40	25.07	10.03		
31	7	17272	17272.00	74.83	1.09	1.37	23.66	9.47	**9.97**	7.15
32	7	16926	16926.00	73.25	1.01	1.42	26.18	10.47		
33	8	17854	17854.00	77.51	1.24	1.30	19.76	7.90	**7.13**	15.33
34	8	18496	18496.00	80.45	1.41	1.20	15.89	6.36		
35	9	18297	18297.00	79.54	1.36	1.23	17.04	6.82	**7.79**	17.71
36	9	17524	17524.00	75.99	1.15	1.34	21.92	8.77		
37	10	18033	18033.00	78.33	1.28	1.27	18.64	7.45	**7.25**	4.08
38	10	18205	18205.00	79.12	1.33	1.25	17.59	7.04		
39	11	13339	13339.00	56.78	0.27	1.81	64.34	25.74	**25.11**	3.51
40	11	13555	13555.00	57.77	0.31	1.79	61.23	24.49		

Appendix A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9988**						
			Slope	**0.0000**						
			Int	**0.0000**						
41	12	11708	11708.00	49.29	-0.03	1.97	93.04	37.22	**35.46**	7.01
42	12	12149	12149.00	51.32	0.05	1.93	84.25	33.70		
43	13	16720	16720.00	72.30	0.96	1.44	27.76	11.10	**11.56**	5.59
44	13	16434	16434.00	70.99	0.89	1.48	30.05	12.02		
45	14	17001	17001.00	73.59	1.02	1.41	25.62	10.25	**10.64**	5.20
46	14	16743	16743.00	72.41	0.96	1.44	27.58	11.03		
47	15	16049	16049.00	69.22	0.81	1.52	33.31	13.33	**12.93**	4.27
48	15	16276	16276.00	70.26	0.86	1.50	31.36	12.54		
49	16	15436	15436.00	66.41	0.68	1.59	39.01	15.61	**15.98**	3.28
50	16	15251	15251.00	65.56	0.64	1.61	40.87	16.35		
51	17	16778	16778.00	72.57	0.97	1.44	27.31	10.92	**11.32**	5.00
52	17	16524	16524.00	71.40	0.91	1.47	29.31	11.73		
53	18	16481	16481.00	71.20	0.91	1.47	29.66	11.86	**12.47**	6.86
54	18	16121	16121.00	69.55	0.83	1.51	32.69	13.07		
55	19	16842	16842.00	72.86	0.99	1.43	26.82	10.73	**10.93**	2.63
56	19	16710	16710.00	72.25	0.96	1.44	27.84	11.14		
57	20	15658	15658.00	67.42	0.73	1.57	36.88	14.75	**15.07**	3.04
58	20	15489	15489.00	66.65	0.69	1.59	38.50	15.40		
59	21	14956	14956.00	64.20	0.58	1.64	43.95	17.58	**17.69**	0.92
60	21	14903	14903.00	63.96	0.57	1.65	44.52	17.81		
61	22	14481	14481.00	62.02	0.49	1.69	49.29	19.72	**21.01**	8.70
62	22	13959	13959.00	59.62	0.39	1.75	55.75	22.30		
63	23	18342	18342.00	79.75	1.37	1.22	16.78	6.71	**10.31**	49.35
64	23	15886	15886.00	68.47	0.78	1.54	34.77	13.91		
65	24	15782	15782.00	67.99	0.75	1.55	35.72	14.29	**15.01**	6.80
66	24	15404	15404.00	66.26	0.67	1.59	39.33	15.73		
67	25	14939	14939.00	64.12	0.58	1.64	44.13	17.65	**15.16**	23.23
68	25	16238	16238.00	70.09	0.85	1.50	31.68	12.67		
69	26	14975	14975.00	64.29	0.59	1.64	43.75	17.50	**17.68**	1.47
70	26	14890	14890.00	63.90	0.57	1.65	44.66	17.87		
71	27	15140	15140.00	65.05	0.62	1.62	42.01	16.80	**17.19**	3.16
72	27	14958	14958.00	64.21	0.58	1.64	43.93	17.57		
73	28	16047	16047.00	69.21	0.81	1.52	33.33	13.33	**12.95**	4.22
74	28	16271	16271.00	70.24	0.86	1.50	31.40	12.56		
75	29	16279	16279.00	70.28	0.86	1.50	31.33	12.53	**13.13**	6.39
76	29	15938	15938.00	68.71	0.79	1.54	34.30	13.72		
77	30	15778	15778.00	67.98	0.75	1.55	35.76	14.30	**14.97**	6.27
78	30	15430	15430.00	66.38	0.68	1.59	39.07	15.63		
79	31	15921	15921.00	68.63	0.78	1.54	34.45	13.78	**13.66**	1.28
80	31	15990	15990.00	68.95	0.80	1.53	33.84	13.53		

Appendix A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9988**						
			Slope	**0.0000**						
			Int	**0.0000**						
81	32	16469	16469.00	71.15	0.90	1.47	29.76	11.90	**12.10**	2.27
82	32	16351	16351.00	70.61	0.88	1.49	30.73	12.29		
83	33	16181	16181.00	69.83	0.84	1.51	32.17	12.87	**12.23**	7.36
84	33	16565	16565.00	71.59	0.92	1.46	28.98	11.59		
85	34	15823	15823.00	68.18	0.76	1.55	35.34	14.14	**15.00**	8.15
86	34	15370	15370.00	66.10	0.67	1.60	39.67	15.87		
87	35	16499	16499.00	71.29	0.91	1.47	29.52	11.81	**12.84**	11.37
88	35	15896	15896.00	68.52	0.78	1.54	34.68	13.87		
89	36	14146	14146.00	60.48	0.43	1.73	53.36	21.35	**21.19**	1.02
90	36	14207	14207.00	60.76	0.44	1.72	52.60	21.04		
91	37	14690	14690.00	62.98	0.53	1.67	46.88	18.75	**19.34**	4.30
92	37	14436	14436.00	61.81	0.48	1.70	49.82	19.93		
93	38	15875	15875.00	68.42	0.77	1.54	34.87	13.95	**14.20**	2.56
94	38	15735	15735.00	67.78	0.74	1.56	36.15	14.46		
95	39	14844	14844.00	63.69	0.56	1.65	45.17	18.07	**17.41**	5.34
96	39	15152	15152.00	65.10	0.62	1.62	41.88	16.75		
97	40	15100	15100.00	64.86	0.61	1.63	42.42	16.97	**16.95**	0.14
98	40	15108	15108.00	64.90	0.61	1.63	42.34	16.94		
99	41	15113	15113.00	64.92	0.62	1.63	42.29	16.91	**16.19**	6.33
100	41	15472	15472.00	66.57	0.69	1.59	38.66	15.46		
101	42	16658	16658.00	72.02	0.95	1.45	28.25	11.30	**12.27**	11.24
102	42	16071	16071.00	69.32	0.82	1.52	33.12	13.25		
103	43	16647	16647.00	71.97	0.94	1.45	28.33	11.33	**12.31**	11.26
104	43	16058	16058.00	69.26	0.81	1.52	33.24	13.29		
105	44	15062	15062.00	64.69	0.61	1.63	42.82	17.13	**16.77**	3.03
106	44	15235	15235.00	65.48	0.64	1.61	41.03	16.41		
107	45	14690	14690.00	62.98	0.53	1.67	46.88	18.75	**19.52**	5.53
108	45	14363	14363.00	61.48	0.47	1.70	50.70	20.28		
109	46	14444	14444.00	61.85	0.48	1.70	49.73	19.89	**20.14**	1.73
110	46	14341	14341.00	61.38	0.46	1.71	50.96	20.38		
111	47	15251	15251.00	65.56	0.64	1.61	40.87	16.35	**15.48**	7.89
112	47	15693	15693.00	67.59	0.73	1.56	36.55	14.62		
113	48	15137	15137.00	65.03	0.62	1.62	42.04	16.81	**16.94**	1.03
114	48	15078	15078.00	64.76	0.61	1.63	42.65	17.06		
115	49	15446	15446.00	66.45	0.68	1.59	38.92	15.57	**14.44**	11.00
116	49	16051	16051.00	69.23	0.81	1.52	33.30	13.32		
117	50	15080	15080.00	64.77	0.61	1.63	42.63	17.05	**15.95**	9.82
118	50	15635	15635.00	67.32	0.72	1.57	37.09	14.84		

Appendix 3A continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9973**						
			Slope	**-0.5435**						
			Int	**1.9499**						
1	NSB	916	922.00							
2	NSB	928								
3	0	24519	24442.00							
4	0	24365								
5	12.5	20839	20674.00	83.98	1.66	1.05	11.21			
6	12.5	20509								
7	25	18002	17848.50	71.97	0.94	1.44	27.38			
8	25	17695								
9	50	15155	15077.00	60.18	0.41	1.73	53.13			
10	50	14999								
11	125	10936	10988.50	42.80	-0.29	2.11	128.09			
12	125	11041								
13	250	8211	8185.00	30.88	-0.81	2.39	244.24			
14	250	8159								
15	500	5935	5789.50	20.70	-1.34	2.68	478.68			
16	500	5644								
17	Pool	13850	13850.00	54.97	0.20	1.84	69.43	27.77	**27.21**	2.91
18	Pool	14041	14041.00	55.78	0.23	1.82	66.64	26.65		
19	51	17713	17713.00	71.39	0.91	1.45	28.37	11.35	**11.30**	0.66
20	51	17749	17749.00	71.54	0.92	1.45	28.11	11.24		
21	52	17820	17820.00	71.85	0.94	1.44	27.59	11.04	**10.64**	5.22
22	52	18097	18097.00	73.02	1.00	1.41	25.62	10.25		
23	53	17019	17019.00	68.44	0.77	1.53	33.82	13.53	**12.99**	5.82
24	53	17349	17349.00	69.84	0.84	1.49	31.15	12.46		
25	54	16263	16263.00	65.23	0.63	1.61	40.55	16.22	**16.23**	0.10
26	54	16257	16257.00	65.20	0.63	1.61	40.61	16.24		
27	55	17254	17254.00	69.44	0.82	1.50	31.90	12.76	**12.97**	2.28
28	55	17125	17125.00	68.89	0.79	1.52	32.95	13.18		
29	56	12973	12973.00	51.24	0.05	1.92	83.75	33.50	**33.86**	1.49
30	56	12874	12874.00	50.82	0.03	1.93	85.53	34.21		
31	57	14592	14592.00	58.12	0.33	1.77	59.12	23.65	**24.17**	3.02
32	57	14396	14396.00	57.29	0.29	1.79	61.70	24.68		
33	58	15122	15122.00	60.37	0.42	1.72	52.60	21.04	**20.56**	3.32
34	58	15332	15332.00	61.27	0.46	1.70	50.19	20.08		
35	59	16301	16301.00	65.39	0.64	1.60	40.19	16.08	**17.41**	10.84
36	59	15636	15636.00	62.56	0.51	1.67	46.87	18.75		
37	60	16082	16082.00	64.46	0.60	1.63	42.30	16.92	**16.95**	0.23
38	60	16068	16068.00	64.40	0.59	1.63	42.44	16.98		
39	61	11473	11473.00	44.86	-0.21	2.06	115.35	46.14	**35.35**	43.17
40	61	14419	14419.00	57.39	0.30	1.79	61.40	24.56		

Appendix A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9973**						
			Slope	**0.0000**						
			Int	**0.0000**						
41	62	16096	16096.00	64.52	0.60	1.62	42.17	16.87	**16.12**	6.54
42	62	16490	16490.00	66.19	0.67	1.58	38.44	15.37		
43	63	16578	16578.00	66.56	0.69	1.58	37.64	15.06	**15.44**	3.49
44	63	16370	16370.00	65.68	0.65	1.60	39.55	15.82		
45	64	16065	16065.00	64.38	0.59	1.63	42.47	16.99	**16.59**	3.42
46	64	16272	16272.00	65.26	0.63	1.61	40.47	16.19		
47	65	16465	16465.00	66.08	0.67	1.59	38.67	15.47	**16.03**	4.99
48	65	16165	16165.00	64.81	0.61	1.62	41.49	16.60		
49	66	14994	14994.00	59.83	0.40	1.73	54.12	21.65	**21.61**	0.25
50	66	15010	15010.00	59.90	0.40	1.73	53.93	21.57		
51	67	15690	15690.00	62.79	0.52	1.67	46.29	18.52	**19.01**	3.65
52	67	15462	15462.00	61.82	0.48	1.69	48.75	19.50		
53	68	15726	15726.00	62.94	0.53	1.66	45.92	18.37	**18.01**	2.83
54	68	15901	15901.00	63.69	0.56	1.64	44.11	17.64		
55	69	16969	16969.00	68.23	0.76	1.53	34.24	13.70	**13.16**	5.72
56	69	17295	17295.00	69.61	0.83	1.50	31.57	12.63		
57	70	16069	16069.00	64.40	0.59	1.63	42.43	16.97	**16.89**	0.67
58	70	16110	16110.00	64.57	0.60	1.62	42.03	16.81		
59	71	17107	17107.00	68.81	0.79	1.52	33.09	13.24	**13.26**	0.28
60	71	17091	17091.00	68.75	0.79	1.52	33.22	13.29		
61	72	17488	17488.00	70.43	0.87	1.48	30.07	12.03	**11.94**	1.00
62	72	17543	17543.00	70.67	0.88	1.47	29.65	11.86		
63	73	17539	17539.00	70.65	0.88	1.47	29.68	11.87	**12.02**	1.81
64	73	17439	17439.00	70.23	0.86	1.48	30.45	12.18		
65	74	16177	16177.00	64.86	0.61	1.62	41.38	16.55	**16.54**	0.08
66	74	16182	16182.00	64.88	0.61	1.62	41.33	16.53		
67	75	14684	14684.00	58.51	0.34	1.76	57.94	23.18	**22.40**	4.90
68	75	14999	14999.00	59.85	0.40	1.73	54.06	21.62		
69	76	16443	16443.00	65.99	0.66	1.59	38.87	15.55	**15.58**	0.27
70	76	16427	16427.00	65.92	0.66	1.59	39.02	15.61		
71	77	14979	14979.00	59.77	0.40	1.73	54.30	21.72	**21.03**	4.67
72	77	15276	15276.00	61.03	0.45	1.71	50.83	20.33		
73	78	14796	14796.00	58.99	0.36	1.75	56.54	22.61	**21.65**	6.32
74	78	15200	15200.00	60.71	0.43	1.71	51.70	20.68		
75	79	15875	15875.00	63.58	0.56	1.65	44.38	17.75	**18.19**	3.41
76	79	15664	15664.00	62.68	0.52	1.67	46.57	18.63		
77	80	15768	15768.00	63.12	0.54	1.66	45.48	18.19	**18.48**	2.22
78	80	15630	15630.00	62.53	0.51	1.67	46.93	18.77		

A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9973**						
			Slope	**0.0000**						
			Int	**0.0000**						
79	81	15343	15343.00	61.31	0.46	1.70	50.07	20.03	**18.47**	11.92
80	81	16084	16084.00	64.46	0.60	1.63	42.28	16.91		
81	82	13987	13987.00	55.55	0.22	1.83	67.42	26.97	**25.91**	5.75
82	82	14363	14363.00	57.15	0.29	1.79	62.15	24.86		
83	83	16060	16060.00	64.36	0.59	1.63	42.52	17.01	**16.62**	3.28
84	83	16259	16259.00	65.21	0.63	1.61	40.59	16.24		
85	84	14597	14597.00	58.14	0.33	1.77	59.06	23.62	**23.51**	0.71
86	84	14643	14643.00	58.34	0.34	1.77	58.47	23.39		
87	85	14244	14244.00	56.64	0.27	1.80	63.77	25.51	**26.03**	2.83
88	85	14059	14059.00	55.85	0.24	1.82	66.38	26.55		
89	86	14780	14780.00	58.92	0.36	1.75	56.74	22.69	**23.36**	4.01
90	86	14521	14521.00	57.82	0.32	1.78	60.05	24.02		
91	87	14088	14088.00	55.98	0.24	1.82	65.96	26.39	**26.84**	2.41
92	87	13930	13930.00	55.31	0.21	1.83	68.25	27.30		
93	88	11640	11640.00	45.57	-0.18	2.05	111.29	44.52	**45.43**	2.86
94	88	11452	11452.00	44.77	-0.21	2.06	115.88	46.35		
95	89	13068	13068.00	51.64	0.07	1.91	82.07	32.83	**33.49**	2.80
96	89	12882	12882.00	50.85	0.03	1.93	85.39	34.16		
97	90	10403	10403.00	40.31	-0.39	2.16	145.63	58.25	**61.35**	7.14
98	90	9950	9950.00	38.38	-0.47	2.21	161.11	64.44		
99	91	9753	9753.00	37.55	-0.51	2.23	168.44	67.38	**68.04**	1.38
100	91	9667	9667.00	37.18	-0.52	2.23	171.77	68.71		
101	92	14586	14586.00	58.10	0.33	1.77	59.20	23.68	**22.72**	5.95
102	92	14969	14969.00	59.72	0.39	1.74	54.42	21.77		
103	93	13779	13779.00	54.66	0.19	1.85	70.50	28.20	**27.40**	4.15
104	93	14052	14052.00	55.82	0.23	1.82	66.48	26.59		
105	94	13967	13967.00	55.46	0.22	1.83	67.71	27.08	**26.08**	5.46
106	94	14324	14324.00	56.98	0.28	1.80	62.68	25.07		
107	95	13923	13923.00	55.28	0.21	1.83	68.35	27.34	**27.68**	1.72
108	95	13810	13810.00	54.80	0.19	1.85	70.03	28.01		
109	96	13580	13580.00	53.82	0.15	1.87	73.57	29.43	**29.36**	0.32
110	96	13601	13601.00	53.91	0.16	1.86	73.24	29.30		
111	97	14710	14710.00	58.62	0.35	1.76	57.61	23.05	**23.10**	0.31
112	97	14690	14690.00	58.54	0.34	1.76	57.87	23.15		
113	98	14470	14470.00	57.60	0.31	1.78	60.72	24.29	**25.19**	5.05
114	98	14141	14141.00	56.20	0.25	1.81	65.21	26.08		
115	99	12713	12713.00	50.13	0.01	1.95	88.52	35.41	**36.53**	4.35
116	99	12424	12424.00	48.90	-0.04	1.97	94.13	37.65		
117	100	11519	11519.00	45.06	-0.20	2.06	114.22	45.69	**46.53**	2.57
118	100	11350	11350.00	44.34	-0.23	2.07	118.45	47.38		
119	101	12083	12083.00	47.45	-0.10	2.01	101.23	40.49	**40.26**	0.80
120	101	12136	12136.00	47.68	-0.09	2.00	100.09	40.04		

Appendix A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9973**						
			Slope	**0.0000**						
			Int	**0.0000**						
121	102	15776	15776.00	63.15	0.54	1.66	45.39	18.16	**17.84**	2.55
122	102	15933	15933.00	63.82	0.57	1.64	43.79	17.52		
123	103	12927	12927.00	51.04	0.04	1.93	84.57	33.83	**33.85**	0.09
124	103	12921	12921.00	51.02	0.04	1.93	84.68	33.87		
125	104	14564	14564.00	58.00	0.32	1.77	59.49	23.79	**24.42**	3.63
126	104	14328	14328.00	57.00	0.28	1.80	62.62	25.05		
127	105	14726	14726.00	58.69	0.35	1.76	57.41	22.97	**23.47**	3.06
128	105	14528	14528.00	57.85	0.32	1.78	59.96	23.98		
129	106	15361	15361.00	61.39	0.46	1.70	49.87	19.95	**18.84**	8.34
130	106	15881	15881.00	63.60	0.56	1.65	44.31	17.73		
131	107	11271	11271.00	44.00	-0.24	2.08	120.49	48.20	**47.67**	1.56
132	107	11373	11373.00	44.43	-0.22	2.07	117.87	47.15		
133	108	12344	12344.00	48.56	-0.06	1.98	95.75	38.30	**39.07**	2.77
134	108	12160	12160.00	47.78	-0.09	2.00	99.58	39.83		
135	109	13118	13118.00	51.85	0.07	1.91	81.20	32.48	**33.04**	2.38
136	109	12960	12960.00	51.18	0.05	1.92	83.98	33.59		
137	110	12661	12661.00	49.91	0.00	1.95	89.50	35.80	**37.99**	8.15
138	110	12119	12119.00	47.61	-0.10	2.00	100.45	40.18		
139	111	14227	14227.00	56.57	0.26	1.81	64.01	25.60	**26.28**	3.65
140	111	13988	13988.00	55.55	0.22	1.83	67.40	26.96		
141	112	11652	11652.00	45.62	-0.18	2.05	111.00	44.40	**49.64**	14.92
142	112	10674	10674.00	41.46	-0.34	2.14	137.19	54.88		
143	113	11959	11959.00	46.93	-0.12	2.02	103.94	41.58	**45.24**	11.44
144	113	11204	11204.00	43.72	-0.25	2.09	122.25	48.90		
145	114	11274	11274.00	44.01	-0.24	2.08	120.41	48.16	**51.03**	7.95
146	114	10756	10756.00	41.81	-0.33	2.13	134.75	53.90		
147	115	11189	11189.00	43.65	-0.26	2.09	122.64	49.06	**49.87**	2.31
148	115	11038	11038.00	43.01	-0.28	2.10	126.72	50.69		
149	116	9213	9213.00	35.25	-0.61	2.28	190.71	76.28	**77.85**	2.85
150	116	9041	9041.00	34.52	-0.64	2.30	198.55	79.42		
151	117	12736	12736.00	50.23	0.01	1.94	88.08	35.23	**32.01**	14.23
152	117	13682	13682.00	54.25	0.17	1.86	71.98	28.79		
153	118	11865	11865.00	46.53	-0.14	2.03	106.05	42.42	**42.20**	0.74
154	118	11914	11914.00	46.73	-0.13	2.02	104.95	41.98		
155	119	10216	10216.00	39.52	-0.43	2.18	151.80	60.72	**62.93**	4.97
156	119	9902	9902.00	38.18	-0.48	2.21	162.86	65.14		

A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9970**						
			Slope	**-0.5652**						
			Int	**1.8708**						
1	NSB	1183	1111.50							
2	NSB	1040								
3	0	23123	23123.00							
4	0									
5	12.5	18519	18576.00	79.34	1.35	1.11	12.89			
6	12.5	18633								
7	25	16937	16898.00	71.72	0.93	1.34	22.12			
8	25	16859								
9	50	13431	13365.50	55.67	0.23	1.74	55.21			
10	50	13300								
11	125	9643	9752.00	39.25	-0.44	2.12	131.10			
12	125	9861								
13	250	7621	7382.00	28.49	-0.92	2.39	246.06			
14	250	7143								
15	500	5356	5344.50	19.23	-1.44	2.68	480.78			
16	500	5333								
17	Pool	13690	13690.00	57.15	0.29	1.71	51.07	20.43	**20.43**	0.05
18	Pool	13687	13687.00	57.13	0.29	1.71	51.11	20.44		
19	120	12906	12906.00	53.58	0.14	1.79	61.61	24.64	**24.97**	1.85
20	120	12796	12796.00	53.08	0.12	1.80	63.24	25.30		
21	121	11448	11448.00	46.96	-0.12	1.94	87.02	34.81	**33.96**	3.55
22	121	11660	11660.00	47.92	-0.08	1.92	82.76	33.10		
23	122	12063	12063.00	49.75	-0.01	1.88	75.23	30.09	**28.27**	9.12
24	122	12609	12609.00	52.23	0.09	1.82	66.11	26.44		
25	123	13403	13403.00	55.84	0.23	1.74	54.72	21.89	**24.15**	13.27
26	123	12613	12613.00	52.25	0.09	1.82	66.05	26.42		
27	124	10184	10184.00	41.22	-0.35	2.07	117.89	47.15	**49.07**	5.53
28	124	9865	9865.00	39.77	-0.42	2.11	127.48	50.99		
29	125	8509	8509.00	33.61	-0.68	2.26	180.15	72.06	**68.00**	8.45
30	125	8967	8967.00	35.69	-0.59	2.20	159.84	63.94		
31	126	10259	10259.00	41.56	-0.34	2.06	115.75	46.30	**46.90**	1.81
32	126	10154	10154.00	41.08	-0.36	2.07	118.75	47.50		
33	127	9320	9320.00	37.29	-0.52	2.16	146.07	58.43	**60.08**	3.88
34	127	9104	9104.00	36.31	-0.56	2.19	154.32	61.73		
35	128	11685	11685.00	48.04	-0.08	1.92	82.27	32.91	**33.43**	2.23
36	128	11552	11552.00	47.43	-0.10	1.93	84.90	33.96		
37	129	11105	11105.00	45.40	-0.18	1.98	94.42	37.77	**39.18**	5.11
38	129	10803	10803.00	44.03	-0.24	2.01	101.50	40.60		
39	130	13046	13046.00	54.22	0.17	1.78	59.59	23.84	**28.26**	22.13
40	130	11714	11714.00	48.17	-0.07	1.91	81.70	32.68		

A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9970**						
			Slope	**0.0000**						
			Int	**0.0000**						
41	131	10051	10051.00	40.61	-0.38	2.09	121.78	48.71	**48.62**	0.28
42	131	10067	10067.00	40.69	-0.38	2.08	121.31	48.52		
43	132	12503	12503.00	51.75	0.07	1.83	67.79	27.12	**26.82**	1.57
44	132	12597	12597.00	52.18	0.09	1.82	66.30	26.52		
45	133	12221	12221.00	50.47	0.02	1.86	72.47	28.99	**28.34**	3.21
46	133	12413	12413.00	51.34	0.05	1.84	69.25	27.70		
47	134	12307	12307.00	50.86	0.03	1.85	71.01	28.40	**35.19**	27.26
48	134	10665	10665.00	43.40	-0.27	2.02	104.92	41.97		
49	135	11450	11450.00	46.97	-0.12	1.94	86.98	34.79	**34.92**	0.52
50	135	11419	11419.00	46.83	-0.13	1.94	87.62	35.05		
51	136	11807	11807.00	48.59	-0.06	1.90	79.93	31.97	**31.04**	4.21
52	136	12059	12059.00	49.74	-0.01	1.88	75.30	30.12		
53	137	11091	11091.00	45.34	-0.19	1.98	94.74	37.90	**36.68**	4.69
54	137	11370	11370.00	46.61	-0.14	1.95	88.65	35.46		
55	138	13828	13828.00	57.77	0.31	1.69	49.39	19.76	**19.42**	2.46
56	138	13971	13971.00	58.42	0.34	1.68	47.71	19.08		
57	139	11503	11503.00	47.21	-0.11	1.93	85.89	34.36	**34.13**	0.94
58	139	11559	11559.00	47.46	-0.10	1.93	84.76	33.90		
59	140	11255	11255.00	46.08	-0.16	1.96	91.11	36.44	**38.79**	8.56
60	140	10748	10748.00	43.78	-0.25	2.01	102.84	41.14		
61	141	12847	12847.00	53.32	0.13	1.80	62.48	24.99	**25.05**	0.32
62	141	12828	12828.00	53.23	0.13	1.80	62.76	25.11		
63	142	13380	13380.00	55.74	0.23	1.74	55.02	22.01	**22.25**	1.51
64	142	13291	13291.00	55.33	0.21	1.75	56.21	22.48		
65	143	12613	12613.00	52.25	0.09	1.82	66.05	26.42	**24.37**	11.90
66	143	13322	13322.00	55.47	0.22	1.75	55.79	22.32		
67	144	13373	13373.00	55.70	0.23	1.74	55.11	22.05	**21.79**	1.66
68	144	13471	13471.00	56.15	0.25	1.73	53.83	21.53		
69	145	13308	13308.00	55.41	0.22	1.75	55.98	22.39	**22.60**	1.30
70	145	13231	13231.00	55.06	0.20	1.76	57.02	22.81		
71	146	13389	13389.00	55.78	0.23	1.74	54.90	21.96	**20.98**	6.60
72	146	13777	13777.00	57.54	0.30	1.70	50.01	20.00		
73	147	13579	13579.00	56.64	0.27	1.72	52.45	20.98	**22.37**	8.81
74	147	13058	13058.00	54.27	0.17	1.77	59.42	23.77		
75	148	12652	12652.00	52.43	0.10	1.82	65.44	26.18	**26.21**	0.20
76	148	12640	12640.00	52.37	0.10	1.82	65.63	26.25		
77	149	10957	10957.00	44.73	-0.21	1.99	97.82	39.13	**38.61**	1.89
78	149	11069	11069.00	45.24	-0.19	1.98	95.24	38.09		
79	150	8904	8904.00	35.40	-0.60	2.21	162.46	64.98	**67.65**	5.57
80	150	8602	8602.00	34.03	-0.66	2.24	175.78	70.31		
81	151	8656	8656.00	34.28	-0.65	2.24	173.30	69.32	**70.69**	2.74
82	151	8509	8509.00	33.61	-0.68	2.26	180.15	72.06		
83	152	11903	11903.00	49.03	-0.04	1.89	78.13	31.25	**30.38**	4.05
84	152	12145	12145.00	50.13	0.01	1.87	73.78	29.51		
85	153	10961	10961.00	44.75	-0.21	1.99	97.73	39.09	**37.88**	4.52
86	153	11229	11229.00	45.96	-0.16	1.96	91.67	36.67		

A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9970**						
			Slope	**0.0000**						
			Int	**0.0000**						
87	154	9316	9316.00	37.27	-0.52	2.17	146.22	58.49	**60.88**	5.55
88	154	9008	9008.00	35.87	-0.58	2.20	158.16	63.26		
89	155	11369	11369.00	46.60	-0.14	1.95	88.67	35.47	**35.19**	1.11
90	155	11435	11435.00	46.90	-0.12	1.94	87.29	34.92		
91	156	11279	11279.00	46.19	-0.15	1.96	90.59	36.24	**34.18**	8.51
92	156	11787	11787.00	48.50	-0.06	1.90	80.30	32.12		
93	157	12597	12597.00	52.18	0.09	1.82	66.30	26.52	**27.21**	3.62
94	157	12381	12381.00	51.20	0.05	1.84	69.78	27.91		
95	158	11242	11242.00	46.02	-0.16	1.96	91.39	36.56	**36.04**	2.03
96	158	11363	11363.00	46.57	-0.14	1.95	88.80	35.52		
97	159	12886	12886.00	53.49	0.14	1.79	61.90	24.76	**27.85**	15.68
98	159	11946	11946.00	49.22	-0.03	1.89	77.34	30.94		
99	160	12075	12075.00	49.81	-0.01	1.88	75.01	30.01	**32.73**	11.78
100	160	11370	11370.00	46.61	-0.14	1.95	88.65	35.46		
101	161	11441	11441.00	46.93	-0.12	1.94	87.17	34.87	**34.89**	0.10
102	161	11435	11435.00	46.90	-0.12	1.94	87.29	34.92		
103	162	11392	11392.00	46.71	-0.13	1.95	88.19	35.28	**37.03**	6.70
104	162	10994	10994.00	44.90	-0.20	1.99	96.96	38.78		
105	163	11406	11406.00	46.77	-0.13	1.94	87.90	35.16	**32.55**	11.31
106	163	12083	12083.00	49.84	-0.01	1.87	74.87	29.95		
107	164	11027	11027.00	45.05	-0.20	1.98	96.20	38.48	**37.01**	5.61
108	164	11360	11360.00	46.56	-0.14	1.95	88.86	35.54		
109	165	12370	12370.00	51.15	0.05	1.84	69.96	27.98	**29.42**	6.89
110	165	11958	11958.00	49.28	-0.03	1.89	77.12	30.85		
111	166	12242	12242.00	50.57	0.02	1.86	72.11	28.84	**28.54**	1.49
112	166	12331	12331.00	50.97	0.04	1.85	70.61	28.24		
113	167	10148	10148.00	41.05	-0.36	2.08	118.93	47.57	**48.93**	3.92
114	167	9922	9922.00	40.03	-0.40	2.10	125.71	50.28		
115	168	9428	9428.00	37.78	-0.50	2.15	142.15	56.86	**54.21**	6.91
116	168	9820	9820.00	39.56	-0.42	2.11	128.91	51.56		
117	169	10111	10111.00	40.89	-0.37	2.08	120.01	48.00	**48.96**	2.78
118	169	9951	9951.00	40.16	-0.40	2.10	124.81	49.92		
119	170	13085	13085.00	54.40	0.18	1.77	59.04	23.62	**21.98**	10.51
120	170	13706	13706.00	57.22	0.29	1.71	50.87	20.35		
121	171	13107	13107.00	54.50	0.18	1.77	58.73	23.49	**23.91**	2.48
122	171	12960	12960.00	53.83	0.15	1.78	60.82	24.33		
123	172	12789	12789.00	53.05	0.12	1.80	63.35	25.34	**24.88**	2.59
124	172	12943	12943.00	53.75	0.15	1.79	61.07	24.43		
125	173	12450	12450.00	51.51	0.06	1.84	68.65	27.46	**28.31**	4.23
126	173	12197	12197.00	50.36	0.01	1.86	72.88	29.15		
127	174	11901	11901.00	49.02	-0.04	1.89	78.17	31.27	**33.41**	9.05
128	174	11360	11360.00	46.56	-0.14	1.95	88.86	35.54		
129	175	12809	12809.00	53.14	0.13	1.80	63.05	25.22	**28.49**	16.23
130	175	11835	11835.00	48.72	-0.05	1.90	79.40	31.76		

A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9970**						
			Slope	**0.0000**						
			Int	**0.0000**						
131	176	11235	11235.00	45.99	-0.16	1.96	91.54	36.62	**37.83**	4.54
132	176	10966	10966.00	44.77	-0.21	1.99	97.61	39.04		
133	177	11898	11898.00	49.00	-0.04	1.89	78.22	31.29	**32.14**	3.75
134	177	11674	11674.00	47.99	-0.08	1.92	82.48	32.99		
135	178	8403	8403.00	33.13	-0.70	2.27	185.30	74.12	**76.74**	4.84
136	178	8149	8149.00	31.97	-0.76	2.30	198.42	79.37		
137	179	11993	11993.00	49.44	-0.02	1.88	76.48	30.59	**29.38**	5.82
138	179	12341	12341.00	51.02	0.04	1.85	70.44	28.18		
139	180	8430	8430.00	33.25	-0.70	2.26	183.97	73.59	**74.24**	1.25
140	180	8364	8364.00	32.95	-0.71	2.27	187.24	74.90		
141	181	11836	11836.00	48.72	-0.05	1.90	79.38	31.75	**31.57**	0.82
142	181	11885	11885.00	48.94	-0.04	1.89	78.46	31.39		
143	182	12430	12430.00	51.42	0.06	1.84	68.97	27.59	**26.35**	6.63
144	182	12826	12826.00	53.22	0.13	1.80	62.79	25.12		
145	183	10589	10589.00	43.06	-0.28	2.03	106.86	42.74	**35.33**	29.66
146	183	12379	12379.00	51.19	0.05	1.84	69.81	27.92		
147	184	16407	16407.00	69.49	0.82	1.41	25.44	10.18	**17.12**	57.37
148	184	13005	13005.00	54.03	0.16	1.78	60.18	24.07		
149	185	11725	11725.00	48.22	-0.07	1.91	81.49	32.60	**32.25**	1.51
150	185	11815	11815.00	48.63	-0.05	1.90	79.77	31.91		
151	186	11094	11094.00	45.35	-0.19	1.98	94.67	37.87	**37.73**	0.52
152	186	11125	11125.00	45.49	-0.18	1.97	93.97	37.59		
153	187	8629	8629.00	34.15	-0.66	2.24	174.53	69.81	**76.27**	11.98
154	187	7997	7997.00	31.28	-0.79	2.32	206.84	82.74		
155	188	11679	11679.00	48.01	-0.08	1.92	82.38	32.95	**33.86**	3.81
156	188	11452	11452.00	46.98	-0.12	1.94	86.94	34.78		
157	189	10452	10452.00	42.43	-0.30	2.04	110.45	44.18	**45.01**	2.61
158	189	10300	10300.00	41.74	-0.33	2.06	114.60	45.84		
159	190	10777	10777.00	43.91	-0.24	2.01	102.13	40.85	**44.99**	13.00
160	190	10017	10017.00	40.46	-0.39	2.09	122.80	49.12		
161	191	11621	11621.00	47.75	-0.09	1.92	83.52	33.41	**31.04**	10.80
162	191	12268	12268.00	50.68	0.03	1.86	71.67	28.67		
163	192	10408	10408.00	42.23	-0.31	2.05	111.64	44.65	**46.52**	5.66
164	192	10079	10079.00	40.74	-0.37	2.08	120.95	48.38		
165	193	11263	11263.00	46.12	-0.16	1.96	90.93	36.37	**36.81**	1.67
166	193	11164	11164.00	45.67	-0.17	1.97	93.10	37.24		
167	194	8567	8567.00	33.87	-0.67	2.25	177.41	70.96	**65.61**	11.55
168	194	9199	9199.00	36.74	-0.54	2.18	150.62	60.25		
169	195	9991	9991.00	40.34	-0.39	2.09	123.59	49.44	**49.57**	0.38
170	195	9969	9969.00	40.24	-0.40	2.09	124.26	49.70		

A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9970**						
			Slope	**0.0000**						
			Int	**0.0000**						
171	196	12256	12256.00	50.63	0.03	1.86	71.87	28.75	**27.83**	4.65
172	196	12534	12534.00	51.89	0.08	1.83	67.29	26.92		
173	197	10433	10433.00	42.35	-0.31	2.05	110.96	44.38	**45.31**	2.88
174	197	10265	10265.00	41.59	-0.34	2.06	115.58	46.23		
175	198	10894	10894.00	44.44	-0.22	2.00	99.31	39.72	**38.00**	6.41
176	198	11274	11274.00	46.17	-0.15	1.96	90.70	36.28		
177	199	10952	10952.00	44.71	-0.21	1.99	97.94	39.17	**38.40**	2.85
178	199	11121	11121.00	45.47	-0.18	1.97	94.06	37.63		
179	200	11293	11293.00	46.26	-0.15	1.96	90.29	36.12	**39.50**	12.11
180	200	10576	10576.00	43.00	-0.28	2.03	107.19	42.88		
181	201	11491	11491.00	47.15	-0.11	1.94	86.14	34.46	**37.66**	12.05
182	201	10775	10775.00	43.90	-0.25	2.01	102.18	40.87		
183	202	11018	11018.00	45.01	-0.20	1.98	96.40	38.56	**39.06**	1.79
184	202	10912	10912.00	44.52	-0.22	2.00	98.88	39.55		
185	203	11952	11952.00	49.25	-0.03	1.89	77.23	30.89	**31.48**	2.64
186	203	11794	11794.00	48.53	-0.06	1.90	80.17	32.07		
187	204	12398	12398.00	51.28	0.05	1.84	69.50	27.80	**28.05**	1.25
188	204	12323	12323.00	50.93	0.04	1.85	70.74	28.30		
189	205	12078	12078.00	49.82	-0.01	1.87	74.96	29.98	**28.32**	8.29
190	205	12574	12574.00	52.08	0.08	1.82	66.66	26.66		
191	206	10574	10574.00	42.99	-0.28	2.03	107.24	42.90	**42.09**	2.71
192	206	10733	10733.00	43.71	-0.25	2.01	103.22	41.29		
193	207	11505	11505.00	47.22	-0.11	1.93	85.85	34.34	**34.82**	1.93
194	207	11390	11390.00	46.70	-0.13	1.95	88.23	35.29		
195	208	10463	10463.00	42.48	-0.30	2.04	110.16	44.06	**43.75**	1.03
196	208	10523	10523.00	42.76	-0.29	2.04	108.57	43.43		

A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9968**						
			Slope	**-0.5383**						
			Int	**1.8915**						
1	NSB	1088	1225.00							
2	NSB	1362								
3	0	24861	24968.00							
4	0	25075								
5	12.5	20383	20825.00	82.55	1.55	1.05	11.35			
6	12.5	21267								
7	25	17984	17953.00	70.45	0.87	1.42	26.53			
8	25	17922								
9	50	14434	14704.50	56.77	0.27	1.74	55.56			
10	50	14975								
11	125	10626	10771.00	40.21	-0.40	2.11	127.40			
12	125	10916								
13	250	8240	8222.50	29.47	-0.87	2.36	229.75			
14	250	8205								
15	500	5590	5564.00	18.27	-1.50	2.70	498.70			
16	500	5538								
17	Pool	14681	14681.00	56.67	0.27	1.75	55.84	22.34	**21.85**	3.12
18	Pool	14888	14888.00	57.55	0.30	1.73	53.43	21.37		
19	209	13303	13303.00	50.87	0.03	1.87	74.61	29.84	**30.48**	2.95
20	209	13103	13103.00	50.03	0.00	1.89	77.79	31.12		
21	210	12215	12215.00	46.29	-0.15	1.97	93.67	37.47	**37.52**	0.18
22	210	12203	12203.00	46.24	-0.15	1.97	93.91	37.56		
23	211	12970	12970.00	49.47	-0.02	1.90	79.98	31.99	**31.80**	0.84
24	211	13027	13027.00	49.71	-0.01	1.90	79.03	31.61		
25	212	14163	14163.00	54.49	0.18	1.79	62.31	24.92	**24.69**	1.34
26	212	14253	14253.00	54.87	0.20	1.79	61.14	24.45		
27	213	14400	14400.00	55.49	0.22	1.77	59.27	23.71	**23.91**	1.22
28	213	14318	14318.00	55.14	0.21	1.78	60.30	24.12		
29	214	13527	13527.00	51.81	0.07	1.85	71.20	28.48	**26.43**	10.99
30	214	14269	14269.00	54.94	0.20	1.78	60.93	24.37		
31	215	14350	14350.00	55.28	0.21	1.78	59.90	23.96	**24.12**	0.97
32	215	14285	14285.00	55.01	0.20	1.78	60.72	24.29		
33	216	14973	14973.00	57.90	0.32	1.72	52.47	20.99	**21.36**	2.48
34	216	14809	14809.00	57.21	0.29	1.74	54.34	21.74		
35	217	15220	15220.00	58.94	0.36	1.70	49.75	19.90	**20.64**	5.04
36	217	14888	14888.00	57.55	0.30	1.73	53.43	21.37		
37	218	9566	9566.00	35.13	-0.61	2.22	166.60	66.64	**45.54**	65.53
38	218	14256	14256.00	54.88	0.20	1.79	61.10	24.44		
39	219	14069	14069.00	54.10	0.16	1.80	63.55	25.42	**24.37**	6.10
40	219	14478	14478.00	55.82	0.23	1.77	58.30	23.32		

A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9968**						
			Slope	**0.0000**						
			Int	**0.0000**						
41	220	14391	14391.00	55.45	0.22	1.77	59.38	23.75	**23.55**	1.21
42	220	14472	14472.00	55.79	0.23	1.77	58.37	23.35		
43	221	14616	14616.00	56.40	0.26	1.75	56.62	22.65	**23.05**	2.49
44	221	14450	14450.00	55.70	0.23	1.77	58.64	23.46		
45	222	13959	13959.00	53.63	0.15	1.81	65.04	26.01	**26.08**	0.36
46	222	13935	13935.00	53.53	0.14	1.82	65.36	26.15		
47	223	15116	15116.00	58.51	0.34	1.71	50.88	20.35	**21.49**	7.49
48	223	14620	14620.00	56.42	0.26	1.75	56.57	22.63		
49	224	13099	13099.00	50.01	0.00	1.89	77.86	31.14	**30.88**	1.18
50	224	13179	13179.00	50.35	0.01	1.88	76.57	30.63		
51	225	12574	12574.00	47.80	-0.09	1.94	86.88	34.75	**35.01**	1.04
52	225	12504	12504.00	47.50	-0.10	1.95	88.16	35.27		
53	226	13141	13141.00	50.19	0.01	1.89	77.18	30.87	**31.60**	3.26
54	226	12920	12920.00	49.26	-0.03	1.91	80.82	32.33		
55	227	10755	10755.00	40.14	-0.40	2.11	127.85	51.14	**39.95**	39.61
56	227	13480	13480.00	51.62	0.06	1.86	71.90	28.76		
57	228	13104	13104.00	50.03	0.00	1.89	77.77	31.11	**30.74**	1.68
58	228	13218	13218.00	50.51	0.02	1.88	75.94	30.38		
59	229	14416	14416.00	55.56	0.22	1.77	59.07	23.63	**23.73**	0.61
60	229	14375	14375.00	55.38	0.22	1.78	59.58	23.83		
61	230	13927	13927.00	53.50	0.14	1.82	65.47	26.19	**26.79**	3.16
62	230	13714	13714.00	52.60	0.10	1.84	68.46	27.39		
63	231	13352	13352.00	51.08	0.04	1.87	73.85	29.54	**28.24**	6.50
64	231	13792	13792.00	52.93	0.12	1.83	67.35	26.94		
65	232	13310	13310.00	50.90	0.04	1.87	74.50	29.80	**29.70**	0.49
66	232	13343	13343.00	51.04	0.04	1.87	73.99	29.59		
67	233	14890	14890.00	57.55	0.30	1.73	53.41	21.36	**21.82**	2.95
68	233	14694	14694.00	56.73	0.27	1.75	55.69	22.27		
69	234	14408	14408.00	55.52	0.22	1.77	59.17	23.67	**23.97**	1.76
70	234	14290	14290.00	55.03	0.20	1.78	60.66	24.26		
71	235	14348	14348.00	55.27	0.21	1.78	59.92	23.97	**24.50**	3.04
72	235	14144	14144.00	54.41	0.18	1.80	62.56	25.02		
73	236	10611	10611.00	39.53	-0.43	2.12	131.92	52.77	**40.06**	44.88
74	236	13721	13721.00	52.63	0.11	1.83	68.36	27.35		
75	237	12817	12817.00	48.82	-0.05	1.92	82.58	33.03	**33.89**	3.58
76	237	12575	12575.00	47.80	-0.09	1.94	86.86	34.75		
77	238	14566	14566.00	56.19	0.25	1.76	57.22	22.89	**21.80**	7.04
78	238	15033	15033.00	58.16	0.33	1.71	51.80	20.72		
79	239	15461	15461.00	59.96	0.40	1.67	47.22	18.89	**18.41**	3.67
80	239	15699	15699.00	60.96	0.45	1.65	44.83	17.93		
81	240	13616	13616.00	52.19	0.09	1.84	69.88	27.95	**26.96**	5.23
82	240	13969	13969.00	53.67	0.15	1.81	64.90	25.96		
83	241	15243	15243.00	59.04	0.37	1.69	49.51	19.80	**19.90**	0.72
84	241	15196	15196.00	58.84	0.36	1.70	50.01	20.01		

Appendix A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9968**						
			Slope	**0.0000**						
			Int	**0.0000**						
85	242	14469	14469.00	55.78	0.23	1.77	58.41	23.36	**24.25**	5.16
86	242	14123	14123.00	54.32	0.17	1.80	62.83	25.13		
87	243	14360	14360.00	55.32	0.21	1.78	59.77	23.91	**31.62**	34.49
88	243	11984	11984.00	45.31	-0.19	1.99	98.33	39.33		
89	244	13649	13649.00	52.33	0.09	1.84	69.40	27.76	**28.10**	1.72
90	244	13533	13533.00	51.84	0.07	1.85	71.11	28.44		
91	245	11325	11325.00	42.54	-0.30	2.05	113.08	45.23	**43.18**	6.73
92	245	11773	11773.00	44.43	-0.22	2.01	102.81	41.13		
93	246	13480	13480.00	51.62	0.06	1.86	71.90	28.76	**29.23**	2.28
94	246	13326	13326.00	50.97	0.04	1.87	74.25	29.70		
95	247	15236	15236.00	59.01	0.36	1.70	49.58	19.83	**20.11**	1.95
96	247	15108	15108.00	58.47	0.34	1.71	50.97	20.39		
97	248	13938	13938.00	53.54	0.14	1.82	65.32	26.13	**26.35**	1.20
98	248	13857	13857.00	53.20	0.13	1.82	66.44	26.58		
99	249	12337	12337.00	46.80	-0.13	1.96	91.30	36.52	**36.90**	1.44
100	249	12240	12240.00	46.39	-0.14	1.97	93.18	37.27		
101	250	14919	14919.00	57.68	0.31	1.72	53.08	21.23	**24.91**	20.86
102	250	13510	13510.00	51.74	0.07	1.85	71.45	28.58		
103	251	14152	14152.00	54.45	0.18	1.80	62.45	24.98	**21.96**	19.42
104	251	15447	15447.00	59.90	0.40	1.68	47.37	18.95		
105	252	12308	12308.00	46.68	-0.13	1.96	91.86	36.74	**35.86**	3.50
106	252	12544	12544.00	47.67	-0.09	1.94	87.43	34.97		
107	253	14242	14242.00	54.82	0.19	1.79	61.28	24.51	**25.77**	6.93
108	253	13775	13775.00	52.86	0.11	1.83	67.59	27.04		
109	254	15374	15374.00	59.59	0.39	1.68	48.13	19.25	**19.92**	4.76
110	254	15062	15062.00	58.28	0.33	1.71	51.48	20.59		
111	255	14447	14447.00	55.69	0.23	1.77	58.68	23.47	**23.72**	1.48
112	255	14348	14348.00	55.27	0.21	1.78	59.92	23.97		
113	256	14942	14942.00	57.77	0.31	1.72	52.82	21.13	**21.73**	3.91
114	256	14683	14683.00	56.68	0.27	1.75	55.82	22.33		
115	257	15187	15187.00	58.80	0.36	1.70	50.11	20.04	**20.14**	0.64
116	257	15145	15145.00	58.63	0.35	1.70	50.57	20.23		
117	258	14038	14038.00	53.97	0.16	1.81	63.97	25.59	**26.31**	3.89
118	258	13776	13776.00	52.86	0.11	1.83	67.58	27.03		
119	259	15022	15022.00	58.11	0.33	1.72	51.92	20.77	**21.45**	4.47
120	259	14726	14726.00	56.86	0.28	1.74	55.31	22.12		
121	260	14019	14019.00	53.89	0.16	1.81	64.22	25.69	**25.98**	1.59
122	260	13912	13912.00	53.43	0.14	1.82	65.68	26.27		
123	261	15264	15264.00	59.13	0.37	1.69	49.28	19.71	**19.58**	0.98
124	261	15328	15328.00	59.40	0.38	1.69	48.61	19.44		

Appendix A3 continued. Fecal glucocorticoid metabolite concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9968**						
			Slope	**0.0000**						
			Int	**0.0000**						
125	262	13774	13774.00	52.85	0.11	1.83	67.61	27.04	**27.12**	0.40
126	262	13747	13747.00	52.74	0.11	1.83	67.99	27.20		
127	263	23448	23448.00	93.60	2.68	0.45	2.80	1.12	**0.85**	46.10
128	263	24063	24063.00	96.19	3.23	0.15	1.42	0.57		
129	264	15207	15207.00	58.89	0.36	1.70	49.89	19.96	**21.40**	9.51
130	264	14577	14577.00	56.24	0.25	1.76	57.09	22.84		
131	265	14683	14683.00	56.68	0.27	1.75	55.82	22.33	**20.91**	9.55
132	265	15314	15314.00	59.34	0.38	1.69	48.75	19.50		
133	266	13884	13884.00	53.32	0.13	1.82	66.07	26.43	**25.96**	2.55
134	266	14056	14056.00	54.04	0.16	1.80	63.72	25.49		
135	267	13144	13144.00	50.20	0.01	1.89	77.13	30.85	**25.28**	31.19
136	267	15267	15267.00	59.14	0.37	1.69	49.25	19.70		
137	268	16047	16047.00	62.43	0.51	1.62	41.51	16.61	**16.28**	2.81
138	268	16225	16225.00	63.18	0.54	1.60	39.90	15.96		
139	269	16196	16196.00	63.05	0.53	1.60	40.16	16.06	**16.63**	4.84
140	269	15888	15888.00	61.76	0.48	1.63	43.01	17.20		
141	270	16670	16670.00	65.05	0.62	1.56	36.06	14.43	**13.97**	4.61
142	270	16952	16952.00	66.24	0.67	1.53	33.78	13.51		
143	271	16991	16991.00	66.40	0.68	1.52	33.48	13.39	**13.14**	2.74
144	271	17156	17156.00	67.10	0.71	1.51	32.20	12.88		
145	272	16220	16220.00	63.16	0.54	1.60	39.94	15.98	**15.53**	4.02
146	272	16472	16472.00	64.22	0.58	1.58	37.73	15.09		
147	273	16033	16033.00	62.37	0.51	1.62	41.64	16.66	**16.43**	2.00
148	273	16160	16160.00	62.90	0.53	1.61	40.48	16.19		
149	274	13937	13937.00	53.54	0.14	1.82	65.34	26.13	**26.36**	1.23
150	274	13854	13854.00	53.19	0.13	1.82	66.48	26.59		
151	275	12701	12701.00	48.33	-0.07	1.93	84.61	33.84	**33.53**	1.30
152	275	12789	12789.00	48.70	-0.05	1.92	83.06	33.23		
153	276	13183	13183.00	50.36	0.01	1.88	76.50	30.60	**31.54**	4.21
154	276	12898	12898.00	49.16	-0.03	1.91	81.19	32.48		
155	277	13180	13180.00	50.35	0.01	1.88	76.55	30.62	**31.73**	4.95
156	277	12845	12845.00	48.94	-0.04	1.91	82.10	32.84		
157	278	14710	14710.00	56.80	0.27	1.74	55.50	22.20	**22.38**	1.14
158	278	14634	14634.00	56.48	0.26	1.75	56.40	22.56		
159	279	13652	13652.00	52.34	0.09	1.84	69.36	27.74	**27.22**	2.71
160	279	13835	13835.00	53.11	0.12	1.82	66.75	26.70		
161	280	13752	13752.00	52.76	0.11	1.83	67.92	27.17	**26.86**	1.64
162	280	13863	13863.00	53.23	0.13	1.82	66.36	26.54		

Appendix 3A continued. Fecal glucocorticoid concentration calculations.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9968**						
			Slope	**0.0000**						
			Int	**0.0000**						
161	280	13752	13752.00	52.76	0.11	1.83	67.92	27.17	**26.86**	1.64
162	280	13863	13863.00	53.23	0.13	1.82	66.36	26.54		
163	281	16289	16289.00	63.45	0.55	1.59	39.33	15.73	**15.62**	1.00
164	281	16352	16352.00	63.71	0.56	1.59	38.77	15.51		
165	282	16085	16085.00	62.59	0.51	1.61	41.17	16.47	**17.36**	7.27
166	282	15619	15619.00	60.62	0.43	1.66	45.63	18.25		
167	283	16813	16813.00	65.65	0.65	1.54	34.89	13.96	**14.63**	6.52
168	283	16410	16410.00	63.96	0.57	1.58	38.27	15.31		
169	284	16056	16056.00	62.46	0.51	1.62	41.43	16.57	**16.80**	1.92
170	284	15934	15934.00	61.95	0.49	1.63	42.57	17.03		
171	285	15075	15075.00	58.33	0.34	1.71	51.33	20.53	**19.29**	9.08
172	285	15668	15668.00	60.83	0.44	1.65	45.14	18.06		
173	286	13484	13484.00	51.63	0.07	1.86	71.84	28.74	**29.95**	5.71
174	286	13097	13097.00	50.00	0.00	1.89	77.89	31.16		
175	287	15983	15983.00	62.16	0.50	1.62	42.11	16.84	**17.27**	3.47
176	287	15761	15761.00	61.22	0.46	1.65	44.23	17.69		
177	288	13481	13481.00	51.62	0.06	1.86	71.88	28.75	**29.01**	1.23
178	288	13398	13398.00	51.27	0.05	1.86	73.14	29.26		
179	289	9431	9431.00	34.56	-0.64	2.24	171.85	68.74	**69.50**	1.54
180	289	9337	9337.00	34.17	-0.66	2.24	175.63	70.25		
181	290	13359	13359.00	51.11	0.04	1.87	73.74	29.50	**27.30**	11.40
182	290	14130	14130.00	54.35	0.17	1.80	62.74	25.10		
183	291	12133	12133.00	45.94	-0.16	1.98	95.30	38.12	**39.01**	3.22
184	291	11917	11917.00	45.03	-0.20	2.00	99.73	39.89		
185	292	10340	10340.00	38.39	-0.47	2.15	140.01	56.00	**55.15**	2.19
186	292	10481	10481.00	38.98	-0.45	2.13	135.73	54.29		
187	293	10969	10969.00	41.04	-0.36	2.09	122.06	48.82	**48.91**	0.24
188	293	10953	10953.00	40.97	-0.37	2.09	122.48	48.99		
189	294	11385	11385.00	42.79	-0.29	2.05	111.64	44.66	**45.08**	1.34
190	294	11296	11296.00	42.42	-0.31	2.06	113.78	45.51		
191	295	14232	14232.00	54.78	0.19	1.79	61.41	24.56	**23.75**	4.87
192	295	14558	14558.00	56.16	0.25	1.76	57.32	22.93		
193	296	14953	14953.00	57.82	0.32	1.72	52.69	21.08	**21.71**	4.13
194	296	14679	14679.00	56.67	0.27	1.75	55.86	22.35		
195	297	14627	14627.00	56.45	0.26	1.75	56.49	22.59	**21.89**	4.52
196	297	14927	14927.00	57.71	0.31	1.72	52.99	21.19		
197	298	12781	12781.00	48.67	-0.05	1.92	83.20	33.28	**40.13**	24.15
198	298	11147	11147.00	41.79	-0.33	2.07	117.47	46.99		
199	299	15610	15610.00	60.59	0.43	1.66	45.72	18.29	**19.89**	11.38
200	299	14863	14863.00	57.44	0.30	1.73	53.72	21.49		
201	300	14803	14803.00	57.19	0.29	1.74	54.41	21.76	**20.78**	6.67
202	300	15243	15243.00	59.04	0.37	1.69	49.51	19.80		

Appendix A4. ANOVA for samples 1 – 50.

12.50	1.09691	1.6587816
25.00	1.39794	1.0313023
50.00	1.69897	0.43844
125.00	2.09691	-0.3171108
250.00	2.39794	-0.8154933
500	2.69897	-1.37

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999401
R Square	0.998801
Adjusted R Square	0.998502
Standard Error	0.023624
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.860244	1.860244	3333.288	5.39E-07
Residual	4	0.002232	0.000558		
Total	5	1.862476			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.953576	0.009692	201.5581	3.63E-09	1.926666	1.980486	1.926666	1.980486
X Variable 1	-0.53174	0.00921	-57.7346	5.39E-07	-0.55731	-0.50617	-0.55731	-0.50617

Appendix A4 continued. ANOVA for samples 51 – 119.

12.50	1.09691	1.6567104
25.00	1.39794	0.9427961
50.00	1.69897	0.4130886
125.00	2.09691	-0.2900262
250.00	2.39794	-0.8057306
500	2.69897	-1.34

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.998634
R Square	0.997269
Adjusted R Square	0.996587
Standard Error	0.035657
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.857391	1.857391	1460.91	2.8E-06
Residual	4	0.005086	0.001271		
Total	5	1.862476			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.949886	0.01462	133.3706	1.9E-08	1.909294	1.990478	1.909294	1.990478
X Variable 1	-0.54352	0.01422	-38.2218	2.8E-06	-0.583	-0.50404	-0.583	-0.50404

Appendix A4 continued. ANOVA for samples 120 – 208.

12.50	1.09691	1.3457026
25.00	1.39794	0.9305817
50.00	1.69897	0.2278162
125.00	2.09691	-0.4366277
250.00	2.39794	-0.9204127
500	2.69897	-1.44

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.998491
R Square	0.996983
Adjusted R Square	0.996229
Standard Error	0.037478
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.856858	1.856858	1322.014	3.42E-06
Residual	4	0.005618	0.001405		
Total	5	1.862476			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.870808	0.015318	122.1287	2.7E-08	1.828277	1.913338	1.828277	1.913338
X Variable 1	-0.56522	0.015545	-36.3595	3.42E-06	-0.60838	-0.52206	-0.60838	-0.52206

Appendix A4 continued. ANOVA for samples 209 – 300.

12.50	1.09691	1.5541094
25.00	1.39794	0.8690332
50.00	1.69897	0.2725761
125.00	2.09691	-0.3969085
250.00	2.39794	-0.8725766
500	2.69897	-1.50

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.998403
R Square	0.996809
Adjusted R Square	0.996011
Standard Error	0.038545
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.856533	1.856533	1249.571	3.82E-06
Residual	4	0.005943	0.001486		
Total	5	1.862476			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.891516	0.015737	120.1948	2.87E-08	1.847823	1.935209	1.847823	1.935209
X Variable 1	-0.53833	0.015229	-35.3493	3.82E-06	-0.58061	-0.49604	-0.58061	-0.49604

Appendix A5. Calculations for redo samples.

Tube	Code	cpm	X cpm	%B/Bo	Logit	Log	pg/tube	ng/g feces	X ng/g	CV
			r2	**0.9942**						
			Slope	**-0.5080**						
			Int	**1.9015**						
1	NSB	1377	1306.00							
2	NSB	1235								
3	0	23585	24028.00							
4	0	24471								
5	12.5	20304	20522.50	84.57	1.70	1.04	10.90			
6	12.5	20741								
7	25	17252	17253.00	70.18	0.86	1.47	29.29			
8	25	17254								
9	50	14522	14630.00	58.64	0.35	1.72	52.99			
10	50	14738								
11	125	10168	10431.50	40.16	-0.40	2.10	127.08			
12	125	10695								
13	250	7625	7900.00	29.02	-0.89	2.36	226.90			
14	250	8175								
15	500	5231	5215.50	17.21	-1.57	2.70	500.71			
16	500	5200								
17	Pool	14667	14667.00	58.80	0.36	1.72	52.58	21.03	**20.65**	2.59
18	Pool	14839	14839.00	59.56	0.39	1.70	50.68	20.27		
19	23	15950	15950.00	64.45	0.59	1.60	39.75	15.90	**14.27**	16.10
20	23	16937	16937.00	68.79	0.79	1.50	31.62	12.65		
21	61	13931	13931.00	55.56	0.22	1.79	61.38	24.55	**25.38**	4.61
22	61	13617	13617.00	54.18	0.17	1.82	65.52	26.21		
23	130	13037	13037.00	51.63	0.07	1.87	73.86	29.54	**28.81**	3.63
24	130	13286	13286.00	52.72	0.11	1.85	70.16	28.07		
25	134	13306	13306.00	52.81	0.11	1.84	69.87	27.95	**28.38**	2.16
26	134	13158	13158.00	52.16	0.09	1.86	72.04	28.82		
27	183	13082	13082.00	51.83	0.07	1.86	73.18	29.27	**29.86**	2.78
28	183	12891	12891.00	50.99	0.04	1.88	76.12	30.45		
29	184	13220	13220.00	52.43	0.10	1.85	71.13	28.45	**28.97**	2.55
30	184	13045	13045.00	51.66	0.07	1.87	73.74	29.50		
31	218	13857	13857.00	55.24	0.21	1.79	62.33	24.93	**24.67**	1.53
32	218	13961	13961.00	55.69	0.23	1.79	61.00	24.40		
33	227	13451	13451.00	53.45	0.14	1.83	67.81	27.12	**27.96**	4.25
34	227	13160	13160.00	52.17	0.09	1.86	72.01	28.80		
35	236	13525	13525.00	53.78	0.15	1.82	66.78	26.71	**26.58**	0.69
36	236	13572	13572.00	53.98	0.16	1.82	66.13	26.45		

Appendix A6. ANOVA output for redo samples.

12.50	1.09691	1.7014361
25.00	1.39794	0.8560314
50.00	1.69897	0.34907
125.00	2.09691	-0.3987397
250.00	2.39794	-0.8943967
500	2.69897	-1.57

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.997111
R Square	0.99423
Adjusted R Square	0.992788
Standard Error	0.051831
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.85173	1.85173	689.2768	1.25E-05
Residual	4	0.010746	0.002686		
Total	5	1.862476			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.90152	0.02116	89.86188	9.19E-08	1.842769	1.960271	1.842769	1.960271
X Variable 1	-0.50796	0.019348	-26.2541	1.25E-05	-0.56168	-0.45424	-0.56168	-0.45424

Appendix A7. Summary of locations for 2001 – 2008.

2001		
Location	**Number of Observations**	**Number of Sheep**
2nd Dam	3	22
Castle	5	60
Crescent	7	84
Little Butte	1	13
Pyramid	30	437
Release Site	35	419
Saddlehorn	16	119
Stairstep	9	71
W Canyon	4	30

2002		
Location	**Number of Observations**	**Number of Sheep**
2nd Dam	5	88
Hampton's	23	156
Castle	10	132
Crescent	9	105
Flattop	4	33
Little Butte	3	18
Pyramid	54	631
Release Site	27	189
Saddlehorn	31	376
Stairstep	2	13
Submarine	11	102
Twin Rocks	2	17
W Canyon	7	120
West End of Cedar Canyon	1	2
Great Wall	4	21

2003		
Location	**Number of Observations**	**Number of Sheep**
2nd Dam	12	138
Hampton's	12	143
Castle	8	99
Pyramid	31	335
Release Site	24	340
Saddlehorn	10	87
Submarine	9	107
W Canyon	2	20
Flattop	3	31
Montz	35	340
Island Butte	2	4
Preston's	2	18

Appendix A7 continued. Summary of locations for 2001 – 2008.

2004		
Location	**Number of Observations**	**Number of Sheep**
2nd Dam	4	27
Hampton's	8	105
Castle	4	48
Pyramid	6	69
Release Site	6	60
Saddlehorn	4	46
Submarine	1	21
W Canyon	1	10
Flattop	1	1
Montz	21	247
Butte East of 2nd Dam	3	37
Between Castle and Saddlehorn	1	19
Stairstep	4	32

2005		
Location	**Number of Observations**	**Number of Sheep**
Castle	11	44
Crescent	19	76
Pyramid	30	161
Submarine	10	97
Release Site	27	123
2nd Dam	11	103
Saddlehorn	26	106
W Canyon	5	38
Flattop	6	45
Stairstep	3	17
Hampton's	24	359
Montz	39	298
Wilkenson's	2	21
Preston's	2	10
Butte East of 2nd Dam	1	15
Butte NW of 2nd Crossing	1	4
Butte West of Saddlehorn	1	5
2 Buttes West of Saddlehorn	2	2
Butte West of Stairstep	3	34
Island Butte	1	7
Ridge East of 2nd Dam	1	4
South of 2nd Dam	1	4
3 Buttes West of Saddlehorn	1	2

Appendix A7 continued. Summary of locations for 2001 – 2008.

2006		
Location	**Number of Observations**	**Number of Sheep**
2nd Dam	7	75
Castle	9	78
Flattop	5	51
Pyramid	40	308
Release Site	22	121
Saddlehorn	8	50
Stairstep	4	23
Submarine	12	86
W Canyon	17	139
Crescent	21	177
North of Enlow's House	1	8
Hampton's	31	185
Montz	41	257
Between Castle and Saddlehorn	1	1
East of Saddlehorn	1	20
West of Saddlehorn	7	70

2007		
Location	**Number of Observations**	**Number of Sheep**
Castle	6	77
Crescent	11	186
Pyramid	13	181
Submarine	12	177
Release Site	14	176
2nd Dam	5	87
Saddlehorn	9	115
W Canyon	3	43
Flattop	3	31
Stairstep	2	23
Between Castle and Saddlehorn	1	8
Butte North of 2nd Crossing	1	22
East Edge of W Canyon	2	27
Hampton's	2	7
Montz	28	212
Vista Trend	1	6
South of 2nd Dam	2	36
West of 2nd Dam	1	7
West of Bald Knob	1	8
West of Saddlehorn	1	6

Appendix A7 continued. Summary of locations for 2001 – 2008.

2008		
Location	**Number of Observations**	**Number of Sheep**
Castle	6	63
Crescent	6	84
Pyramid	6	77
Submarine	5	58
Release Site	4	28
2nd Dam	2	15
Saddlehorn	3	17
W Canyon	1	6
Flattop	3	28
Stairstep	1	19
2 Buttes West of Saddlehorn	1	2
Between Crescent and Release Site	2	26
Montz	6	42
Schaneman's	1	14
Schaneman's Windmill	1	5
West of Saddlehorn	2	2
West of Stairstep	1	10