A PRODUCT OF THE WAFWA
WILDLIFE HEALTH COMMITTEE

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Western Association of Fish & Wildlife Agencies

WILD UNGULATE CAPTURE TIMING CONSIDERATIONS AND BEST PRACTICES

Dec. 2025

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Wild Ungulate Capture Timing Considerations and Best Practices

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Suggested citation: Western Association of Fish and Wildlife Agencies. 2025. Ungulate capture timing considerations and best practices. WAFWA Wildlife Health Committee, Boise, Idaho, USA.

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Recommended Best Practices

When planning ungulate captures, wildlife professionals must consider both the animals and the complex systems in which they live, in addition to logistical and financial challenges. The species, age, reproductive status, time of year, reason for capture, habitat, weather, terrain, and available resources all affect capture outcomes. The available literature on both domestic and wild animal restraint, capture, and handling provides strong evidence that they are stressors that can have significant physiological and behavioral implications for the animals involved as well as conspecifics. To minimize adverse effects during capture events, we summarize best practices to follow humane and safe principles considering animal behavior, physiology, and well-being, while building capacity for professionals to modify capture methods to address specific considerations for the animals and their habitats. If capture is necessary to research, manage, or conserve a population, a peer-supported common-sense approach that is practical and flexible and includes an adaptive learning component is critical. Coupled with effective and consistent communication, an adaptive guidance document allows for the creation of practices that support animal well-being and human safety and ensures the validity of data collected.

The WAFWA Wildlife Health Committee and partners summarized current literature and collective experience into the following best practices.

- **Ensure every capture event has a highly experienced capture lead who has been involved with planning and is a decision maker (has the capacity to modify events as needed).**

  Capture leads with demonstrated expertise can incorporate timing considerations into capture planning to improve restraint and handling outcomes, minimize stress and injury, and reduce handling times**.** Having the experience to make decisions as required allows the lead to modify operations in changing conditions. Considering event timing during planning is critical for the capture lead to achieve the best outcome for the animals, humans, and data.

- **Schedule captures to minimize the number of stressors to the animal.**

  The goal is to reduce the additive effects of stress by reducing seasonal stressors such as poor body condition, late-term pregnancy, thermal stress, early lactation, or rut.

- **If animal rectal temperatures are consistently $\geq$ 41°C (~106°F), capture operations should pause until ambient temperatures are lower and/or other mitigations can be implemented to avoid harm from hyperthermia.**

  When body temperatures exceed 41°C (~106°F), direct cellular damage begins to occur, leading to organ damage and increased mortality. Capture activities should be adjusted or paused if animals consistently have high temperatures.

- **Avoid capturing females during the third trimester of pregnancy.**

  In late pregnancy, there are increased cardiovascular demands to support oxygen and blood supply to the fetus, increased energy demands to support growing fetus(es), and decreased respiratory and gastrointestinal capacity due to the large fetus. Certain drugs may exacerbate cardiovascular issues or induce early parturition or abortion. Understanding the typical time of parturition for each species in each latitude is critical. Late pregnancy captures should be avoided unless a specific research question requires this and the capture timing is justified.

- **Avoid capturing males during the rut.**

  Capturing males during the rut creates risks; of disrupting the social dominance structure, adding stress when the animal is in a negative energetic balance (not eating well), and inconsistent drug responses occur due to changes in physiology that affect drug metabolism. Capturing during the rut should be avoided unless a specific research question requires this and the capture timing is justified.

- **Limit projects involving capture of neonates or females with neonates.**

  Neonates (newly born animals) are particularly vulnerable. Stress and maternal abandonment are risks when neonates are handled or when dams with dependent young are handled. This practice should be avoided unless a specific research question requires capture of neonates and the capture timing is justified. If such captures are deemed necessary, use best practices to minimize handling time, scent transfer, and disturbance.

- **Provide consistent capture training and mentorship for early career wildlife professionals.**

  Incorporate capture timing considerations into training of early career wildlife professionals and refresher training of seasoned professionals, emphasizing stressors associated with capture and how to mitigate them. Create active mentorship programs and incorporate institutional knowledge of capture considerations specific to their work.

- **Support, require, and report the collection of standardized data on capture methods and outcomes.**

  Unfortunately, negative captive outcomes are not reported consistently. Wildlife professionals are encouraged to collect standardized capture data, biological samples, post-capture movement and mortality data, and other information to evaluate capture methods and understand how outcomes may vary based on timing.

- **During planning, develop protocols for addressing capture injuries and/or mortalities, including creating mortality thresholds.**

  Most capture methods used for wild ungulates have baseline experiential information on mortality rates reported or recognized under favorable capture conditions. Mortality rates exceeding the expected threshold may indicate that conditions are not suitable to continue capture. All direct capture injuries and/or mortalities should trigger a discussion with field staff to determine if changes to protocols are needed or captures should cease. Indirect capture mortalities (those that occur within thirty days after capture) should be assessed since expedient investigation of mortalities can provide information on suitability of capture methods.

Introduction and Background

Wildlife professionals must consider seasonal and breeding ecology, animal growth and development, rearing of young, and various other species-specific and environmental factors when selecting the timing of capture. The welfare of the individual and its offspring, and the scientific integrity of the data obtained, are affected by those decisions. Though not all proposed capture requires review by an Institutional Animal Care and Use Committee, similar preparation and evaluation of when and how to accomplish such work should be conducted.

The effects of capture, restraint, and handling are typically evaluated on the occurrence of immediate observable harm, such as obvious injuries to or mortality of the animal during or immediately following capture. However, reliance on these criteria alone is not sufficient to adequately assess capture, handling, and monitoring procedures and protocols on animal welfare and data validity since effects of capture on the animal(s) may not manifest until days or weeks after the capture event (Hampton and Arnemo 2023). The assessment should include the collection and analysis of broader and longer-term data associated with physical, behavioral, and physiological effects in a standardized manner (Wilson and McMahon 2006, Holt et al. 2009, Jewell 2013). Unfortunately, these effects are often difficult to measure in free-ranging animals, and the ability to obtain the required data is often dependent on the very same capture techniques being assessed. This creates challenges in establishing adequate controls and producing high quality data (Wilson and McMahon 2006, Cattet et al. 2008, Zemanova 2020). Improving capture methods, equipment, and protocols requires asking the hard questions, challenging the status quo, and exploring opportunities to better measure the impacts of our actions and interventions on wild individuals and populations.

Many decisions on the timing of wild ungulate capture and post-capture outcomes on offspring rely heavily on studies on other species, especially domestic animals and humans due to the challenges of free ranging studies. In this document, we summarize information from published data sources as well as from wildlife experts to incorporate relevant information from wild ungulate, domestic animal, and human literature into one source. We surveyed wildlife professionals in western provincial, state, territorial, federal, and tribal agencies as well as universities to capture institutional knowledge that may not be represented in published literature and gather information on ungulate capture practices and lessons learned. We incorporated these survey results throughout the document and outline best practices in promoting animal well-being and human safety when making decisions on the timing of wild ungulate captures.

Survey of Wildlife Professionals

In 2023, the WAFWA Wildlife Health Committee surveyed wildlife biologists, managers, researchers, and veterinarians in western provincial, state, territorial, federal, and tribal agencies, as well as at universities, to collect information about free-ranging ungulate capture practices (Appendix A). There were 53 respondents representing at least 20 different entities. Out of the 53 respondents, 43 reported having some type of established wildlife capture guidance for ungulates, and 44 respondents reported that their organization had some type of established restrictions in place on the timing of ungulate capture. A wide array of restrictions was reported, including weather/environmental, stage of gestation, dependent young, breeding season, and nutrition. The most common restrictions were related to environmental conditions, including maximum ambient temperature and risk of adverse weather events; reproduction, including the third trimester of pregnancy and animals with dependent young; and hunting seasons.

Respondents also provided extensive comments throughout the survey. Many provided both negative and positive individual experiences with ungulate captures such as negative outcomes in net gunning moose or caribou with limited snow, unexpected success capturing animals while in summer pelage, negative outcomes from immobilizing bighorn sheep in late pregnancy, and certain species with specific drug or capture intolerances. Although we were unable to list every comment in this document, Appendix B provides a sample of experiences and observations related to ungulate capture timing from survey responses. The most consistent response was recognition of the need for flexibility in wild ungulate captures so that operations could be tailored to local context, such as the individual species, terrain, research objectives, and more. Many respondents also commented on the lack of direct data to inform ungulate capture guidance.

Reproductive Physiology

There are several critical time periods or events during the wild ungulate annual reproductive cycle which are closely associated with nutritional or behavioral requirements. Female ungulates exhibit seasonal polyestry, cycling spontaneously multiple times in a breeding season. Male ungulates experience a seasonal increase in male reproductive hormones ("rut") that coincides with the seasonal polyestry of females (Figure 1). For most ungulate species, estrus occurs in the fall (September through November) and parturition in spring (April through June) to synchronize lactation with high quality nutritional sources (English et al. 2012, Turnley et al. 2024). The "seasonality" can vary based on daylight, latitude, nutrient availability, and other factors, depending on species. Typical parturition dates for each species in each area of study should be documented by both historic data and local knowledge since there can be significant variations in timing depending on species, latitude, and elevation. In addition, climate change may result in further changes in the timing of these events. Physiological and behavioral changes that occur during these reproductive cycles can greatly impact capture operations. In particular, changes during the rut and during late pregnancy should be considered during capture planning.

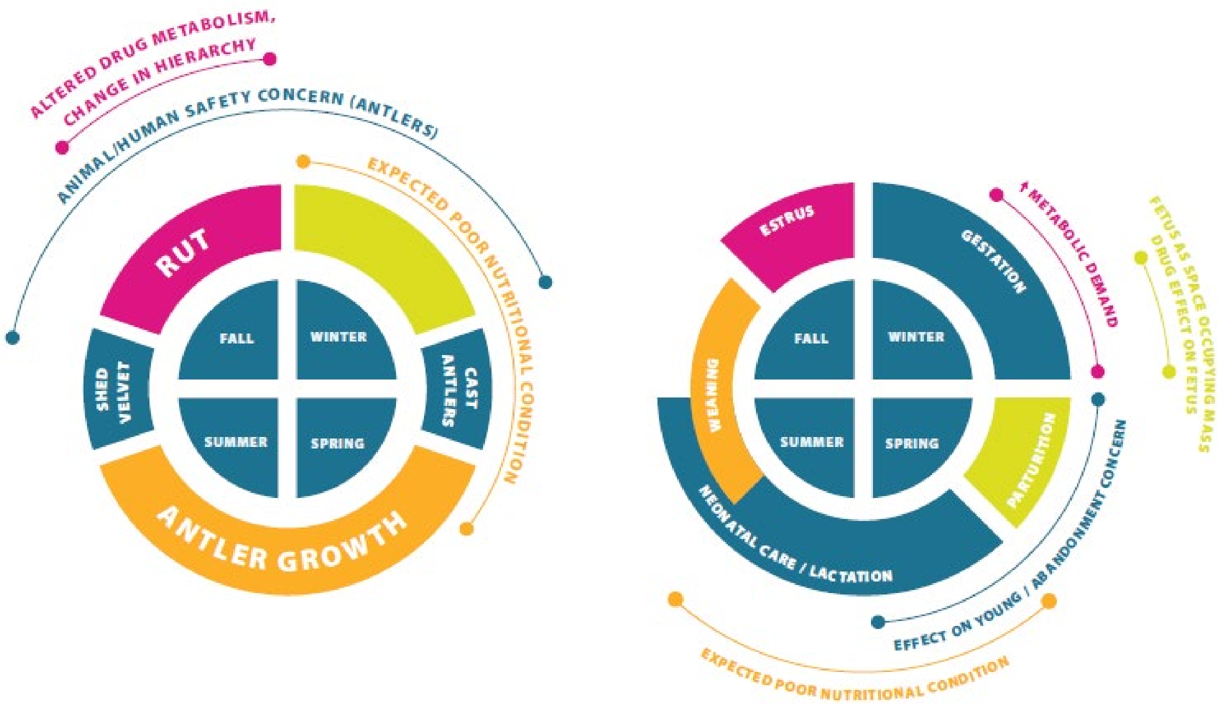


Figure 1: Timing of ungulate reproduction cycles for males (left) and females (right). Note that antlers may or may not be present in the species and antlers are present in female caribou. Credit: S. Guerere, California Department of Fish and Wildlife.

Throughout pregnancy, females undergo various metabolic and hormonal alterations to maintain pregnancy and provide adequate oxygen and nutrients for fetal development (Table 1). Particularly during the third trimester of pregnancy, rapid fetal growth and development lead to increased oxygen and nutritional requirements (Sparks et al. 1983, Bell 1995), which is much higher should the species twin (e.g., moose or deer species). The metabolic rate of the mother increases to meet fetal demands, resulting in increased oxygen consumption for energy production (Hegewald and Crapo 2011). At the same time, enlargement of the uterus displaces abdominal organs and reduces respiratory capacity. The respiratory system adapts to these heightened oxygen needs by increasing respiratory rate and tidal volume (Reynolds et al. 2010, Hegewald and Crapo 2011). Cardiovascular adaptations include increased heart rate and cardiac output to facilitate increased oxygen delivery (Reynolds et al. 1995, 2010; Hegewald and Crapo 2011). Overall, the third trimester of pregnancy has major respiratory and cardiovascular requirements to ensure adequate oxygenation for both maternal health and fetal development (Table 1).

In addition to third trimester risks, pregnant females may also be at risk of embryonic loss when chased, handled, and restrained during the first trimester. Environmental stressors, such as aversive human handling and restraint, activate the hypothalamus-pituitary-adrenal axis and increase plasma cortisol concentration in cattle, which can increase risk of embryonic loss (Hansen 2007, Szenci et al. 2011). Szelényi et al. (2023) highlights studies that have observed late embryonic/early fetal death in response to high stress associated with transporting cattle, events which may induce similar stress responses as capture, handling, and restraint for wild ungulates. Garcia-Ispierto et al. (2006) also observed a strong relationship between pregnancy loss and heat stress in dairy cattle.

Table 1. Physiological changes associated with each trimester of pregnancy in wild ungulates.

Physiological Changes	First Trimester	Second Trimester	Third Trimester
Fetal Growth and Maternal Changes	Growth and formation of major organ systems. Minor enlargement of the uterus to accommodate the growing fetus(es).	Accelerated fetal growth and development of distinct features. Further enlargement of the uterus, displacing abdominal organs.	Greatest fetal growth occurs, placing increased demands on maternal resources. Greatest enlargement of the uterus, affecting respiratory and cardiovascular function.
Metabolic Changes	Increased nutrient requirements to support embryonic growth.	Alterations in nutrient metabolism to support fetal growth.	Increased energy expenditure to sustain fetal growth and maternal health.
Respiratory & Cardiovascular Adjustments	Minimal changes.	Moderate increases in respiratory rate and tidal volume.	Greatest increase in respiratory rate, heart rate, and tidal volume to meet elevated oxygen demands.
Nutrient Exchange	Diffusion facilitates nutrient exchange between maternal and fetal circulations.	Enhanced nutrient and gas exchange facilitated by maturing placental structures.	Optimization of nutrient and gas exchange to support rapid fetal growth.

Literature citations: Sparks et al. 1983, Bell 1995, Reynolds et al. 1995, 2010, Hegewald and Crapo 2011

Wildlife professionals should recognize the physiological changes associated with pregnancy during capture planning and mitigate stressors. Some drugs used for capture can reduce blood pressure and oxygen levels for both the dam and fetus(es). Therefore, capture methods involving immobilization drugs may create greater risk during the third trimester of pregnancy when oxygen demand is greater (see Capture Drugs section). One survey respondent reported mortality in a bighorn sheep immobilized during late pregnancy that was attributed to hypoxia, potentially due to the combination of immobilization drugs and reduced respiratory capacity during late pregnancy (Appendix B). Animals in their third trimester of pregnancy may have decreased capacity to manage sudden increased cardiovascular and respiratory demands associated with capture methods, especially when chase is required. Studies of domestic sheep demonstrated reduced oxygenation to the fetus during exercise in late pregnancy (Emmanouilides et al. 1972, Longo et al. 1978, Clapp 1980, Handler and Bell 1981); however, one study reported no significant hypoxia in the fetus during exercise (Lotgering et al. 1983). Given the substantial literature describing increased oxygen demand during late pregnancy and potential for reduced oxygenation to fetuses, managers should avoid capturing females during late pregnancy to prevent potential capture effects on both the dam and fetus.

Wildlife professionals should also avoid capture of male animals during the breeding season. Pelletier and others (2004) suspected that male bighorn sheep in rut tended to lose fights and thus, social ranking with other males following immobilization. Immobilizing males in rut is also problematic in terms of quality of induction. Changes in physiology and body condition during rut may alter drug metabolism, affecting both the required drug dose and time to recumbency in certain species (Kreeger and Arnemo 2018, see drug section for additional details). Male ungulates often reduce foraging and resting time and increase activity during the rut (Miquelle 1990, Pelletier et al. 2009, Brivio et al. 2010), creating a negative energy balance that may make them more vulnerable to injury or mortality if captured. Finally, fitting equipment like radio collars becomes difficult in species where male neck circumference increases during breeding season, so consideration must be made (e.g., use of collar expanders, drop-off timing, alternate tagging methods) to minimize welfare concerns from inappropriate collar fit.

Stress Physiology and Influences

Stress is a broad term used to describe a response to a stimulus that affects an animal's normal balance or comfort, such as changes in the environment, handling, or perceived threats. It is an everyday occurrence and animals will counteract stress through a variety of behavioral and physiological changes aimed at the reestablishment of a balanced state (Chrousos and Gold 1992). The stress response of an individual may vary based on genetics, environment, and the length and intensity of the stressor. Prolonged or high intensity stressors result in responses that can have detrimental effects on a variety of physiological functions, including cardiovascular, immune, and brain/cognitive function, growth, reproduction, metabolism, and behavior (Table 2; Tsigos et al. 2020). Stress effects can be additive, and the stress response can be much greater when multiple stressors occur at the same time (Aleme et al. 2014).

Table 2. Stress responses associated with different physiologic functions by wild ungulates.

System	Stress Response
Thermoregulation	Physical exertion coupled with stress may increase body temperatures that persist even after the physical exertion has stopped.
Immune function	Inhibition or proliferation of immune cells and alterations in immune cell function that result in immune suppression. Some diseases might be more likely to be associated with stress depending on required immune responses.
Reproduction/ Growth	Suppression of reproductive, growth, and thyroid hormones.
Digestion/ Nutrition	Suppressed feeding behavior, decreased rumination and gut motility, increased colon motility, increased gastrointestinal permeability, increased glucose production and utilization, breakdown of protein (in muscles, bone, and skin), breakdown of fat.
Brain/Cognition	Arousal, alertness, vigilance, focused attention, increased cognition, anxiety.
Cardiovascular	Increased heart rate and blood pressure.

Stress Effects on Young Animals

The response to stressful events may vary by the species, individual, and age of the animal, but young animals are especially vulnerable to stress with prenatal, neonatal, and juvenile life stages being critical points in developing the stress response (Tsigos et al. 2020). High intensity or prolonged stressors during the neonatal or juvenile stages may permanently affect an animal's stress response, behavior, and immune function. There is evidence in domestic species that prenatal, neonatal, and juvenile animals subjected to prolonged stress may experience permanent alterations in hormone regulation, behavior, and immune function (Otten et al. 2015). While it is not confirmed, it is assumed that wild species respond in a similar – and not benign – manner and that stressful situations should be avoided whenever possible.

Nutritional Stress

Most western North American ungulate species are in their poorest nutritional condition during late winter and early spring before green-up. Mule deer in poor nutritional condition entering the winter season have lower pregnancy rates, overwinter survival, and fawning rates (Tollefson et al. 2010). Nutritionally stressed domestic ewes in the breeding season have decreased reproduction, and one out of three ewes stopped estrus (Wagenmaker et al. 2010). The additional stress and energetic demand of capture events may be additive stress on animals already in an energetically deficient state; however, data on nutritional stress and capture outcomes are limited. Van de Kerk et al. (2020) found that larger body mass was associated with lower capture mortality risk in mule deer, suggesting that animals in better nutritional condition (or not experiencing nutritional stress) are less affected by capture. Additionally, domestic goats that experienced aversive handling stress had impaired placental development (Baxter et al. 2016), presumably early in pregnancy, suggesting that prenatal stress may impair nutrient transport from doe to fetus(es) in goats. Conversely, some capture studies have found that mule deer in poorer body condition were not more susceptible to capture-related mortality (Bender 2015, LaSharr et al. 2023). Along the same line but in reverse, repeated capture stress may affect the nutritional status of animals. In black and brown bears, repeated capture resulted in animals having poorer body condition than bears captured only once (Cattet et al. 2008). Overall, there remains a lack of understanding about how nutritional condition may affect the ability of an animal to handle the stress associated with capture, and more research is warranted, especially in species regularly captured.

Animal condition varies over the course of a year. Trauma of this ram's head is likely due to rut, but some damage can also be due to breaking barrel cactus. Body condition, inflammation around nasal passages due to injuries such as this, time of rut, and sensitivity to drugs should all be considered in capture timing. Credit: E. Lantz, California Department of Fish and Wildlife.

Understanding the Effects of Stress

Capture is considered an acute stress and results in physiological changes, even when applying the most benign capture protocols and preventative care. There is growing literature describing the physiological impacts of stress on animals during capture and relating these physiological changes to the risk of capture myopathy (Breed et al. 2019). Such research includes a broad range of species, including bighorn sheep (Kock et al. 1987a, 1987b), deer (Mentaberre et al. 2010, Roug et al. 2022), chamois (López-Olvera et al. 2007), brown and black bears (Cattet et al. 2008, Esteruelas et al. 2016), moose (Thompson et al. 2020), and rhinoceros (Pohlin et al. 2020). Some researchers have also evaluated the behavior of captured animals in the days immediately following the capture, showing reduced activity for various periods of time before resuming normal behavior (Northrup et al. 2014, Brivio et al. 2015). Additionally, capture and its effects on physiology and behavior may predispose animals to predation (Dulude-de Broin et al. 2020). Factors such as suboptimal environmental conditions, poor nutritional condition, location of release (if not the same as location of capture), breeding season, and pregnancy are likely to act as additional stressors on the animal during capture. Timing captures to minimize the potential for seasonally important additive stressors may reduce capture-related morbidity and mortality.

Drugs Used During Capture

The time of year, target species, decision to use drugs, and the type of drug(s) used must be carefully considered when planning a capture event. In some cases, the use of drugs is necessary due to the animal's size or temperament, and use of drugs may decrease the risk of stress, injury, capture myopathy, or mortality compared to using physical capture methods. It is critical to consult with others experienced with the species and drug options since their use can carry additional risks. Some drug combinations can increase the likelihood of thermal stress, hypoxemia, and regurgitation and potentially affect pregnancy. Responses to capture drugs can also vary by species, age, sex, time of year, and body condition (Kreeger and Arnemo 2018, Bengsen et al. 2021). For example, animals in poor condition in the spring may need a lower dosage than at other times of the year, whereas animals with greater fat storage may be more challenging to inject due to thickness of fat layers preventing injections from reaching the muscle (Kreeger and Arnemo 2018). In some species, males may require higher drug dosages during the rut or may be more sensitive to drug effects. For example, male reindeer and caribou are very sensitive to alpha-2 agonists and cyclohexanes during the rut (Lian et al. 2019). Further, many wild ungulate species are consumed, and drug withdrawal times need to be considered or established by the associated veterinarian, particularly before and during hunting seasons.

When chemically immobilizing females, direct drug effects on the uterus, placenta, or fetus(es) and the potential transfer of drug through the milk are also concerns. The placental barrier is a lipoprotein, and any drug with high lipid solubility can permeate the barrier and diffuse passively to the fetus (Mathews 2005). Alpha-2 adrenergic agonists such as xylazine and medetomidine (one component of “BAM”), cyclohexanes such as ketamine and tiletamine (in Telazol®/TZed™/Zoletil™), and opioids such as butorphanol (another component of “BAM”) and thiafentanil are commonly used in wildlife immobilization and readily cross the placental barrier (Mathews 2005, Bush et al. 2012, Musk et al. 2012, KuKanich and Papich 2018). Although the fetal response to many immobilization drugs has not been evaluated, it is well documented that immobilization with combinations containing potent opioid and alpha-2 adrenergic agonists can cause profound hypoxemia in many wildlife species (Mich et al. 2008, Wolfe et al. 2014, Lian et al. 2016, Barros et al. 2018, , White et al. 2021), which in turn may cause hypoxemia in the fetus. Several studies in domestic animals have shown that alpha-2 agonists decrease uterine blood flow, increase uterine pressure and vascular resistance, and may induce uterine contractions (Ko et al. 1990, Sakamoto et al., 1996, Hodgeson et al., 2002, Brivio et al. 2015). Alpha-2 agonists have been associated with abortion in late gestation cattle (Dart et al. 1999), whereas others did not report any effect on calving in cows when using xylazine or medetomidine during the last two months of pregnancy (Arnemo and Søli 1993). Based on the physiological effects as well as data on the risk of abortion, alpha-2 agonists should be used with caution in ruminants during late pregnancy. In agreement with these findings, many of our survey respondents reported that they avoid use of alpha-2 agonists in ungulates in late pregnancy (Appendix B).

Few studies have directly evaluated the effect of capture drug administration on pregnancy and reproduction in wildlife. One study compared litter size and fawn weights after fawning in captive deer that did or did not get immobilized 10 times during pregnancy with xylazine and ketamine and did not find any significant differences in fawn weight (DelGiudice et al. 1986). Another study immobilized pregnant moose with carfentanil, fentanyl citrate, xylazine hydrochloride, and hyaluronidase in late winter. Although prenatal survival was not affected by immobilization, postnatal survival was reduced in calves from moose that were immobilized 2-3 months prior to parturition. The authors hypothesized that long term effects of immobilization on the cow made her less able to defend the calf from predators (Larsen and Gauthier 1989); however, another hypothesis could be that sublethal effects to the fetus decreased postnatal fitness. In another study, three- to four-year-old female mountain goats chemically immobilized one to five months before the breeding season had decreased kid production and abandoned their kids more often than undrugged females (Côté et al. 1998). In summary, the direct effect of capture drugs on reproduction and survival is difficult to measure quantitatively. The use of drugs during wildlife capture may significantly reduce stress and injury rates of the animals, however all result in some degree of physiological alteration that may be influenced by many factors including time of year, sex, reproductive status, season, and body condition. These effects must be taken into consideration when planning a capture event involving immobilization drugs.

Hyperthermia

Chase, capture, restraint, and handling cause physiological changes on the targeted animal, including fluctuations in body temperature (Sawicka et al. 2015). Hyperthermia can be defined as the rise in core body temperature when heat accumulation overrides heat dissipation during exercise or exposure to environmental heat stress (Epstein and Yanovich 2019). An elevation of body temperature >40°C (104°F) is generally accepted as the threshold at which wild ungulates are considered hyperthermic (Kreeger and Arnemo 2018, Graesli et al. 2023). Hyperthermia can become a serious concern during capture by either physical or chemical immobilization and can cause morbidity or mortality (Nunez et al. 2020). When mammals become hyperthermic, heat-damaged cells leak potassium and damaged proteins, which can overwork the liver and damage the kidneys (Nunez et al. 2020). High levels of leaked potassium in the bloodstream are toxic to heart muscle cells. The resulting damage to skeletal muscle from hyperthermia and overexertion is known as myopathy, which may result in immediate loss of function or predisposition to injury or mortality.

Severe capture myopathy grossly evident by the pale muscles in the right rear leg of a Dall's sheep ewe in poor late-winter body condition when captured by net-gun. Credit: K. Beckmen, Alaska Department of Fish and Game.

Factors potentially contributing to hyperthermia include direct chemical effects of immobilization drugs, inappropriate dosing of drugs (especially underdosing), physical exertion, and high ambient temperatures relevant to the time of year (Nunez et al. 2020). Mild hyperthermia may cause few to no deleterious effects in animals, and compensatory responses can prevent damage. However, as body temperature and duration of hyperthermia increase, significant injury and death can occur. At body temperatures of 41.5-42°C (106.7-107.6°F), cellular enzymes and other proteins are damaged and cell death begins (Sakaguchi et al. 1995, Lepock 2003). At 43°C (109.4°F), marked organ damage and high risk of mortality occur (Fejardo 1984).

Studies examining the effects of temperature and exercise on pregnant animals suggest that fetuses are thermally protected, likely through umbilical blood flow acting as a fetal heat exchange (Oakes et al. 1976, Cefalo and Hellegers 1978, Faurie et al. 2001, Laburn et al. 2002). Similarly, domestic ungulate fetuses may not be sensitive to mild degrees of maternal hyperthermia due to physiological mechanisms that protect them from maternal temperature fluctuations. Nonetheless, there is established evidence that significant hyperthermia has direct negative effects on pregnant ungulates and severe maternal hyperthermia could negatively affect the fetus. Wildlife managers must strive to minimize the development of hyperthermia in pregnant ungulates during all wildlife capture operations.

Time of year is an important consideration for hyperthermia. Managers should consider ambient temperatures relative to the season, capture method, body condition, species, reproductive status, and whether an animal is in winter or summer haircoat. Many survey respondents highlighted winter as an optimal time for ungulate capture due to low ambient temperatures and cushioning effects of snow cover; however, there were also numerous responses that reported successful captures in late summer when animals are in their summer haircoat and may be more adapted to managing heat (Appendix B). Multiple comments reported successful capture of desert bighorn in the summer when their hair is less dense. Therefore, considerations for ambient temperature thresholds should remain in context to the time of year. For example, an ambient temperature of 16°C (60.8°F) may be a concern in late winter when an animal is still in its winter coat but may be optimal in late summer. Post-release ambient temperature may also need to be taken into account. For example, hair loss in pronghorn due to net-gunning and/or handling may negatively affect an animal's cold tolerance in the winter.

Preventative measures are necessary to address hyperthermia since it is challenging to treat effectively in the field. To reduce the risk of hyperthermia, capture plans should consider season and time of day, limit chase duration, avoid multiple chase events on groups, provide shade for immobilized animals, place traps or drop nets in shaded areas, and set temperature thresholds appropriate to the season. Some survey respondents highlighted that animal body temperatures can be a more critical indicator than ambient temperatures during a capture event. All capture protocols should include monitoring body temperature trends with predetermined temperature thresholds and implementation of mitigation measures if thresholds are reached. For captures involving prolonged physical restraint or transport of animals, managers may consider the use of specific sedative or tranquilizing drugs that relieve anxiety and provide muscle relaxation to reduce the likelihood of hyperthermia and capture myopathy.

Left: Significant hemorrhage (dark red areas) in lungs and heart fat consistent with Disseminated Intravascular Coagulation (DIC) in a hyperthermic bighorn sheep captured via net-gun. Right: Ecchymosis (bruising under the skin) associated with longer chase time and hyperthermia in a bighorn sheep. Credit: J. Burco, Oregon Department of Fish and Wildlife

Physical Injury

Reports of mortality associated with different capture methods vary greatly in the literature; however, few studies report physical injuries related to capture efforts. Broken bones, punctures, abrasions, bruising, and other traumas can occur during capture. These injuries can be immediately fatal or negatively affect long-term survival. Injuries may also bias data when not accounted for or recognized. Whereas some types of trauma, such as a broken leg or large abrasion/degloving injury, are obvious, other types of trauma may go unnoticed or be difficult to assess. Injuries such as muscle, nerve, or corneal damage, internal bleeding, or a fractured vertebra, tooth, jaw, or rib may not be readily identified during handling or release, but these injuries may affect survival by hindering movement, the ability to evade predators, or foraging success.

Injury risk can vary with the capture method. Physical capture methods, such as net gunning from a helicopter, drive nets, net boma captures, Clover traps, and drop nets, may lead to a greater risk of physical injury compared to chemical capture methods; however, risk varies with species (Kock et al. 1987b, Webb et al. 2008) and is highly dependent on operator experience. Planning captures to ensure enough well-trained handlers and avoid times of high weather variability and poor animal condition may offer more consistent capture success and fewer capture-related injuries. Environmental conditions play a large role in the risk of physical injury, and multiple survey participants working in areas that receive snow stressed the importance of snow cover in reducing injury risk. Snow can slow animal movement during helicopter captures and facilitate shorter chase times, slower speeds at the time of capture, and less injury associated with falls, such as when net gunning (Barrett et al. 1982). Snow may also allow for the use of steeper or rockier terrain than otherwise possible and colder weather allows for more favorable density altitude at elevation when working with helicopters. Wildlife professionals cited observing fewer severe injuries in larger ungulates such as elk or moose when snow depth is deep enough to provide cushioning (Appendix B). Conversely, frozen ground without snow cover increases the risk of injury, and spring or wet conditions may be more appropriate when snow is not available. The ability to adapt capture methods to current environmental conditions on short notice was also reported as important for reducing the risk of injury for the animals, such as changing from physical (e.g., net gun) to chemical capture (e.g., helicopter darting) if snow depth is inadequate in a given year. Planning captures around times of and locations with moderate snow depth may also be beneficial in improving capture success with other methods. DelGuidice et al. (2005) and Thompson et al. (1989) both reported increased Clover trapping success with greater snow depth, likely due to the lack of natural forage making bait more attractive.

Physical attributes associated with seasonality may also increase the risk of trauma during capture. Antlers in velvet are soft and vascularized and may break during capture or transport, leading to hemorrhage and infection risk. When chemically capturing herd animals, other herd members may attack the immobilized animal during induction to test hierarchy, especially during the time of rut. Heavily pregnant animals may not be as prepared for a fall as can occur when net-gunning and may acquire more traumatic injuries.

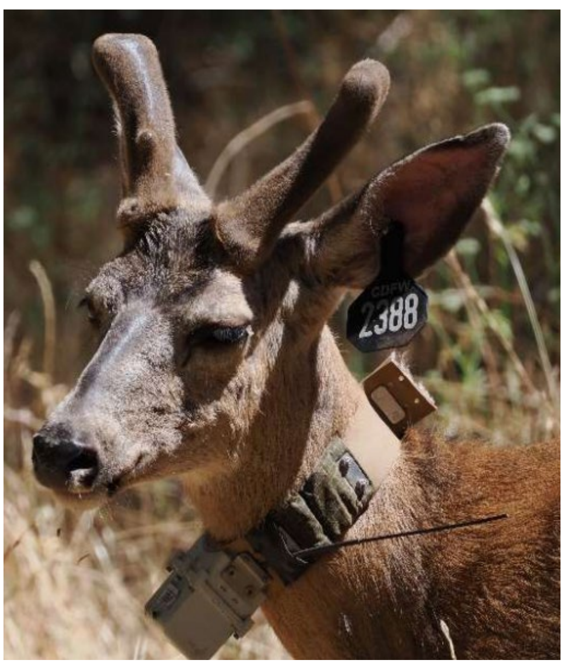
Terrain with rocks interspersed with frozen tufts of grass in a region that experiences minimal snow cover in winter. Under these conditions, aerial darting is a superior choice to net-gunning for minimizing injuries and/or mortalities. Credit: R. Shinn, California Department of Fish and Wildlife.

Left: Severe bruising and hemorrhage in the dorsal spine region of a bighorn sheep that died 36 hours post net-gun capture. Right: Broken bone sustained from net-gun injury. Credit: J. Burco, Oregon Department of Fish and Wildlife.

An experienced and prepared capture crew should thoroughly evaluate each capture scenario to identify which methods will be most appropriate given the time of year, current environmental conditions, and seasonal animal physiology. Planning should involve contacting others with experience so that both grey and published experience can be accessed. During a capture event, crews should be allowed flexibility to modify animal capture and handling methods if necessary to reduce the likelihood of injuries (Thompson et al. 1989).

Injuries are not always related to the capture itself. Poor-fitting tracking devices (e.g., collars, ear-tag transmitters) have the potential to cause significant damage and, in some cases, can directly contribute to mortality (Swenson et al. 1999, Krausman et al. 2004, Bleich et al. 2007, Wiig et al. 2017). Careful considerations must be made for transmitter fit based on sex, age, reproductive status, forage availability, nutritional condition, time of year, and habitat conditions. Recording and analyzing neck and collar measurements collected from similar populations and age classes and using such information to inform both belting length and width as well as collar shape can minimize negative impacts on collared individuals. This is of particular concern with males as they age and experience rut and with fawns or calves, but this concern may also apply to animals experiencing drought versus normal forage years.

Exposed fascia and keratin horn grown over the belting of a collar fit years prior on a bighorn ram. Collection and use of contemporary morphometrics for a local population may minimize the frequency of this occurrence as estimates of mature neck circumference can guide collar fit. Credit: E. Lantz, California Department of Fish and Wildlife.



A common method used to mitigate injury caused by changes in neck circumference is to include expansions that allow for seasonal widening of the collar circumference; however, expansions are not without problems. The need to collar animals that may experience a significant change in their neck circumference should be evaluated carefully and their need for collaring must be scientifically justifiable. Though not without their own issues, alternatives may include not collaring, collaring for a limited amount of time (e.g., using timed drop-offs to avoid rut), placing ear tag transmitters, or non-invasive monitoring such as camera traps.

A male mule deer wearing a collar with an expander to accommodate seasonal changes in neck circumference. Credit: M. Abraham, California Department of Fish and Wildlife.

Neonate Capture and Considerations

Neonatal ungulates are precocious but remarkably vulnerable to predation and extremes in climate or weather. Young are nutritionally and behaviorally dependent on the dam for a varying time, but primarily until weaning, which often coincides with the breeding season. Young of the year, regardless of sex, regularly stay with their dams or female groups until the following spring. Capture timing of females with dependent young is an important consideration. In one survey response, a lamb was reported to have been injured when its dam was chased during a helicopter capture (Appendix B). Young neonates are particularly vulnerable during capture operations, as they can be injured easily or become separated from their dam. Separation can prevent the neonate from nursing and may lead to dehydration or predation. To reduce these risks, capture of females should be avoided during the first few weeks following parturition, when offspring are most dependent and have limited mobility. Whenever possible, capture planning should incorporate knowledge of local birthing seasons and timing of neonate mobility and discuss the pros and cons with others experienced with the species to minimize negative impacts on young animals.

Capture and marking of neonates allows researchers to obtain important ecological data such as survival, cause-specific mortality, movement, and demographics (Chitwood et al. 2017). However, this requires very specific capture timing, and there are many challenges associated with neonate capture that can potentially bias the data and negatively affect the neonate, potentially reducing survival rate. Therefore, neonate capture activities that can impact survival should be avoided. Neonates can be located and hand-captured opportunistically by surveying typical habitats in which they reside or with the aid of vaginal implant transmitters (VITs), aerial infrared camera technology, or helicopter (e.g., caribou). The use of VITs has improved capture success by improving the ability to locate appropriately aged neonates. However, this method requires appropriate capture timing of pregnant dams to determine pregnancy status prior to VIT insertion.

Understanding the influence of human disturbance during neonate capture is important. Capture-induced abandonment of ungulate neonates by their dams can occur and knowing factors that facilitate or contribute to abandonment are crucial when devising a capture protocol (Powell et al. 2005, Grigg et al. 2017, Delgiudice et al. 2018). For example, bighorn sheep lambs remain continuously with their dams from birth, unlike some cervid species that leave their young alone for periods of time. Certain types of capture-related disturbances may trigger abandonment behaviors by ewes that would otherwise not induce abandonment in other species (Grigg et al. 2017). Multiple survey responses mentioned experiences with capture operations leading to abandonment of bighorn lambs and mountain goat kids (Appendix B). Other important considerations should include careful assessment of causes of neonatal mortality. Researchers often use the term “starvation” as the cause of death but hesitate to note that maternal abandonment due to capture activities could be the underlying cause of starvation or even predation. Documentation of abandonment is inherently difficult and complex; however, with ever-improving remote technologies, we are better equipped to make more informed determinations regarding neonatal mortality and consequences of capture activities. DelGiudice et al. (2015) intensively monitored movements of moose cow and calf pairs post-capture and demonstrated that abandonment may still occur, despite documenting multiple episodes of reunion. This emphasizes that one, or even multiple, observations of mother and offspring coming together do not necessarily mean a successful re-bonding has occurred. More research is needed toward minimizing impacts of capture on neonatal animals. In the meantime, using best practices such as wearing gloves to reduce scent, minimizing handling time, and leaving the area quickly after handling to allow the mother to quickly reunite with offspring may reduce abandonment.

Neonates can be particularly difficult to collar as their neck size is expected to change more than at any other point in their life. Rot-offs, drop-offs, stitching or other design meant to accommodate this may fail. Expandable (not retractable) calf collars have been used extensively on caribou calves in maternity penning projects in British Columbia but two complications occurred 1) a change in the stitching design that did not allow collars to expand adequately - all calves were immobilized at 4-6 weeks age to remove collars, and 2) a collar had extensive ice build-up around the transmitter/battery that caused mobility and foraging issues and resulted in calf death. When follow up on free-ranging animals is not possible, a model that results in a collar falling off earlier may be preferable as consequences of the alternative can be fatal and cause significant suffering.

Two caribou calves wearing expandable collars to accommodate their growing necks. Credit: C. Thacker, Ministry of Water, Land and Resource Stewardship, Government of British Columbia.

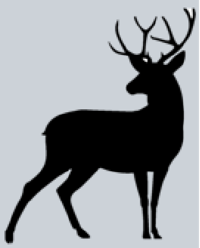
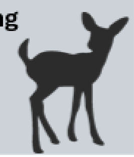
Conclusion: Evaluating Capture Events

Capturing wildlife for management and research purposes should only occur when the benefit to the population significantly outweighs the effects on captured individuals. Capture itself is inherently stressful to wildlife and will have negative impacts on the individual, which may be intensified by additional aspects at the time of capture, such as season, sex, and age. Capture effects can be difficult to observe or interpret, and capture consequences can range from temporary (e.g., deviation from normal grazing behavior for 24 hours post capture) to long-term (e.g., chronic debilitation, mortality) behaviors.

Proper preparation and standardized evaluation are critical before, during, and after capture events are performed (Cristescu et al. 2022). At minimum, evaluation should include a study design, sample size (minimum and maximum numbers of animals needed), a valid statistical approach, methods to measure and record capture effect data, mortality thresholds, and development of alternative plans if time of year or weather deviates from expectations tailored for the species, age, and sex being captured. Evaluating environmental conditions and demographics of the targeted animals (sex and age) will ensure that the capture events are being conducted with animal care and welfare in mind and will improve the availability and data obtained. Standardized evaluation allows for improvement of methods, data collection, and data quality. Evaluation of capture effects should occur and be documented during (e.g., physical exam, biological samples, etc.) and after (e.g., mortality investigation, movement and behavior patterns, etc.) each capture event. Methods of evaluation will vary depending on the situation, but should include investigation and/or necropsy of mortalities that occur within the first 30 days after capture, regardless of cause. Although the 30-day window may not account for all capture-related mortalities (e.g., renal injury may take longer to manifest) and may also include mortalities ultimately unassociated with capture (e.g., predation would have occurred anyway), it can be useful in evaluating a capture event (Van de Kerk et al. 2020; Hampton and Armeno 2023). Whether or not mortalities within the window are censored for other analyses (e.g., survival) may depend on the questions being asked. Assessing recaptured animals and visual observation of previously captured animals to assess collar fit and condition can also provide valuable feedback. Finally, analysis of post-capture data, including evaluation of the data obtained (e.g., survival), and debriefing with the capture team should be conducted to inform and improve future efforts.

Mortality investigations may result in more or less understanding as to cause of death but provide important follow-up regardless. All mortalities within 30 days of capture should be considered capture-related when evaluating protocols. Credit: A. Hunnicutt, California Department of Fish and Wildlife.

Table 3. A summary of general considerations when capturing, handling, and administering drugs to ungulates based on time of year.

	Spring	Summer	Autumn	Winter
Adult male 	• Poor body condition: may need lower drug dosage • Nutritional stress may increase capture stress, injury, or mortality	• Added hyperthermia concerns • Drug residues a concern if persist into fall hunting seasons • Antlers in velvet increase risk of capture injury	• Rut: may need greater drug dosage or may experience greater sensitivity to drugs • Rut: potential effects on hierarchy • Rut: complications with fitting equipment (collars) • Hard antlers increase risk of capture injury • Drug residues are a concern during the hunting season	• Frozen ground and snow can influence physical injury risk • Hard antlers increase risk of capture injury
Adult female 	• Poor body condition: may need lower drug dosage • Nutritional stress may increase capture stress, injury, or mortality • Pregnancy: drug can directly affect uterus, placenta, and fetus • Third-trimester pregnancy: increased risk of injury or mortality during chase and capture • Lactation: drug can transfer through milk if nursing	• Added hyperthermia concerns • Drug residues a concern if persist into fall hunting seasons • Lactation: drug can transfer through milk if nursing. Dehydration of young during chase, capture, and recovery of mother	• Drug residues are a concern during the hunting season	• Frozen ground and snow can influence physical injury risk • Pregnancy: drug can directly affect uterus, placenta, and fetus
Dependent young 	• Risk of maternal abandonment when mother or young are captured. Reunion and rebonding not certain • Particularly vulnerable to stress	• Added hyperthermia concerns • Drug residues a concern if persist into fall hunting seasons	• Drug residues are a concern during the hunting season	• Frozen ground and snow can influence physical injury risk

Acknowledgements

We thank our many colleagues, particularly M. Verant, L. Baeten, N. Galloway, J. Powers, and S. Ratchford with the National Park Service Wildlife Health Branch, for reviewing and improving this document. We also thank the many wildlife health professionals who responded to the ungulate capture survey. Their experiences and knowledge are invaluable.

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Appendix A: Ungulate capture survey response data from wildlife experts

Tables 1 and 2. Summary information on the number of respondents, represented organizations, and years of capture experience.

Agency/organization	Number of Respondents
Alaska Department of Fish and Game	1
Alberta Fish and Wildlife Division	1
University of Alberta	1
Arizona Game and Fish Department	2
British Columbia Ministries	5
California Department of Fish and Wildlife	13
Colorado Parks and Wildlife	5
Idaho Department of Fish and Game	1
Nevada Department of Wildlife	1
New Mexico Department of Game and Fish	4
Oregon Department of Fish and Wildlife	1
University of Saskatchewan	1
South Dakota Game Fish and Parks	1
Utah Division of Wildlife Resources	2
Washington Department of Fish and Wildlife	6
Wyoming Game and Fish Department	3
Muckleshoot Indian Tribe Wildlife Program	1
National Park Service	2
Navajo Nation Department of Fish and Wildlife	1
Total	**53**

Years of Experience	Number of Respondents
1 to 5	3 (6%)
5 to 10	10 (19%)
10+	40 (75%)

Table 3. Responses from wildlife experts to the survey question: “Does your organization have a standard jurisdiction-wide guidance for ungulate captures or are there individual plans for specific regions or species?”

Type of Capture Plans	Number of Respondents
Multiple plans for specific regions or species within jurisdiction	28 (53%)
Single plan for whole state or province	15 (28%)
No Response	10 (21%)

Table 4. Responses from wildlife experts reporting if their represented organization has ungulate capture restrictions and, if so, the type of restrictions.

Type of Restriction	Number of respondents reporting
Stage of Gestation	39 (74%)
Weather/Environmental	36 (68%)
Breeding/hunting Season	33 (62%)
Dependent Young	23 (43%)
Nutrition/Forage Availability	4 (7.5%)
Other	5 (9%)

Table 5. The number of surveyed wildlife experts who indicated that their represented organization has species-specific seasonal capture restrictions in place based on weather or other environmental variables.

	Minimum ambient temperature	**Maximum ambient temperature**	**Terrain**	**Snow depth**	**Risk of adverse weather event**	**Temperature/ elevation and aircraft ceiling**	**Drug stability concerns**
Bighorn sheep	8	22	11	4	12	11	5
Bison	4	6	3	2	5	3	3
Caribou	2	5	3	2	2	2	1
Deer	11	22	9	6	12	10	2
Elk	13	22	10	6	13	13	5
Moose	9	13	3	6	5	6	5
Mountain goat	5	13	7	2	6	7	2
Muskox	0	1	0	0	1	1	1
Pronghorn	7	16	8	3	9	8	3
Thinhorn sheep	3	4	2	1	1	1	0

Table 6. The number of surveyed wildlife experts who indicated that their represented organization has species-specific seasonal capture restrictions in place based on reproduction and hunting timing.

	Within first trimester of pregnancy	**Within second trimester of pregnancy**	**Within third trimester of pregnancy**	**Dependent young**	**Breeding season**	**Hunting season**
Bighorn sheep	2	2	19	13	4	16
Bison	1	1	5	4	3	3
Caribou	1	1	5	2	1	2
Deer	2	3	30	16	3	26
Elk	2	2	31	17	6	24
Moose	1	1	16	8	5	10
Mountain goat	2	2	13	10	4	11
Muskox	0	0	0	0	0	0
Pronghorn	1	1	16	10	3	14
Thinhorn sheep	1	1	2	1	1	1

Table 7. Total number of species-specific seasonal capture restrictions based on nutrition or forage availability in place by represented organizations as reported by surveyed wildlife experts.

	Expected poor body condition (e.g., low seasonal forage availability)	Expected poor body condition (e.g., recent drought or severe weather)	High energetic demand (e.g., lactation)	Known trace mineral deficiencies
Bighorn sheep	1	0	1	0
Bison	0	0	0	0
Caribou	0	0	0	0
Deer	0	3	1	0
Elk	0	2	1	0
Moose	0	1	0	0
Mountain goat	0	1	0	0
Muskox	0	0	0	0
Pronghorn	0	2	1	0
Thinhorn sheep	0	0	0	0

Table 8. Responses from wildlife experts to the survey question: “Does your agency have a mortality rate cutoff (e.g., if 10% of captured animals over 2 weeks die within that timeframe or if 3 individuals die, then captures are called off)?”

Mortality rate cutoff	Number of Responses
Yes	29
No	11
No response	13

Table 9. Capture-related mortality thresholds used by the organizations represented by wildlife expert survey respondents.

Mortality threshold	Number of Responses
5% of animals	8 (15%)
Individual judgement call/species specific	5 (9%)
2-3 animals	4 (7.5%)
2% of animals	4 (7.5%)
10% of animals	4 (7.5%)
5-10%	2 (4%)
3-5% dependent of species or method	2 (4%)
No response	24 (45%)

Appendix B: Comments provided in ungulate capture survey of wildlife experts (Appendix A)

Weather/Environmental Restrictions

Summary

- Though most have some high ambient temperature restriction at which they stop capture, some have had success capturing in summer. Consideration should be given to summer captures and heat-adapted species.
- Some temperature restrictions are based on ambient temperature, body temperature of animals being captured, or both.
- Ambient temperature and capture method interact – ground darting restrictions may not be applicable with high ambient temperature.
- Low ambient temperature cutoffs are prescribed for a variety of reasons: human safety with aircraft, drug stability/freezing (naltrexone in particular) leading to partial immobilization, extended chase times risking cold damage to the lungs, etc.
- For regions with significant snowfall, waiting for snow accumulation prior to netgunning is ideal. Snow depth is particularly important for caribou and moose calf (~eight month old) netgunning. Minimal snow may prompt a switch from aerial netgunning to aerial darting for larger ungulates to minimize injury. For regions without significant snowfall and netgunning, ambient temperature well below freezing may be less ideal because of the risk of trauma to the animal.
- Limit darting to avoid low light (dusk and night) in case complications occur (e.g., incomplete induction). Ensure enough daylight to track.
- Knowledge of a capture area is critical, including avalanche risk in applicable areas.
- Fully prepare for any weather changes, particularly in the shoulder season.
- Elevation may affect efficacy of drug combinations.

Individual Comments

- “Capturing caribou earlier in the winter has resulted in more injuries.”
- “Tule elk tend to overheat when run too much, captures are timed during early hours or colder months to reduce the chance of negatively impacting elk.”
- “Summer capture is very restricted due to temperature concerns, but also over concern over drugging females in late pregnancy or while lactating.”
- “Deer captured by net gun with snow on ground have lower mortality rate than those captured without snow on ground.”
- “I have experienced heat stress in animals during late winter captures, and I no longer design projects that require capture at that time of year.”
- “Due to first hand experience with mortality associated with xylazine, chemical immobilization at high elevations (summer range greater than 7,000 feet) had restrictions on chemicals and combinations used. We tried to emphasize captures on winter ranges when possible.”
- “Complications with sudden weather changes in shoulder season - unseasonably and unexpected hot weather.”
- “We've experienced slightly higher post-capture myopathy-related deaths in mule deer when we've had to capture between mid-Feb to end of March. We feel that after mid-Feb the ambient temps start to negatively affect post-capture recovery, and may also have to

do with the deteriorating body conditions of mule deer at the end of their winter season before they migrate."

- "With little, or no snow cover and hard frozen ground, large bodied ungulates such as moose (in boreal habitats) are more susceptible to injury, i.e., they are running faster, they stumble through and go down in fallen trees, and can suffer from pressure injuries following immobilization."
- "We do conduct captures with or without snow, but injury rates are less when snow is present."
- "We concentrate our captures in Jan and Feb to gain the most snow depth possible. We have had open years (little to no snow fall events) when we captured pronghorn in corn stubble fields or deer in a large burn with timber fall across the ground, that have both caused injury to deer that we now avoid by focusing on only areas with snow depths sufficient to pad their fall whenever possible."
- "Snow conditions seem to drive a lot of decisions on whether or not to capture. Without snow, captures become more difficult from the air (hard to see cryptic animals, animals falling on hard ground causing injury) and ground (darting without snow cover makes it much harder to track animals that flee). Snow also is useful to quickly cool animals because hyperthermia tends to be the bigger issue. However, hypothermia has been an occurrence when using BAM."
- "Capture timing is largely centered around avoiding high ambient temperatures in our state, especially when considering adult ungulates."
- "Helicopter netgun captures of large ungulates (elk or moose) with either low snow or very deep, crusty snow have resulted in animals falling and breaking their necks. In low snow and open terrain - some animals run too fast and fall really hard increasing the risk of severe injury."
- "Susceptibility to capture myopathy and heat and stress related injury will vary seasonally with cold adapted species (Winter capture not always best)."
- "We have also had great success in conducting summer captures even in hot weather. We don't have an ambient temperature cut off since wind, humidity, cloud cover and snow load are all other variables. Instead we base our decision on when to cut off captures based on animal temperatures, notably multiple animals coming in over 105F. This may occur at 90F in the summer or at 40F in winter."
- "We have been very successful with no known negative outcomes, even when temperatures have been exceeding 100 degrees. I think that noting these exceptions to a temperature threshold is important."
- "For example, an argument that capturing desert-adapted animals during winter (when pelage is at its densest and animals are best adapted to conserving body heat) is antithetical to what logic suggests would be the best time to capture such species (i.e., summer, when pelage is thinnest and they are most apt physiologically best adapted to shed body heat) and physical efforts to cool hyperthermic animals by soaking them would be most effective."
- "In extreme winters, we will evaluate the true need of a specific capture and may choose to postpone it. We have conducted many deer captures in severe winters and have not detected an impact, but there is a very strong social component where many members of the public are concerned that the capture will be too much for the animals."
- "For all species above we will not capture animals in late winter if the winter conditions are harsh and undue stress is expected."

Reproductive/Hunting Restrictions

Summary

- Limited capture during or near the hunt season (often the preceding 2-4 weeks), whether for drug withdrawal times or to avoid optics of "harassing" animals while the public is hunting.
- General avoidance of capture during the last trimester, especially with alpha-2 agonists or as an interaction with high ambient temperature but this may not be a strict restriction.
- Avoidance of capture when young are at heel (often for the first six weeks), particularly with bighorn sheep, for fear of abandonment.

Individual Comments

- "We have captured calves associated with elk chemically-immobilized up to April 14 so we know that mid to late trimester chemical captures do not significantly affect producing viable calves."
- "We have received complaints from hunters when helicopter captures or even surveys occur during a hunting season. We have had unhappy hunters who have complained to us after harvesting an animal before the drug withdrawal period has passed."
- "Had a pregnant bighorn ewe die after chemical immobilization in late pregnancy. Pathologist determined that hypoxia was likely cause of death and may have been due to the large fetus inhibiting adequate respiration under sedation."
- "Seen multiple abandonments of bighorn lambs after handling shortly after birth."
- "There are several Native American tribes on the Olympic Peninsula that have hunting seasons different from state seasons; their timing could also influence our capture efforts. Timing can also be influenced on when animals are most likely to be encountered/captured. For blacktail bucks, you would target July or August, early am/before 10:00 or late pm/hour or two before sunset, for best results, as an example."
- "We avoid the last trimester of pregnancy for all species. The long-term mountain goat study in Alberta has found that females may abandon kids captured in box or Clover traps. Consequently, capture has been postponed until yearling age (Festa-Bianchet and Cote, 2008. Mountain goats. Island Press. 265 pp.) In most instances, capture during the breeding season and hunting seasons are avoided to maximize breeding potential and to avoid conflicts with hunters."
- "We do not recommend chemical immobilization of ungulates in our parks during the last trimester of pregnancy for all species and limit captures during the rearing seasons. We do not have areas with hunting but animals do cross jurisdictional lines so we discourage capture of ungulates one month prior to the hunting season or emphasize the marking in animals with a 'do not consume' tag. For human safety reasons, we do not recommend capture of larger male ungulates during the breeding season (elk, bison, moose). We do not recommend immobilization of females with unweaned young."
- "In general we've been told to not capture in the third trimester of pregnancy, particularly when A2 chemical immobilization is involved. We tend to avoid helicopter capture when dependent young are on the ground (mostly with bighorn), though sometimes capture of lambs is planned. In general we recommend that our staff not capture during hunting season, particularly if they are using chemical immobilization on harvestable animals. It's more of a recommendation than a rule, and it's more about the optics of "harassing" animals while hunters are trying to harvest, though it often lines up with breeding season."

- “Bighorn sheep capture is avoided when lambs are less than 6 weeks of age due to possible abandonment issues.”
- “No low-level flights in ranges where lambs are less than 3-4 months old.”
- “We do not conduct chemical immobilization during the last trimester for all species and do not capture one month prior to the start of hunting in almost all occasions. We avoid captures for approximately 3-months post parturition (August) to decrease risk of abandonment.”
- “Colleagues have seen ewes behave erratically when flying near young lambs, saw a lamb impale itself on a yucca while running from the helicopter."

Nutrition and Forage Availability Restrictions

Summary

- If winter or drought is extreme, need for a specific capture may be reassessed. There may be an animal morbidity/mortality component but this may also be done to meet public expectations.

Sources of Information

Summary

- Respondents commented that they rarely reference universities/colleges and non-profit research institutions.
- Most often reference veterinarians and colleagues.
- Respondent noted the lack of published information and limited study design options for capture-related research.

Mortality Threshold

Summary

- Some organizations have a stated mortality rate cutoff (often 5-10%, though as low as 2% in some cases) but most consider this factor with regards to capture method, species, and stochasticity of mortalities.
- In other organizations, procedures are reassessed with two mortalities at a single capture event.
- Often mortalities within two to four weeks of handling are attributed to capture for assessment purposes.
- Netgun morbidity and mortality may bear significant correlation to crew performance; when choosing external contractors, experience and record should be considered.

Individual Comments

- “This is species and capture method dependent but our IACUC prefers to use 2-3% mortality as the cut-off point. We may accept 5% mortality for helicopter captures in some locations.”
- “5% mortality during a project's capture season triggers a mandatory consultation with ACUC Chair/Officer and veterinary staff.”
- “This is typically a judgement call based on the biologists assisting or participating in the capture activities. This may be related to capture related mortalities or changing environmental conditions. If biologists determine mortality levels are unacceptable or conditions are no longer safe for the animals or biologists, we immediately abandon capture efforts.”
- “2% is the figure to stop and re-evaluate.”

- “Dependent on species (i.e., Pronghorn Antelope is 10% via aerial capture efforts). Other ungulates are historically less than that threshold and have presented little to no restrictions necessary.”
- “Generally not more than 5% mortality within 2 weeks of capture.”
- “In general high levels of consecutive mortality result in a conversation to see if there are any mitigating steps to prevent further mortality. Significant mortality in a short period of time, may result in halting captures, particularly if the project goals are called into question. One example was drop netting antelope which resulted in almost 100% mortality (4/4 dead) within 2 weeks. It led to a halt on that particular capture, and a rethinking of that method of capture. We have expected rates of mortality, but not a specific cut-off rate as far as I am aware.”
- “We have stopped helicopter captures if we got 10% mortalities during the capture event.”
- “If two mortalities occur during a single capture operation, the operation must be temporarily suspended, including landing of the helicopter crew, to allow all parties to review capture and handling procedures and determine whether modifications are necessary. If it is determined that operations can safely continue, then the capture may resume the same day.”
- “Typically, 5% but all captures are monitored and capture teams make decisions as capture progress.”
- “Use 2% as a cut-off, at which point discussion with wildlife vet on next steps.”
- “We become concerned at 5% and will cancel if it continues.”
- “3-5% during capture, once the capture is over, no mort rate decisions just removing those animals from the data set.”

Other

- Human safety should be the priority.
- Organizations were split between having specific written protocols and general guidelines, as well as whether the work falls under a formal IACUC framework or guidelines are developed internally.
- Group and/or individual chase time restrictions are very commonly used to minimize stress and potential for capture myopathy. These may change based on ambient temperature or body temperature of the animal.
- Never try to dart or net two animals at once – it increases mortality risk significantly.
- Ensure team has eyes on darted animal to assess need to re-dose as soon as needed.
- My experience suggests that formal restrictions to capture timing is rarely work and they generate a lot of angst. General guidelines and the opportunity for group discussion on a case-by-case basis typically result in better decisions, although this does require more work.
- Have very experienced team members who understand animal behavior and can use lethal means if needed (e.g., large groups of bison during winter may protect darted animals).
- Every capture experience influences future capture experiences. And we communicate our successes and failures to one another, typically by word of mouth.
- Most of my decisions on capture timing is based on tried-and-true experience capturing ungulates. Also, timing can be dictated by objectives of the study such as the need for

body condition and lactation status of captured females (usually late autumn, early winter).

- The primary factors affecting our capture approach is usually animal welfare and biologist safety. We attempt to minimize risk to both the animal and biologists. Late winter capture efforts are generally avoided unless it is required to meet a specific objective (e.g., assessing fetal rates of deer).