CODE OF PRACTICE FOR THE CARE AND HANDLING OF BISON: REVIEW OF SCIENTIFIC RESEARCH ON PRIORITY ISSUES

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Bison Code of Practice Scientists' Committee

John Church Ph.D. (Chair)
Associate Professor (Cattle Research Chair)
Thompson Rivers University

Jayson Galbraith Ph.D.
Bison/Elk Specialist
Alberta Agriculture and Forestry

Rob McCorkell D.V.M., Ph.D.
Associate Professor (Game Farm and Wildlife)
Faculty of Veterinary Medicine, University of Calgary

Fiona C. Rioja-Lang Ph.D.
Research Writer

Mark Silzer *(Ex officio)*
Canadian Bison Association
Bison Code Development Committee Chair

NATIONAL FARM ANIMAL CARE COUNCIL
CONSEIL NATIONAL POUR LES SOINS AUX ANIMAUX D'ÉLEVAGE

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Excerpt from Scientific Committee Terms of Reference

BACKGROUND

It is widely accepted that animal welfare codes, guidelines, standards or legislation should take advantage of the best available knowledge. This knowledge is often generated from the scientific literature.

In re-establishing a Code of Practice development process, NFACC recognized the need for a more formal means of integrating scientific input into the Code of Practice process. A Scientific Committee review of priority animal welfare issues for the species being addressed will provide valuable information to the Code Development Committee in developing or revising a Code of Practice. As the Scientific Committee report is publicly available, the transparency and credibility of the Code is enhanced.

For each Code of Practice being developed or revised, NFACC will identify a Scientific Committee. This committee will consist of a target number of 6 scientists familiar with research on the care and management of the animals under consideration. NFACC will request nominations from 1) Canadian Veterinary Medical Association, 2) Canadian Society of Animal Science, and 3) Canadian Chapter of the International Society for Applied Ethology. At least one representative from each of these professional scientific bodies will be named to the Scientific Committee. Other professional scientific organizations as appropriate may also serve on the Scientific Committee.

PURPOSE AND GOALS

The Scientific Committee will develop a report synthesizing the results of research relating to key animal welfare issues, as identified by the Scientific Committee and the Code Development Committee. The report will be used by the Code Development Committee in drafting a Code of Practice for the species in question.

The Scientific Committee report will not contain recommendations following from any research results. Its purpose is to present a compilation of the scientific findings without bias.

The full Terms of Reference for the Scientific Committee can be found within the NFACC Development Process for Codes of Practice for the Care and Handling of Farm Animals, available at www.nfacc.ca/code-development-process#appendixc.

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1. HOW DOES SEASONALITY AFFECT THE NUTRITIONAL REQUIREMENTS OF BISON?

Conclusions:

1. **The ability of bison to build muscle and lay down fat varies with season. Seasonal changes in protein and energy metabolism are more specifically related to day length (not season). Bison alter their activity budget from summer to winter by increasing foraging time and decreasing resting time.**

2. **Feeding bison high concentrate finishing diets (>80%) over a significant period of time may cause ruminal acidosis.**

3. **Very little scientific information is available for optimal feeding of bison heifers and cows. All studies conducted on metabolic rates have been on growing animals. It is unclear how pregnancy and lactation alter energy requirements.**

4. **Planning feed programs prior to periods of weight loss is essential (for autumn weight gain). Nutritional seasonality can be used to optimize production, however, failure of bison to compensate in summer reduces herd fertility.**

5. **Current optimum mineral requirements are based on cattle. Bison specific values are required. Mineral supplements should be provided specific to a region's soil, water quality, and feed quality. Failure to do so results in low conception rates, weak calves, increased morbidity and mortality, and increased parasite load.**

1.1 Introduction

Bison have become optimal candidates for sustainable agricultural systems, especially in the northern regions of North America due to their ability to: i) respond to cold stress by lowering their metabolic rate (Christopherson et al., 1979a; Christopherson et al., 1979b), ii) winter graze even with snow depths up to four feet (McHugh, 1958), and iii) exhibit efficient utilization of low quality forages (Peden et al., 1974; Richmond et. al, 1977; Schaefer et al., 1978; Reynolds et al., 1982, cited in Rutley, 1998). Bison are extremely well-adapted for harsh winter weather: they add fat over the late summer and early fall, and then utilize those energy reserves during the cold and snowy winter months (Klemm, 2009).

In contrast to cattle, bison have not yet been genetically selected for production traits to any significant degree. A key trait that bison still exhibit is greater seasonal adaptation to their environment in comparison to cattle that were first introduced in Canada from Europe in 1541 (Church, 1997). Social structure, season and other factors also affect bison more than other domesticated ruminants (Anderson and Feist, 2015).

Seasonal cycles of energy metabolism are strongly developed in many wild ruminants of temperate and arctic regions (McEwan, 1968; Jenkinson et al., 1975), and previous studies on forage intake, digestion and live weight gain suggest that seasonal cycles also may exist in bison and cattle (Richmond et al., 1977; Christopherson et al., 1978, cited in Christopherson et al., 1979b). Sparing energy reserves at a time when cold stress and scarcity of food in the natural environment are often superimposed could greatly enhance survival in harsh environments (Christopherson et al., 1979b). This physiologically based seasonality of feed intake and how best to feed bison during different seasons will be discussed below.

1.2 Seasonality

Bison are relatively new domesticates; and, as such, they exhibit many natural behaviour patterns observed in wild animals, including reduced feed intake and activity levels during the winter (Christopherson et al., 1979b). Wild ruminants alter their daily activity pattern in response to seasonal fluctuation in forage biomass and environmental temperature (Trudel and White, 1981; Hudson and Frank, 1987). However, seasonal changes in foraging activity for bison appear to be more related to forage quality than biomass (Rutley and Hudson, 2001). Bison clearly exhibit seasonal cycles for appetence and energy requirements; their peak voluntary intake and maintenance requirement has been reported to be in June and September (Rutley and Hudson, 2001), which also corresponds to when forage quality is highest.

A number of other wild ruminants also adapt to seasonal environments with endogenous bioenergetic rhythms in which voluntary feed intake, digestive capacity and growth is restricted during winter months (Nordon et al., 1968). It has been shown that adult deer and caribou (Wood et al., 1962; McEwan, 1968) exhibit a cyclical pattern of growth characterized by weight accretion in summer followed by weight loss in winter (McEwan and Whitehead, 1970). A study investigating the seasonal changes in energy for reindeer and caribou reported that caloric intake was 35–45% lower in winter than during the summer growth period (McEwan and Whitehead, 1970).

Similarly, the high quality forage that muskoxen consume (namely grasses and sedges) is only briefly available in summer (Thing et al., 1987; Klein and Bay, 1990), and access to nearly all forage may be severely restricted by snow for 8–10 months annually (Jingfors, 1981). A study investigating the seasonal variation in intake by muskoxen (Adamczewski et al., 1994) reported that although body weight and feed intake of non-breeding muskoxen were less clearly seasonal than that in breeding females, they showed some evidence of a photoperiodic effect. Both breeding and non-breeding muskoxen tended to lose weight in late winter and spring, and to re-gain it during autumn and early winter. Mature bison, like other native ruminants from North America, experience a winter weight loss of up to 10–15% of pre-winter weight (Christopherson et al., 1979b).

Traditional ruminant livestock, such as beef cattle, follow a growth curve whereby they increase their live weight mass continually. This is not the case with bison. Bison tend to grow from birth to 18 months of age, then their metabolism slows to a maintenance state where the impetus to grow is drastically reduced or eliminated (Rutley, 1998). This phenomenon may result in increased time on feed, reduced feed efficiency, and increased cost of gain (Anderson et al., 1996). Photoperiod and cold temperatures may account for reduced daily gains in winter; however, the cold tolerance of bison would suggest photoperiod may have a greater effect (Christopherson et al., 1979b). The natural inactivity of bison in winter apparently includes reduced feed intake, even when feed is readily available (Anderson et al., 1996).

Variation in intake over seasons was observed in bison where pen intake was measured during a February/March time period compared to an April/May time period (group intakes were measured during the last 5 days of each of the two adjustment periods). It was found that bison had a lower Dry Matter Intake (g of feed per $kg^{-0.75}$ body weight) when fed *ad libitum* alfalfa pellets during the February/March time period (67.6 g $kg^{-0.75}$ ± 6.8) when compared to the April/May time period (95.21 g $kg^{-0.75}$ ± 9.4) in the same year (Galbraith et al., 1998).

Rutley and Hudson (2000) provided evidence of seasonal energetic cycles in penned and free-grazing bison and explored methods to evaluate the energy balance of free-ranging bison. They reported that the maximum consumption rates for bison yearlings (51 g min^{-1}) were lower than the pooled consumption rates of sub-adult males, adult females and yearlings (68 g min^{-1}) (Hudson and Frank, 1987, cited in Rutley and Hudson, 2000). The decline in consumption rates from June to September is 41 and 35 g min^{-1}, respectively. Seasonal variation in consumption rates was expected, and it is clear from this research that maximum consumption rates occur during the growing season; however, bison were able to consume up to 11.9 ± 1.2 kg day^{-1} while winter grazing under adequate sward cover and in acceptable snow conditions (Rutley and Hudson, 2000).

It has been suggested that bison can exist on lower quality diets than cattle because historically their ability to overwinter on grasslands has not been altered by management practices such as supplemental feeding (Stanton et al., 1996). Evolutionary adaptation to an environment where diet quality is markedly reduced in winter has resulted in bison that can survive on fairly meagre resources relative to cattle in winter. They do, however, need to compensate for reduced nutrition in winter with increased intake in summer comparable to cattle, or else herd fertility rates will be reduced (Hauer, 2005). Prior planning of feeding management can help minimise the weight loss that occurs at certain times of the year.

Bison, like cattle, are considered generalist foragers; yet differences in food habits indicate that cattle are more selective foragers than bison (Peden et al., 1974). Larter and Gates (1991) described a study whereby they observed the diet and habitat selection of free-ranging wood bison (*B. b. athabascae*) in relation to seasonal changes in forage characteristics between habitats in the Northwest Territories. The wood bison showed pronounced seasonal changes in diet. During summer, the diet became a more diverse mix of sedge (*Carex spp*.), grass (*Graminae*) and willow (*Salix spp*.). Lichen (*Cladina mitis*) became a major dietary component in fall. Wet sedge meadows provided the most available crude protein in summer and were a preferred winter habitat. Forage availability was the main factor determining habitat selection. The authors also observed that during both winter and summer, wood bison selected habitats that provided the most available crude protein. In fall, forage quantity and quality became more homogeneous throughout the habitats.

Diet selection is sufficiently plastic that other forages (besides bison's preferred forages) in other habitats can assume a transitory importance so that the nutritional requirements for maintenance and growth can be met (Larter and Gates, 1991).

1.2.1 Photoperiod

The changes observed in body weight (BWT) and dry matter intake (DMI) by bison 18 months of age and older is directly related to season, but more specifically day length (Saskatchewan Agriculture, 2000) (see Figure 1).

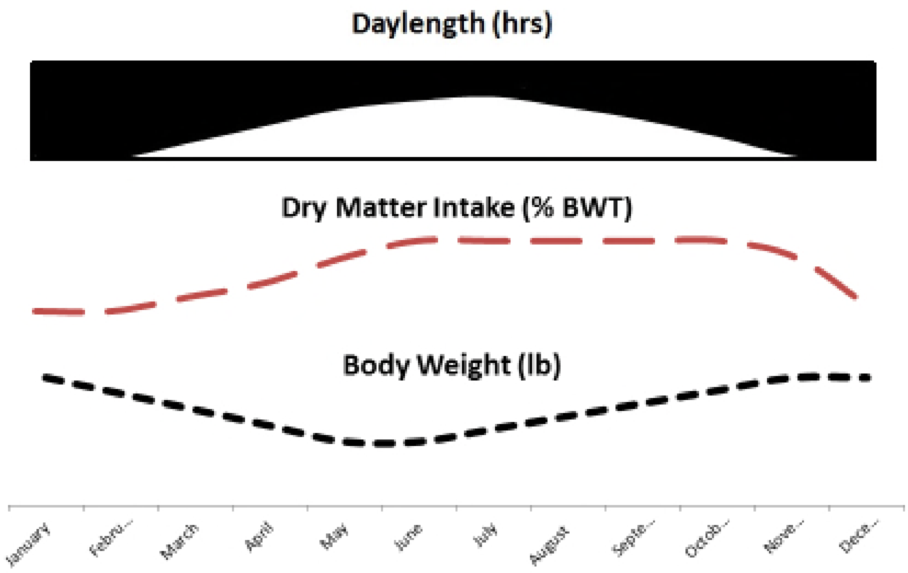

Figure 1. Bison energetics throughout the year (Feist, 2015).

It is probable that animals perceive photoperiod as a relative, rather than an absolute, phenomenon, and there are critical parts of the day that regulate photoperiod perception (Stanton et al., 1996). This rhythm of perceived photoperiod is ingrained from an early age, probably in utero, and can have considerable residual effects after photoperiodic manipulation (Stanton et al., 1996).

Ambient temperatures beyond the thermoneutral zones (TNZ) of animals reduce feed intake (Christopherson et al., 1979b), growth rates and reproductive efficiency (Tucker et al., 1984). However, the cold tolerance of bison would suggest photoperiod may have a greater effect (Christopherson et al., 1979b). There is evidence that intake, and hence productivity, is decreased during short photoperiods in most ungulate species (Phillips, 1992). In winter, short day length encourages the maintenance of body fat reserves at the expense of lean tissue growth or milk production.

1.2.2 Physiology of seasonality

Metabolic rate in bison varies with season and interacts with temperature and physiological stage (Stuth, 1992). In a study examining the seasonal energy expenditure and thermoregulatory responses of bison, bison displayed a low metabolic rate, which was viewed as a factor serving to improve metabolic efficiency (Christopherson et al., 1979b).

Under conditions where cattle metabolic rates are high and temperature is in the thermoneutral zone (TNZ), bison metabolic rates are 2–5% less in spring and fall and 5% higher in summer (Stuth, 1992). On average, during non-winter months, bison net basal metabolism averages 3% less than cattle (Stuth, 1992). In winter, they can reduce their metabolic rates by about 12%; however, when excessive cold occurs in spring, their metabolic rates drop as much as 35% (Stuth, 1992).

Christopherson et al. (1978) measured the metabolic responses of Highland cattle, Hereford cattle, yak and bison, and among the most striking observations was the qualitatively different response of bison to intense cold. Whereas the other species increased metabolic rates to offset heat loss, the bison reduced metabolic rates during all periods of exposure to temperatures of -30°C and below. Christopherson et al. (1978) reported seasonal variation in energy requirements for penned bison (higher spring than winter values) – variation similar to other northern wild ruminants – and Rutley (1998) states that bison clearly have highly developed seasonal cycles. Bison alter their activity budget from summer to winter by increasing foraging time and decreasing bedding time (Rutley, 1998). However, there are limited studies that have determined the extent of these seasonal cycles on free-grazing bison.

Since all studies conducted on metabolic rates of bison have been on growing animals, it is unclear how pregnancy and lactation alter their energy requirements. However, the few studies conducted do provide an estimate of differences in net metabolism between cattle and bison (Stuth, 1992).

1.2.3 Intensive feeding of bison

In the Northern Plains states and provinces, farmed bison bull calves that are not retained for breeding purposes are often confined in a feed lot and fed for meat production (Anderson et al., 1996). Slaughter typically takes place when the animal is less than 30 months of age, at approximately 550kg live weight (Anderson et al., 1996). Winter gains are a particular concern (due to reasons explained above) with very low and erratic gains experienced by many bison feeders (Stanton et al., 1996). Performance data for bison suggests average daily gains (ADG) may range from 1.30 to 1.95 lbs per day during the spring, summer and fall, whereas winter average daily weight (ADW) changes may range from weight loss to gaining 0.9 lbs per day. Fluctuations in daily gains and daily feed intake will affect feed to gain ratios, thereby affecting the total cost of gain (Feist, 2000b). To try to overcome these irregularities, bison are generally fed supplemental feed.

Finishing by feeding a grain ration is commonly practiced in the bison industry, both on pasture and in dedicated feedlots. Bison are increasingly fed on grain to promote evenness and proper fat cover and colour (Church et al., 1999), which usually occurs for around 90–120 days before slaughter. However, Church et al. (1999) suggest that bison may not perform well when confined and handled and they may finish less quickly and efficiently in some seasons. Christopherson et al. (1978; 1979a; 1979b) reported seasonal effects on energy metabolism; therefore, there may be an advantage to grain finishing bison in the summer, as opposed to winter, season. However, a study looking at the performance of American bison in feedlots (Church et al., 1999) reported that the feed conversion ratio (grain, forage or combined) was the same between seasons, which may serve to diminish any advantage beyond simple intake.

Many feeding systems finish bison using a single total mixed ration (TMR) high in concentrate and low in roughage (Brown, 2013). A study by Stanton et al. (1996) evaluated performance and digestibility of 30, 50 and 90% concentrate (grain) levels in bison finishing diets. The authors reported that feed intake was not significantly affected by concentrate level or protein level during the 266-day study. Overall, the authors suggested that feeding bison a 70–90% concentrate finishing diet appears to optimize feedyard performance during summer through mid-fall.

Anderson et al. (1996) conducted a study to determine the feedlot performance of bison bull calves fed during the four seasons of the year using four different diets. Weaned, intact male calves were assigned to four feedlot diets with season in a 4x4 Latin square design. Diet formulations were wheat screenings from durum wheat, wheat middlings from durum wheat, crambe meal and commercial bison ration. Gains were lower ($P<0.01$) during the winter than the other three seasons (spring =0.78; summer=0.63; fall=0.80; winter=0.17 ADG, kg/head); however, daily gains were not different ($P=0.24$) for dietary treatments when pooled across all seasons (Anderson et al., 1996). When the daily gains were analysed for spring, summer and fall only (excluding winter), the average daily gain was greater for the screenings diet. Bison digest fibre more thoroughly than cattle (Koch et al., 1995) making co-product feeds that are higher in fibre and protein and lower in energy than many common feed grains potentially more useful (Anderson et al., 1996).

Church et al. (1999) conducted a study whereby they compared the relative importance of season and starting weight on average daily gain. One hundred and fifty-six bulls from approximately 20 herds were evaluated in two winter and two summer trials, each for a period of 90 days. The bulls were offered free choice of standard ration of rolled and blended oats and barley (50:50 or 75:25), high quality fescue or barley straw, cattle mineral and water. The authors reported that overall the average daily gain was considerably greater ($P<0.05$) in summer than in winter. Over the first summer period (1993), the bison consumed 16.0–16.4kg total feed per animal daily, compared to 7.2–10.0kg the previous winter (1992). Throughout the second summer/winter period the bison consumed 12.4–14.1kg v 11.5–13.9kg, respectively.

In a recent study, Walpole et al. (2015) investigated the effect of feeding finishing bison high grain diets in feedlots. The results of this study indicate that feeding bison 80% grain diets (in this instance, rolled barley) resulted in rumen acidosis. In fact, the authors reported that when they analysed the structural integrity of the rumen wall they observed “burning” of the papillae due to the high level of acid build-up. A description of nutritional diseases, including acidosis associated with high concentrate feeding, can be found in detail in the NFACC Review of Beef Scientific Research Report (2012). Bison producers have very little information available on feeds and feedlot management to use for improving animal performance and profit in their feeding operations (Anderson et al., 1996).

1.2.4 Feeding heifers and cows

The feeding of bison heifers and cows for optimal production is a topic for which there is little scientific information available. It is, however, an important consideration with the high percentage of heifers being used for slaughter in North America. Data on the distribution of the gender of animals processed is collected by the Canadian Bison Association (CBA). Over the past five years, the number of heifers slaughtered has averaged 44%. This is comparable to the export statistics where over the past seven years the feeder females were 43% of the total feeder exports to the United States (Kremeniuk, 2016). Much of what we know has been learned from experience or extrapolated from beef cattle information (Hauer, 2005). In one study investigating seasonal variation in intake by muskoxen (Adamczewski et al., 1994), the authors reported that breeding muskox cows ate about as much in winter as non-breeding females and castrate males, but ate substantially more in summer; peak intake of lactating females was about 48% higher than in non-breeding muskoxen, thus highlighting the physiological demand of lactation.

There is a significant nutritional demand on pregnant heifers as they not only require sufficient nutrient intake to continue growing but also must meet the demands of supporting a growing calf. The objective when raising replacement heifers is to achieve an acceptable body weight in a period of two years, but pushing heifer calves to breed as yearlings may result in a heifer that will not conceive the following year (Feist, 2000a). Feist (2000a) suggests that a sample feeding program that should enable bison heifers to reach 660lbs or greater when two years old would involve pasture grazing during the summers. Having a robust feeding management plan should improve profitability in the long run as the producer will have to invest in fewer replacements.

Agabriel et al. (1996) examined the seasonal variations in intake and growth of yearling female bison (12–16 months) by feeding them a hay diet, ad libitum, indoors for 34 weeks. The bison were split into two groups: group one was fed first cut of hay (OMD = 0.570), and group two was fed second cut, from the same field (OMD = 0.685). The dry matter intake (DMI) was 5.6±0.5 and 5.2±0.3 kg/day respectively and average daily gains (ADG) were 202±45 g/day. The intake capacity per kg of live weight was 20 to 25% higher than those calculated for bovine Salers heifers of the same age eating the same diet. The intakes varied widely with season (Agabriel et al., 1996) with the minimum ADG occurring between December and February.

Years of surviving on low quality winter diets in the wild has resulted in bison cows having the physiological capability to live on fairly meagre diets in the winter. They do, however, need to compensate for this in the summer or else herd fertility rates will be disappointing (Hauer, 2005). Thin or poorly conditioned bison cows most likely will not conceive. This weight loss in the wintering period is a result of a reduced metabolic rate and cannot be changed, hence the importance placed on prior planning for autumn weight gain (Saskatchewan Agriculture, 2000).

1.3 Nutrient deficiencies

Similar to cattle, bison will suffer from mineral and vitamin deficiencies if they do not have access to minerals and vitamins on a regular basis. By confining bison to boundaries, we have limited their opportunity to seek out their nutritional demands and limited them to what is available within their fenced boundary (Lefaive, 2009). For many other domesticated livestock species, including swine, poultry, feedlot cattle and dairy cows, mineral supplements are incorporated into concentrate diets, which generally insures that animals are receiving the required minerals (Chládek and Zapletal, 2007). Grazing cattle and bison that are not fed concentrates are often provided with minerals using various methods, including lick blocks and supplements. Minerals and vitamins can be provided through several sources: loose, powder/granular/crumble form mixed with grain, or salt; either top dressed, or offered alone free choice, through liquid supplement feeders, or as part of a fortified pellet or supplement (Saskatchewan Agriculture, 2000). Free choice feeding of minerals is probably the easiest and most widespread practice of supplying minerals; however, with this method of supplementation, wide variation can exist (Government of Saskatchewan, 2008).

A chronic nutrient/mineral deficiency may take two or more years to develop and will be manifested in poor growth rates, diseases and an increased parasite load (Lewis, 2010). Nutritional deficiencies can also lead to weak or crippled calves and should be carefully noted and studied with a local veterinarian so that an appropriate solution can be implemented (Klemm, 2009). With deficiencies being slow to develop, correcting them also takes time: there is no “magic shot” (Lewis, 2010). McDowell (1992) described phosphorus deficiency as the most widespread mineral deficiency in grazing livestock throughout the world.

The effects of both copper and phosphorus deficiencies are discussed in more detail below, as these are two of the most common deficiencies observed in bison. However, bison can be deficient in any of the essential minerals listed here.

1.3.1 Copper deficiency

It is very difficult to find specific information regarding nutrient deficiencies in bison; however, it is helpful to look at those found in beef cattle. According to Woodbury (2005), bison are at least as sensitive as cattle to Cu imbalance. Copper deficiency in beef cattle is a widespread problem in many areas of the United States and Canada. It is one of the most common mineral deficiencies in western Canada (where the majority of bison production occurs). Signs of copper deficiency include anaemia, reduced growth, depigmentation (usually the earliest clinical sign) and changes in the growth and physical appearance of hair, cardiac failure, fragile bones, diarrhea, and low fertility characterized by delayed or depressed oestrus (Nutrient Requirements of Beef Cattle, 2000). Copper deficiency can be primary or secondary to other factors (either results in the same problems, but there is a difference in the approach to correcting either type) (Woodbury, 2005). Primary copper deficiency occurs when dietary copper levels are insufficient to meet metabolic demand, and secondary Cu deficiency develops when Cu absorption or metabolism is inadequate (Woodbury, 2005).

Cattle requirements for copper can vary from 4 to more than 15mg/kg depending largely on the concentration of dietary molybdenum and sulphur; however, the recommended concentration is 10mg Cu/kg diet (if the diet does not exceed 0.25% sulphur and 2 mg Mo/kg diet) (Nutrient Requirements of Beef Cattle, 2000). A concentrate diet less than 10 mg Cu/kg diet may meet requirements of feedlot cattle because copper is more available in concentrate diets than in forage diets (Nutrient Requirements of Beef Cattle, 2000). Ingestion of water containing sulfate at a concentration of 600 mg/L has been reported to induce Cu deficiency in Saskatchewan beef cattle (Smart, 1984). Requirements are greatly increased when molybdenum, sulphur, iron and zinc are present, resulting in the need for increased copper supplementation. For example, high levels of molybdenum (Mo) in the diet can bind with Cu in the reticulo-rumen creating an insoluble copper molybdate complex (Woodbury, 2005). Conversely, copper toxicity can also occur in cattle as a result of excessive supplementation of copper or the use of feeds that have been contaminated with copper from agricultural or industrial sources (Nutrient Requirements of Beef Cattle, 2000). By the time cattle show any signs of toxicity, large amounts of copper may have already accumulated in the liver.

1.3.2 Phosphorus deficiency

Phosphorus and calcium work together in bone formation, with approximately 80% of phosphorus in the body being found in bones and teeth, with the remainder distributed in soft tissue (Nutrient Requirements of Beef Cattle, 2000). Phosphorus also has many other cellular functions. In beef cattle the estimated requirement of phosphorus is about 16 mg P/kg body weight. Phosphorus deficiency results in reduced growth and feed efficiency, decreased appetite, impaired reproduction, reduced milk production, and weak fragile bones (Underwood, 1981; Shupe et al., 1988). The skeleton provides a large reserve of phosphorus that can be drawn on during periods of inadequate phosphorus intake in mature animals and subsequently replaced during long periods of high intake (Nutrient Requirements of Beef Cattle, 2000). Sources of phosphorus include (but are not limited to) animal and fish products, and supplemental sources including dicalcium phosphate and defluorinated phosphate.

1.3.3 Selenium deficiency

Selenium is deficient in much of western Canada (Lewis, 2010). Deficiencies can show up especially at handling when bison run excessively, resulting in down animals due to muscle damage (capture myopathy) (Lewis, 2010). In beef cows, selenium deficiency is most commonly expressed as white muscle disease (of calves), but also results in reduced disease resistance, retained placenta and weak or dead calves (Government of Saskatchewan, 2008). Because a deficiency can manifest itself in a number of ways, sometimes these conditions are referred to as "selenium responsive disease" (Hauer, 1999). Since selenium is extremely toxic, great care should be exercised when including selenium in a mineral mix or a ration: feeding directions for this trace mineral must be followed carefully (Government of Saskatchewan, 2008). Selenium is required by livestock at low levels (about 1.0–3.0 mg/head/day) (Hauer, 1999). Injectable forms of selenium exist, but for elk and bison this is not practical, and consumption from a free choice mineral or salt lick is unpredictable; therefore, feeding grain that has selenium mixed in is the most reliable means of supplementation (Hauer, 1999).

1.3.4 Testing for deficiencies and supplementation

Examination of forage samples available to bison during different times of the year is necessary to determine the correct mineral supplements. Forage samples alone may indicate that the forage or feed is sufficient for the bison's need, but examining the water might show that a critical element like copper could be tied up by iron and manganese resulting in a deficiency. Molybdenum, sulfate, nitrate, calcium and sodium can also cause mineral deficiencies due to interference (from cross binding).

Water sample analysis can provide an understanding of the minerals available for bison health. For example, hard water can have a drastic effect on bison feed, making something that would normally be otherwise sufficient become deficient (Lefaive, 2009). Samples of blood and/or tissue from harvested animals can also be evaluated to determine what the animals are lacking (Lefaive, 2009). Liver samples can be tested post-mortem: this is much more accurate than blood sampling (Lewis, 2010). Diagnosis of trace mineral deficiencies should be based on a complete assessment of the animal group (and/or feed and water sampling). Individual animal diagnosis is generally not sufficient to adequately address trace mineral deficiency problems (Government of Saskatchewan, 2008). The variation amongst individuals, and within herds, can lead to marked variation in mineral status.

In cases of known mineral deficiency, or where extra energy is required due to limited forage or other circumstances, there is interest in supplementing the grazing diet during the breeding season (Anderson et al., 2002). A study by Church et al. (1999) compared the seasonal differences in daily intake and found that bison consumed more minerals daily (0.04–0.06 kg d^{-1}) in summer than in winter (0.02–0.03 kg d^{-1}).

There are at least 17 minerals required by beef cattle (Nutrient Requirements of Beef Cattle, 2000). Currently, all mineral (and vitamin) requirements for bison have been based on beef requirements (Saskatchewan Agriculture, 2000). Until research to determine the minimal requirements or maximum tolerances has been published, a broad-based mineral supplement suited for grain-fed beef cattle is also recommended for grain-fed bison (Anderson and Feist, 2015).

1.3.5 Vitamins

As well as minerals, vitamins are also vital to all ruminants. Vitamins are required in adequate amounts to enable animals to efficiently utilize other nutrients; furthermore, many metabolic processes are initiated and controlled by specific vitamins during various stages of life (Nutrient Requirements of Beef Cattle, 2000). Similar to the mineral requirements, the same recommendations used for cattle are normally used for bison. The vitamin requirements for cattle include vitamins A, D, E, K, B12, thiamine and choline.

Vitamins, while commonly present in liquid and fortified pellet supplements, may or may not be included in granular mineral supplements (Feist, 2000a). As an option, a producer might consider that Vitamin ADE injections be given to bison calves in the autumn or whenever the calves are weaned/ processed to ensure vitamin deficiencies will not occur, and that vitamin supplements be fed throughout the year to all class of bison (Feist, 2000a). When the calves are first born, they will receive vitamins from the dams' colostrum (provided the dam has adequate stores).

1.4 Future research

Much of the peer-reviewed bison feeding information currently comes from free-ranging and park bison herds and the beef industry. Research is specifically required on commercially raised bison to address the gaps in our knowledge. Research is required into strategies that could help producers manage the effects of seasonality (reduced intake and daily gains) and to make it work to their advantage, such as diet manipulation and other approaches to help increase feed intake. Specific information is needed regarding the nutritional requirements (including vitamin and mineral requirements) for each stage of the lifecycle of each different bison class: bison calves, heifers, mature cows and bulls. It is particularly important to understand the optimal feed management practices for finishing bison and feeding heifers for meat. The feeding of bison heifers and cows for optimal production is a topic for which there is very little scientific information available. The Canadian Bison Association has coordinated a multi-year production benchmarking study that captures weaning weights, market weights, days on feed, average daily gains and many other factors (Woynarski, 2015). This information should be continually expanded and built on to allow producers a true comparison to their own herd performance.

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2 BISON BEHAVIOUR

Conclusions:

1. **Calm handling of bison differs from traditional cattle handling techniques.**
2. **In bison handling facilities, bison's vision must be restricted and loud noises kept to a minimum. Bison should <u>not be left in isolation</u> as solitary bison display high levels of agitation.**
3. **The position of the bison's tail and head is a good indication of body language.**
4. **Habituating bison to routinely accept handling procedures in a squeeze chute can help reduce injuries to both bison and stockworkers. Bison that have minimal human contact are more likely to have a greater flight zone.**
5. **Requirements for wallowing and rubbing are likely to be due to shedding, male-male interaction (typically rutting behaviour), social behaviour for group cohesion, play behaviour, relief from skin irritation due to biting insects, reduction of ectoparasites (ticks and lice) and thermoregulation.**
6. **It is not yet known if bison also derive a benefit from shelters/windbreaks.**

2.1 Introduction

In order to safely carry out routine husbandry procedures, producers must have the ability and knowledge to be able to gather, segregate and confine their animals. Injuries and death during handling are more frequent with bison than with cattle, which have been bred for calm temperaments (Lanier et al., 1999). Bison handling techniques are considerably different from traditional cattle handling techniques. The aim of this review is to provide some specific information about the natural behaviour of bison, and how that can be used to the advantage of the producer for calm handling practices.

2.2 Difference in behaviour between classes of animals

The majority of peer reviewed articles describing bison behaviour are ecological studies, and the bison are observed in wild or semi-wild situations (e.g., National Parks). There is a lack of research studies that observe bison in modern, commercial settings. It would be expected that the bison behave differently in commercial ranches as their social groups, feeding, management and environment would be different to that in the wild. For instance, bison have a very intact social structure that has definite spacing requirements between individuals and family groups. This spacing requirement may be different for different sexes and ages of animals throughout various times of year (Kossler, 2009).

Some of the differences in behaviour observed in different sexes and ages have been described in greater detail below.

2.2.1 Males

Bulls will separate from the herds after breeding and only young bulls are allowed to stay with the cows and calves (Hunter, 2009). Bison exhibit male-dominance female-defence polygyny with males guarding (tending) individual females from other rival males during the breeding season (rut) by using dominance displays involving vocalizations (called bellows), postural displays, scent urination, pawing, head rubbing, wallowing and physical fights (Lott 1974 &1979; Berger and Cunningham, 1995, cited in Wyman, 2012). Bulls also spend a lot of time tending cows that are not in estrus (Lott, 1981). Overall, high ranking dominant bulls obtain more copulations and sire more offspring than low ranking bulls (Wyman, 2008).

McHugh (1958) observed male bison arching their backs during vicious battles, during some “mock battles,” and while walking among the rutting herd – or, more typically, in a bull sub-group during the rut. He also observed bison “playing,” and notes that older bison butted and hooked their horns together while pushing back and forth and circling. McHugh (1958) also describes that many battles were initiated when one opponent approached another, shaking its head or bucking on its front legs. As battles occurred between a variety of sexes and ages, many opponents were unevenly matched; however, viciousness or severe exchanges were rare. McHugh (1958) also noted that mounting and battling were often coupled in play, as one frequently initiated or followed the other. While observing behaviour to develop dominance hierarchies, McHugh (1958) was only able to do this in captive herds, as individuals could not be easily recognised/distinguished in the wild. However, it was observed that the frequency of dominance behaviours was much less in the wild than in the captive herds.

<u>Rut</u>

There is more general activity in the herd during the rut than during other seasons, and peaks in rutting activity occurred just after dawn and dusk. Males display a very specific set of behaviours during the rut. These activities included sniffing of vulvas, tending of cows, bellowing, wallowing, horning, vicious and non-vicious battles, and incomplete and fertile mountings (McHugh, 1958). Active participation during the rut is physically exhausting, with bulls estimated to lose up to 10% of their body mass over the course of the season (Lott, 1979).

The bond between a bull and a cow during the rut is called the *tending bond*. When a bull is tending a female, this usually means that he keeps a very close distance to her (usually one to five feet) and is sometimes touching the cow (McHugh, 1958). Other observations that McHugh (1958) made regarding tending behaviour include the following: almost all of the tending observed was done by bulls ranging in age from six to at least 14, and bulls appear to take either a passive or an aggressive part in the tending bond (some follow cows, and others guide the movements of cows). Despite this, McHugh (1958) states that the tending bond is still essentially matriarchal.

<u>Vocalizations (bellowing and snorting)</u>

The sound made by adult male American bison (*Bison bison*) during agonistic behaviour has been described as a “roar” (Gunderson and Mahan, 1980). McHugh (1958) describes bellowing as an extreme variation of the grunt, which is only produced by bulls, more specifically older bulls. McHugh (1958) describes the sound of bellowing like that of a growling roar which can be audible for at least three miles in calm conditions. The bellowing bull may also open his mouth, stick out his tongue a few inches and contract his abdominal muscles so that his belly rises slightly.

Bulls roar any time of the year, but more commonly and most intensively during the rut when there are many agonistic confrontations between competing males (Gunderson and Mahan, 1980). It is suggested that bulls bellow for several reasons, including maintaining bonds with females, approaching another male, while following the trail of the herd, in answer to the bellow of another bull or in response to an automobile. It has also been observed that bellows are sometimes accompanied by snorts (McHugh, 1958), and were most commonly given by one bull approaching another prior to meeting, or by a lone bull heading towards and entering a cow group.

The male bellow is the most frequent and pervasive communication signal given during the rut and is thought to be sexually selected within the context of male-male competition and perhaps female choice (Wolff, 1998). In a study investigating the fitness of a male North American bison and how this is related to acoustic cues, the authors concluded that the bellows with lower formants reflect greater fitness in bulls. Increased time spent bellowing reflects the reduced time foraging or resting (Mooring et al., 2006). Female bison may exert choice over mating partners by approaching higher-ranked bulls during bellow contests in order to force aggressive interactions, by running through the herd, to trigger multiple fights or ”fighting storms” by male pursuers (Wolff, 1998).

2.2.2 Females

Bison cows and juveniles form relatively large herds in which members maintain close proximity and synchronized activity patterns (McHugh, 1958). Solitary bison, with the exception of older bulls, are rare, as bison are a very social species with strong matriarchal divisions. Cows stimulate bulls to compete for the opportunity to tend them, then cooperate with the successful bull to copulate (Lott, 1981). Breeding is strongly seasonal: about 90% of all copulations take place in a two-week period (Lott, 1981).

<u>Pre-parturition</u>

Bison cows are known to separate from the herd shortly before parturition. It is generally thought that the reason for doing this is to find shelter from predators (e.g., wolves) and to give birth to her calf without interruptions/annoyance from other members of the herd. This period of isolation can also help to strengthen the bond between mother and calf. In his description of the social behaviour of American bison, McHugh (1958) described instances whereby the cows gave birth to calves while remaining in cow groups: these groups were usually smaller and composed of several cows that either were pregnant or possessed young calves. In other instances, the pregnant cow was restless and wandered short trips away from the herd for one to sometimes several days prior to calving (McHugh, 1958).

<u>Cows and calves</u>

Of the relationship between cows and calves, McHugh (1958) reported that for the first few days the calves remained particularly close their mother, and up to two to three weeks they generally lay down within a few feet of their cows, while older calves often lay further away in subgroups. Up to an age of eight to twelve months, cohesion between cow and calf was sufficiently evident to identify each pair during most periods of the day (McHugh, 1958). After this age the attachment weakens considerably, particularly with bull calves.

Recognition between calf and mother depends upon scent, sight or sound (McHugh, 1958). However, McHugh (1958) also reported that instances of recognition by scent were rare for calves older than one month and that recognition by grunts without aid of sight showed that some grunts were distinctive.

Rarely, cows will not establish a pair-bond with their calves. Of the bison McHugh (1958) observed, mothers never abandoned their calves or hesitated to defend them against approaching animals or human beings by quick charges or slow advances. In the instance of twins, a bison cow will first attempt to care for both, but if the bison are free-roaming and she has to travel to keep up with the herd, she will quickly lose interest in one of the calves and it will most likely die of starvation (Klemm, 2009). The occurrence of twin calves is very uncommon in commercial operations and in the wild.

2.3 Body language

In a thorough paper written by McHugh (1958), the author writes a detailed account of the social behaviour of the American Buffalo, known at the time. The author observed both free-ranging and confined herds throughout the seasons. Some of the most notable observations regarding their behaviour recorded will be summarised below. For example, when describing fear or alarm responses, McHugh (1958) notes that these responses were usually elicited due to disturbances by strange objects, usually human beings. The bison stopped and stared for several seconds with ears brought forwards and head directed towards the disturbance. This was followed by the bison running away.

The position of the bison's tail is also a great indication of body language. McHugh (1958) describes the switching of the tail back and forth to flush insects; however, frequent tail-switching also occurred in a variety of situations, predominantly during play, such as chasing and bounding. Elevation and switching of the tail also occurred during the violent battles of the rut, by the calves during nursing and during herd movements (when they were hesitating between staying with the calf subgroup or moving on with the cows). The tail was raised and stiffly held 0° to 90° above the horizontal most frequently during trotting/running/bounding such as in playful chases, stampedes or in short charges, while moving forward and investigating unfamiliar objects (e.g., new bull, new calf, human), or during moments of tenseness or excitement, such as moving through the herd in the rut or before an attempted mount.

In many species, it has been observed that tail elevation and high postural tonus (muscle contraction) are correlated and indicate a preparation for locomotion and an increase in pace (Kiley-Worthington, 1976). This upright posture has become of communicative value to indicate a preparation for locomotion, alertness and warning. It is also used in confident approach and often associated with aggressive intentions (in some species this posture has become exaggerated specifically to increase its signal values) (Kiley-Worthington, 1976).

Another behaviour frequently observed by McHugh (1958) during play was bucking. This behaviour involves the hind legs, either singly or together, and the bison kicks its legs up or out to the side. Bucking is usually observed during play bouts. The bison were also observed "horning" lodgepole pine by stripping bark with the ends of their horns; this was sometimes accompanied by eating the bark and rubbing. This behaviour was most commonly observed during the rut. Interestingly, McHugh (1958) observed that bison preferred horning the bark or branches of previously horned trees rather than starting on fresh material.

Some behaviours are particularly useful for producers to be able to recognize, e.g., "sickness behaviours." These are a group of postures typically associated with the animal experiencing poor health. Identifying sickness behaviours in bison can be very challenging, particularly as prey animals do not want to advertise the fact that they are a weak member of the herd. Typical signs of fever include animals spending additional time at water sources, more frequent trips to the water source, drooping ears, mouth breathing and time spent away from the herd (Hunter, 2009). Bison that lag behind when bison move to graze new pastures are suspect, as it might encompass either problems with locomotion or rejection from other herd animals (Hunter, 2009).

2.4 Bison behaviour during handling

Bison, like cattle, are routinely handled to maintain herd health and meet the requirements of various regulatory agencies for diseases. Injuries and death during handling are more frequent in bison than in cattle, which have been bred for calm temperaments (Lanier et al., 1999). Bison can break off a horn cap, gore one another, attempt to jump out or smash through a holding pen, and even die due to excessive stress cause by handling (Lanier et al., 1999). Calm handling of bison, an excitable animal, requires attention to detail and strategies that differ greatly from traditional animal handling (Lanier et al. 1999).

It is beneficial to understand bison's behavioural signs of stress and allow them a chance to recuperate (Lefaive, 2009). For example, when bison are suffering from heat stress, they will display heavy, open-mouthed panting, sometimes accompanied by a protruding tongue and excessive salivation. Bison calves activate a stress adaptation response to significant stress that can cause an increased level of cortisol in the blood, which results in an inhibition of the animal's immune response system. This will render the calf more susceptible to infection (Lefaive, 2009). Also, animals that exhibit a high level of stress when handled may be a real challenge the next time through the corrals. Transitioning their exposure to people, equipment, vehicles and other things in their environment usually pays off by maintaining a low stress environment (Lefaive, 2009).

As mentioned previously, bison are not domestic cattle, and therefore will not move the same way through handling facilities. In a study conducted in Colorado in 1997, Lanier et al. (1999) conditioned (trained) bison calves to some common handling practices, such as standing calmly in a chute and standing calmly during a novel experience. The authors began this process by using operant conditioning techniques to teach the calves to stand still in the chute (this was achieved by offering a food reward in response to the desired behaviour). Lanier et al. (1999) suggest that habituation (training) changes the animal's perception of a frightening experience, and habituating bison to routinely accept handling procedures in a squeeze chute will help reduce injuries, thus allowing the wild genetic type to remain in the herd.

The frequency of human contact will determine how wary the bison are, and will affect their flight zone. Also, previous negative handing experiences can make subsequent handling more difficult (Goddard, 2014). The flight zone is the critical distance at which an animal, or group of animals, will make an escape response upon the approach of another animal, human handler or object. The flight zone of bison tends to be much greater than that of cattle, and bison can be moved most effectively if the handlers work on the edge of it. Handlers should stay out of the blind spot directly behind the animal, and where possible handlers should always work bison from one side only, and preferably outside of the pen. Handlers should avoid deep penetration of the flight zones because this will cause panic and attempts to escape. Panic behaviour typified by excessive and disorientated running may take place, increasing the risk of animals sustaining injuries by running into fences, corrals and other objects. Bison that are held individually, in small groups away from the herd, or who are exposed to unfamiliar handlers, objects or noises tend to be flightier. Ideally, a bison handling facility should be designed in such a way that the bison intuitively want to move in the desired direction (i.e., they will want to exit at the same point they entered a corral), thus reducing the stress associated with handling.

2.5 Requirements for wallowing/rubbing

Wallowing (in which the animal rolls in dirt) is a common behaviour observed in American bison, which is not typical of domestic cattle. Wallowing appears to be primarily a grooming or comfort behaviour (Coppedge and Shaw, 2000); however, it may serve many other functions. There are several different suggestions for why bison require to perform wallowing and rubbing behaviours, including grooming associated with shedding, male-male interaction (typically rutting behaviour), social behaviour for group cohesion, play behaviour, relief from skin irritation due to biting insects, reduction of ectoparasites (ticks and lice), and thermoregulation (McMillan et al., 2000). Shedding, rut and insect harassment all occur simultaneously in summer; therefore, it may be a combination of these factors that result in horning and wallowing behaviours (Coppedge and Shaw, 1997).

Wallowing and rubbing behaviours include oral grooming by means of tongue licking, scratching with the hind hoof, and rubbing against trees and other stationary objects, which would all be effective to varying degrees in dislodging unattached, traversing ticks (Mooring and Samuel, 1998). A bison's first line of defence from ticks is its coat, which has more primary hairs per square inch than any other members of the bovid family—ten times more than cattle—and a woolly undercoat as well (Lott, 2002). McHugh (1958) described that bison commonly rubbed their heads, necks and sometimes their sides on stumps, large low branches and trunks of trees. He also remarks that rubbing on trees removed tufts of shed winter fur, although this was not the sole purpose of rubbing since this behaviour was observed in all four seasons.

McHugh (1958) described bison wallowing as consisting of one to three actions: a sniffing of the ground, a preliminary pawing, and rolling on the ground. He also observed that the first two actions were sometimes omitted, although rolling never was. In McHugh's observations of wild and commercial bison, over all seasons, he also stated that wallowing was preceded or followed by horning or rubbing the head in the earth and a type of "neck-crooking" where the neck was stretched and flexed and the horns occasionally scratched against the back. Most wallowing was also done where previous wallowing had broken the sod. Other areas of preferred wallowing occurred in natural bare areas, prairie dog mounds, wet mud holes and occasionally on snow. Wallowing was the most noticeable among bulls during the rut (McHugh, 1958), although it was observed in both sexes at all times of year. Within the herd, it is thought that adult males wallow more frequently than adult females, and both adult males and females wallow more frequently than yearlings.

In a social study of confined bison, Reinhardt (1985) reported that 13% of wallowing was also accompanied by aggression; however, it is probable that the sex structure of the study herd pre-empted aggressive wallowing behaviour by bulls as the male: female ratio was 1:7, thus increasing the competition for mating access. Although many studies (Coppedge and Shaw, 2000; McHugh, 1958; Reinhardt, 1985) support the hypothesis that wallowing is primarily an adult behaviour as the behaviour increases with age, Coppedge and Shaw (2000) also reported that even with the altered age and sex structure of their study animals, wallowing behaviour still occurred, and the authors did observe some aggressive interactions between wallowing cows. Wallowing was also observed in calves by McHugh (1958) as early as 13 days of age; however, he reports that the behaviour did not mimic that of the adult animals until one month.

Reinhardt (1985) reported that wallowing increased substantially during summer, and was practiced mostly by adult animals with higher social ranking. McMillan et al. (2000) observed the circannual and circadian patterns of wallowing frequency by American bison in a region of tallgrass prairie. The authors reported that wallowing activity increased between April and late June in the first year, and April to July the second year, peaked again in September and remained low from November to March. Wallowing was also observed more frequently early morning and increased to a peak in the early afternoon, decreasing mid afternoon and evening.

In a study investigating the role of grooming and hair coat as a tick defence strategy, Mooring and Samuel (1998) observed the plains bison of Elk Island National Park between October and June, 1996. They observed that during this period, bison groomed the highest rate during the month of October, when winter tick larvae were blood feeding. Scratch bouts and episodes per hour were significantly different across life-stage periods for all age/sex classes, peaking during the larval feeding period in October. Wallowing behaviour for all classes of bison in the herd also peaked in October.

Coppedge and Shaw (2000) suggested that bison have preferences towards microsites, which influences their wallowing behaviour; for instance, the presence of small areas of exposed coarse soil, resulting from either the removal of aboveground vegetation by burning or disturbance by other animals. Vinton et al. (2015) reported that bison preferentially graze burned areas over not burned areas, and, furthermore, spring and fall burns were highly preferred as grazing sites by the bison in a 1998 study (Coppedge and Shaw, 1998). Recently burned areas also have the highest amounts of bare ground and exposed soil, microsite features that bison clearly prefer as wallowing locations (Bowyer et al., 1998). Coppedge and Shaw (2000) and Coppock et al. (1983) observed in the North America Great Plains that bison are attracted to soil disturbances for wallowing, which in the study by Coppedge and Shaw (2000) included coyote (*Canus latrans*) or badger (*Taxidea laxus*) diggings or ant mounds (*Formicidae*).

2.6 Requirements for bedding/shade/wind protection

There is currently no scientific evidence as to whether or not bison either require or would use bedding, shade or wind protection. However, it is known that bison are extremely cold tolerant, and, unlike other wild oxen and domestic cattle species (which raise metabolic output at cold temperatures), bison maintain or reduce their metabolic rate in still air to -30°C (Christopherson et al., 1978; Christopherson et al., 1979a). Conservation of thermal energy during times of cold and food deprivation is accomplished by minimizing physical activity (Mooring and Samuel, 1998). Bison have evolved many physiological and anatomical adaptations making them extremely successful in surviving harsh winters. Other species of animal, such as cattle and horses, can usually be seen exposing their backs to the direction the wind is coming from. However, bison instinctively face the storm and are able, as a result, to survive (HaBpacher, 1999). In doing so they prevent snow, ice and cold air from blowing under their coats and thus becoming chilled; moreover, their dense, woolly winter coat keeps them warm (HaBpacher, 1999).

Bison have several morphological adaptations towards cold stress, including their hair coat. The insulation of the fur is higher in bison than in any other bovid, owing to the extremely dense fur and thick woolly undercoat (Mooring and Samuel, 1998). Thus, the bison hair coat, although doubtless evolved as an adaptation to winter cold stress, also acts as a barrier to tick movement which offsets the sharp decline in grooming during the winter and early spring, when bison must conserve energy (Mooring and Samuel, 1998).

2.7 Future research

A better understanding of basic bison behaviour and body language would lead to lower stress during routine handling, improved round up methods, improved stock-worker safety, and could be used to improve the design of handling facilities. Research is required to assess the welfare benefits of providing bedding, shade and wind protection to bison, especially as protection against freezing rain and mud during the spring/fall months. It is generally considered that cattle do derive a welfare benefit from using shelters; however, as bison have different physiological and anatomical features than cattle, it is not yet known if bison also derive a benefit. Detailed behavioural observations are required to quantify if bison will actually use these types of shelter (either natural or fabricated), and at what age and under what weather conditions they will use them. Detailed assessment of factors underlying the wallowing behaviour of bison is needed, especially comparisons between preferred wallowing sites.

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3 EUTHANASIA ON-FARM

Conclusions:

1. Specific information regarding the gauge, calibre of firearm, and bullet selection that should be used for euthanizing bison is lacking. However, the combination of firearm and ammunition selected must achieve a muzzle energy of at least 300 ft-lb (407 J) for animals weighing up to 400lb (180kg). For animals larger than 400lb, 1000 ft-lb (1356J) is required.

2. Understanding the correct landmarks for euthanasia is essential, and it is important to recognize that in bison these are quite different from cattle. Due to the physical thickness of a bison skull, higher calibre firearms or heavier gauge shotguns are required than those used for other species.

3. Euthanasia by the intravenous injection of approved euthanasia drugs is very rare and can only be done by qualified personnel, usually a licensed veterinarian.

3.1 Introduction

The word *euthanasia* is Greek, and literally means "good death." The aim therefore is to end an animal's life with a minimum of pain, fear and distress. The American Veterinary Medical Association (AVMA) *Guidelines for the Euthanasia of Animals* (2013) defines euthanasia as "a method of killing that minimizes pain, distress, and anxiety experienced by the animal prior to loss of consciousness, and causes rapid loss of consciousness, followed by cardiac or respiratory arrest and death."

The humane euthanasia of bison presents a significant challenge to producers and veterinarians. These challenges are largely due to size and behaviour of bison, which are uniquely different from most other farmed livestock. For example, difficulties can arise due to the anatomy of bison (e.g., thick skull, especially of mature males). Euthanasia on-farm may be necessary due to a number of reasons, including a severe injury, escapes or serious disease. Regardless of the reason for carrying out euthanasia on-farm, it is the primary responsibility of the stockperson to relieve the animal from pain and distress in the most effective and stress-free way.

3.2 Euthanasia techniques

When the decision has been made to euthanize an animal, the goal is to minimize pain, distress and negative impact on the animal. The humaneness of the technique (i.e., how we bring about the death of animals) is an important ethical issue (AVMA, 2013). The technique deployed should result in rapid loss of consciousness followed by cardiac or respiratory arrest and, ultimately, a loss of brain function. In addition to the euthanasia technique, animal handling should minimize distress experienced by the animal prior to loss of consciousness (AVMA, 2013).

Bison specific guidelines can be found on the Canadian Food Inspection Agency (CFIA) website (Annex A – Species specific stunning guidelines); however, these guidelines specifically relate to slaughter plants and not on-farm euthanasia. The CFIA guidelines describe in detail the handling and restraint requirements and the landmarks and approaches for mature and immature males and mature females (see Appendix). The mechanical stunning devices that are described are the captive bolt and firearms. Other guidelines pertaining to the humane slaughter of livestock (not bison specific) have also been developed by USDA Food Safety Inspection Service, American Meat Institute Guidelines, American Association of Bovine Practitioners, the Humane Slaughter Association, the American Veterinary Medical Association and the Canadian Veterinary Medical Association.

Finally, the following techniques are all unacceptable for the euthanasia of bison: blunt trauma, injection of unapproved agents, air embolism, electrocution and exsanguination without stunning.

3.2.1 Handling and restraint

On-farm euthanasia of bison is most likely to be handled in an open field or pen setting; therefore, the animals will not be handled or restrained. Minimal handling prior to shooting results in lowest cortisol levels in the blood (Galbraith, 2011). For animals unaccustomed to human contact, gunshot should be delivered with the least amount of human contact necessary (Shearer and Ramirez, 2013). Bison that are unaccustomed to being handled can suffer from a recognised condition known as capture myopathy. Capture myopathy is a degenerative muscle fibre condition seen occasionally in bison. It is brought on by extreme exertion and overheating, and almost all cases result in death. Depending on the herd, either feeding the animals and then taking a shot, or driving to the herd in a familiar vehicle will give the best chance of the animals remaining still for some time and giving the shooter adequate time to take a good shot. As with all aspects of the euthanasia process, it is the responsibility of stockpeople to do all they can to minimize anxiety, fear, pain and distress for the animal.

In a study conducted by Galbraith (2011) investigating the meat quality traits from animals processed through a mobile location abattoir in a pen or confined prior to dispatching, the data supported the pen shot scenario for on-farm slaughter of bison. Plasma cortisol levels were significantly ($P<0.01$) lower in the pen shot animals compared to either the confined group of animals or the ones transported to a slaughter plant. The higher plasma cortisol level in the confined or transported animals reflects the aversion bison have to separation from herd mates, handling, confinement and disruption to their natural behaviour associated with these treatments.

This pattern of results is consistent with those of Pollard et al. (2002), who investigated the effects of pre-slaughter handling on the blood chemistry of red deer (*Cervus elaphus*) that were either paddock-shot or commercially harvested after transport to a slaughter facility. Plasma cortisol concentrations in paddock-shot deer were consistent with an unstressed state compared to concentrations in the commercially harvested deer which were indicative of stress.

3.2.2 Anatomical landmarks/shot placement

Understanding the correct landmarks for any animal is essential, and it is important to recognize that in bison they are quite different from cattle. It is of upmost importance that a projectile enters the animal's brain and causes instant unconsciousness. In the case of firearms, the angle of fire should cause the bullet to exit through the foramen magnum. Pictorial diagrams of bison anatomical landmarks can be seen in the Appendix (courtesy of W. Olson, 2015). The National Animal Health Emergency Management System (NAHEMS) euthanasia operational guidelines (2004) suggest that persons who have not studied anatomy of the animal species should have careful instruction to help them visualize the location of the foramen magnum since the path of the projectile is critical to successful euthanasia. For freely roaming animals (such as bison), the AVMA Euthanasia Guidelines

(2013) state that the preferred target area should be the head. However, there may be certain circumstances whereby a head shot does not present itself. In this instance a heart shot may be taken. The heart lies very low in the chest cavity (see Appendix). Also, bison that are alarmed or aggressive often face the threat, and stand with the head in an elevated position. In this instance a forehead shot should not be attempted as the bullet will glance off the bone. In this circumstance, a shot to the heart/lung area would be preferred.

3.2.3 Captive bolt

This method is rarely used for euthanizing bison on-farm; however, it will briefly be covered in this section. According to Canadian Food Inspection Agency (CFIA) stunning guidelines, the bolt length used for immature animals must be at least 12cm (4 ¾ in), and the bolt length for animals over one year of age must be at least 15cm (6 in). CFIA also recommends the .25 calibre and larger captive bolt stunning devices with heavier charges, as they are far more effective. The bolt velocity should also be assessed daily by using the manufacturer's bolt velocity testing device or similar means. The guidelines also state that stunning problems are usually due to using improper landmarks and/or holding the mechanical stunning device at an angle other than perpendicular to the skull (CFIA, 2013). The use of a captive bolt gun requires either secondary pithing or bleeding. The captive bolt gun alone is not sufficient for euthanasia.

3.2.4 Firearms and calibre

Due to the lack of control over free-ranging livestock (such as bison), and the stress associated with human contact, the use of firearms is often the most appropriate, and preferred, means of euthanasia. Used properly, firearms provide one of the quickest and most effective methods of humane killing of livestock (Humane Slaughter Association, 2013). When properly executed, gunshot induces instantaneous unconsciousness and death, is inexpensive and does not require close contact with the animal (American Association of Bovine Practioners, 2014). The latter is an especially important consideration for euthanizing bison. A basic principle is that a larger, more powerful cartridge and firearm is required when the animal will not be bled out post shooting.

Handguns, rifles and shotguns discharged at close quarters all fire free projectiles (single bullets or shot-charges) and their use is intended to kill animals outright, with no need for further action on the part of the operator (Humane Slaughter Association, 2013). The purpose of discharging a firearm from close quarters at an animal's head is to kill the animal instantly. The free projectile (bullet or lead shot) achieves this by destroying the part of the brain that controls breathing and other vital functions, the medulla oblongata (the brain stem); before this, the projectile could also pass through the cerebral cortex (upper brain) and the cerebrum (mid-brain), causing extensive damage and destruction (Humane Slaughter Association, 2013).

In reference to firearms, the bullet's kinetic energy (muzzle energy) is the energy of a bullet as it leaves the end of the barrel when the firearm is discharged (AVMA, 2013). Muzzle energy is frequently used as an indicator of a bullet's destructive potential: the heavier the bullet and the greater its velocity, the higher its muzzle energy and capacity for destruction of objects in its path (AVMA, 2013). Rifles are capable of higher muzzle energies compared with handguns and are often a better choice in situations where a fractious animal must be shot from a distance (American Association of Bovine Practioners, 2014). Due to the physical thickness of a bison skull, higher calibre firearms or heavier gauge shotguns are required than those used for other species like cattle. Canadian Food Inspection Agency (2013) recommends using the slowest velocity and minimum energy required to effectively euthanize the animal; this should help to prevent ricochet, which is a safety concern with high velocity calibre firearms. Regardless of the type of firearm used, the operator must have had appropriate training.

To determine whether a firearm or type of ammunition is appropriate for euthanizing animals, some basic principles must be understood. For example, the kinetic energy of an object increases as the speed and weight or mass of the object increase (AVMA, 2013). In addition, lighter weight, higher velocity bullets can have high muzzle energy but decreased penetration, which can be an issue when penetrating thick bones such as bison skulls (AVMA, 2013).

In a study by McCorkell et al. (2013), which was investigating the physiological stress associated with transport compared with on-farm slaughter of bison, the animals destined for on-farm slaughter were killed by an intercranial shot from a 12-gauge shotgun with a 2 ¾ inch foster slug (1 ounce). While much of the emphasis in euthanasia by gunshot is placed on choosing the most appropriate firearm it should be remembered that the gun is only the means of delivery; bullet selection is possibly the most important consideration for euthanasia of livestock by gunshot (AVMA, 2013). For euthanasia, the combination of firearm and ammunition selected must achieve a muzzle energy of at least 300 ft-lb (407 J) for animals weighing up to 400 lb (180 kg), and for animals larger than 400 lb, 1000 ft-lb (1,356 J) is required (AVMA, 2013). Handguns typically do not achieve the muzzle energy required to euthanize animals weighing more than 400 lb (180 kg), and therefore rifles must be used to euthanize these animals (AVMA, 2013).

Animal Welfare Approved (2015) guidelines state that euthanasia of bison should be carried out using a high powered hunting rifle, and that euthanizing bison and calves in a way that poses unnecessary pain or suffering is prohibited. Prohibited methods include: electrocution, suffocation, exsanguination without prior unconsciousness, poison and blow to the head by blunt instrument (Animal Welfare Approved).

3.2.5 Euthanasia by the intravenous injection of approved euthanasia drugs

This procedure is very rare and can only be done by qualified personnel, usually a licensed veterinarian. Control of the animal is of paramount importance before the procedure is attempted. In cases where the animal is still capable of movement, methods of restraint must be employed to ensure the procedure can be conducted safely and without interruption. In some circumstances, animals may first be tranquilized prior to euthanasia, but it is not required. Access to a superficial vein with adequate size to accommodate a large gauge needle is required, which limits injection sites to the limbs and neck. Once the animal has been euthanized the carcass is dangerous if consumed by other animals and must be disposed of in a manner that prevents scavenging.

3.2.6 Determining death

Regardless of the method chosen to euthanize the animal, it is important to correctly confirm that the animal is dead. In some cases, confirmation may require specific training with, and observation of, live animals (Woods et al., 2010b). When an animal is correctly killed with a shot to the head it will collapse immediately, stop breathing and may bleed profusely from the entry wound, the mouth and/or the nose. There may or may not be immediate exaggerated tonic activities of the muscles, or the carcass may appear completely relaxed (Humane Slaughter Association, 2013).

There are a number of indicators to confirm that death has occurred and these include no blink reflex, pupils fixed and dilated, no regular breathing, jaw relaxed and tongue floppy, and no heartbeat (DairyNZ, 2014). Care must be taken when confirming that death has occurred, as an unconscious animal may have very shallow breathing and a weak heartbeat that is difficult to detect. The operator should check for any signs of life immediately after the animal's slaughter and reconfirm death 3–5 minutes later (DairyNZ, 2014).

Indicators of an effective shot include:

- animal collapses immediately and stops breathing
- carcass can be tonic or relaxed
- a fixed, glazed expression in the eye
- no corneal reflex
- convulsions may occur after a lapse of up to one minute.

3.3 Special considerations for different class of animal (cows, bulls, young)

The correct method, and other considerations, for humane euthanasia will depend on the size of animal. Specifically, calves and bulls require special considerations in selecting the proper method of euthanasia (e.g., ethical considerations do not change for the calf because it is small or more easily handled) (American Association of Bovine Practioners, 2014). Euthanasia of bulls presents unique challenges because of their size, temperament and thickness of their skull (American Association of Bovine Practioners, 2014). The hide over the frontal bone and the frontal bone itself of a bull bison can each be up to 3.8cm thick, plus mature bulls frequently have long thick hair on their heads, which makes it difficult to see landmarks other than the horns (CFIA).

As described in Olson (2015), the composition of the herd in the field can also influence the process of euthanasia. If there are cows and calves, for example, there could be a different herd reaction when compared to a group of bulls. If several animals from the pen are going to be processed they can be shot one at a time and removed quickly after the shot. It is desirable to have more animals in the pasture/pen than what will be processed on any given day. This eliminates the scenario where there would be only one or two animals in a pen by themselves. The purpose of field shooting is to reduce stress, and ending up with an animal being by itself is certainly very stressful.

3.4 Deciding when to euthanize

Euthanasia is the humane termination of an animal's life. Reasons for considering euthanasia on-farm include an animal not responding favourably to treatment or with a poor prognosis, escapes, human safety, regulatory requirements and field harvest. The reality is that the situations whereby a person may be required to perform euthanasia do occur on-farm; in some cases it is an emergency procedure perhaps associated with a traumatic event, or in others, it is a decision based upon one's assessment of a sick animal's locomotory status, prognosis for recovery or perceived status (Woods et al., 2010b). Factors that have to be taken into consideration when deciding whether or not to euthanize any animal include the level of pain and distress being experienced, the likelihood of recovery, their ability to eat and drink water, and economic considerations.

Every farm must have provisions for humane euthanasia without delay, either by on-farm methods carried out by a trained, competent member of staff, by a licensed processor, or by a veterinarian called to carry out the procedure (HFAC, 2014). Blackwell (2004) has found that it was easier for farm stockpeople to euthanize a sick or injured pig if the farm had a written policy that clearly stated the conditions when an animal should be euthanized. As animal caretakers, there is a great responsibility to provide a humane end of life. A good death is tantamount to the humane termination of an animal's life (AVMA, 2013).

Prey animals (such as bison) instinctively avoid expressions of pain in order to evade the notice of predators (Woods et al., 2010a). If unsure if the animal may be experiencing pain or why the animal is in pain, consult an experienced stockperson or professional to assist in assessing the situation (Woods et al., 2010a).

3.5 Future research

There are currently no bison specific published scientific papers regarding bison euthanasia techniques (although there are several sets of guidelines from various professional bodies). Specific information regarding the gauge and calibre of firearm and the bullet selection that should be used for euthanizing bison of different ages is lacking.

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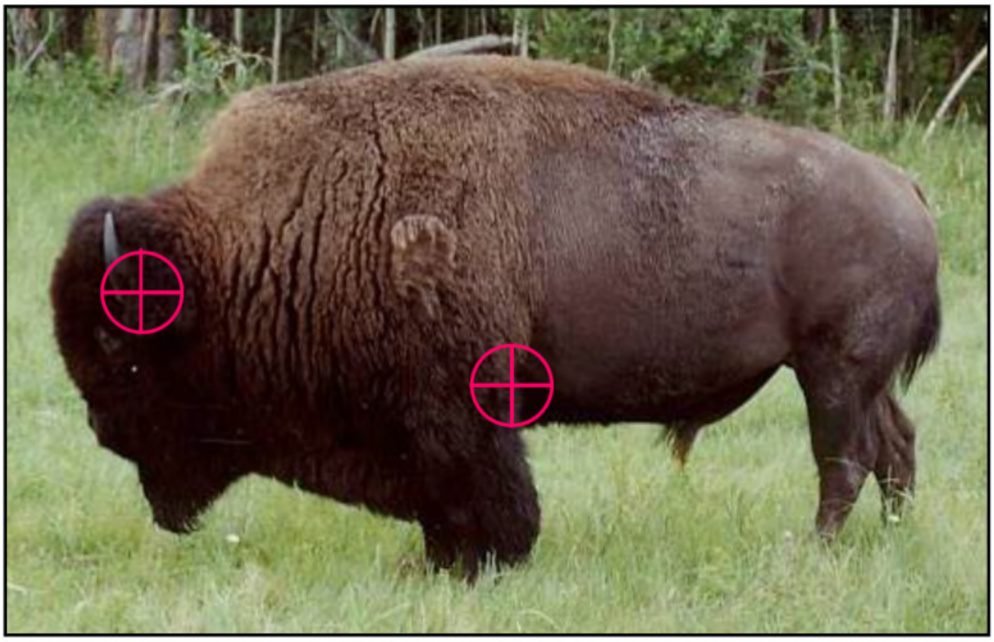
APPENDIX



When the bison is standing in full body profile, two shots are presented. When using a shot to the side of the head, aim for the posterior base of the horn. This will put the bullet into the brain case and cause instantaneous death.

If the head shot does not present itself, the heart shot can be used. The heart lies very low in the chest cavity, right at the cape demarcation line and only about 4" (10 cm) above the ventral chest line. Aim just above the intersection of the of the chest and the elbow.

Do not shoot to the rear of the cape demarcation, as it roughly approximates the location of the diaphragm. A shot to the rear of this line will put the bullet into the stomach or possibly into the lung, and it will not be fatal.

If required, put the shot slightly ahead of the cape line; the front leg will be shattered, slowing the movement of the bison. Take a second shot to ensure quick death.

Bison that are alarmed or aggressive will often face the threat and stand with the head in an elevated position.

Do not attempt a forehead shot in this case; the bullet will glance off the bone.

Draw a line across the animal, where his belly and front legs intersect, then centre the shot left to right. This will place the bullet into the heart / lung area and will ensure a quick, but not instantaneous, death.

Below:

The preferred shot placement is always when the animal is quartering away. With this angle, aim at the base of the horn and death is instantaneous. If the bullet pulls into the neck, often the spinal column will be shattered, and if it pulls to the right, the skull plate will still be destroyed.

The predictable behaviour of bison when a herd member dies quickly is to immediately investigate the downed bison.

This behaviour is what doomed the vast herds to extirpation. Shooting a large number of bison, one after the other, was referred to a conducting a "stand," and the principles used in the 1800s remain valid today.

A stand can only be successful if each bison is shot and drops in place. If an animal is wounded, becomes agitated and runs, the stand is over as the wounded bison will take the entire herd with it when it leaves.

Historical stands were successful because the barrels of the rifles used became hot and lost their accuracy if the shooter fired too quickly. This flaw in rifle design forced the shooter to take his time and place accurate, methodical shots that dropped each animal where it stood. The number of bison killed in these stands was then limited by the number and skill of the skinners.

This holds true in modern times if multiple kills are planned, especially if any meat or products are to be salvaged. Bison carcasses heat up quickly—far faster than all other ungulates, and meat spoilage can quickly become a concern.

CFIA - Proper Landmarks for Stunning

Mature males


[a]


[b]


[c]

Immature Males


[d]

[e]

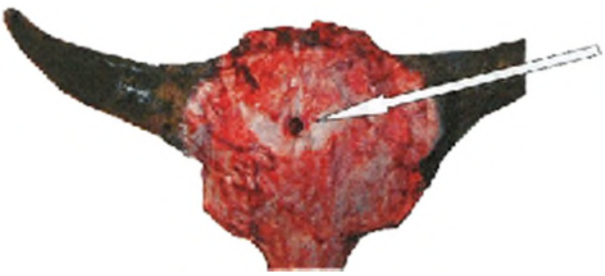
Mature Females

[g]

Projectile Entry Point

[e]

[f]



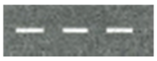
Projectile entry point

[e]

[h]

Projectile entry and imaginary line from the base of one horn to the other

Legend - proper landmarks for stunning bison

Image	Description
	Line running from the base of one horn to the other.
	Location of the brainstem and midbrain - in the middle of the skull.
	Entry point of the projectile (bullet).
	Trajectory of the projectile as it travels to the midbrain and brainstem.
	Arrow indicating projectile entry point to the skull and brain cavity.

Improper Landmarks for Stunning

Bison Skull

[i]

Note: This is an example of **the impact of using improper landmarks**. This bison skull contained 10 bullet holes. They were in the front, side and back of the skull. Most of the bullet holes in the front are too low (bovine landmarks), or too much off the midline of the skull (thereby missing the midbrain and brainstem) to be effective.

Table 1. Suitable methods for euthanasia

(* note the absence of captive bolt)

Method	Suitable for	Procedure and Equipment
Gunshot	Calves (under 181kg [400lbs])	Requires a minimum of 407 joules (300ft-lb) muzzle energy. Examples of appropriate firearms include: centrefire high powered rifle or shotgun (20 gauge or greater, from no more than 10m [32ft]). *Note: A standard .22 calibre long rifle only produces 119-138 joules (116-135 ft-lb) of muzzle energy and is not sufficient to humanely kill bison. Most handguns produce muzzle energy levels less than 1350 Joules (1000 ft-lb) making them not sufficient to humanely kill bison.*
	Yearlings, Cows and Mature Bulls	Requires a minimum of 1356 joules (1000 ft-lb) muzzle energy (NAHEMS, 2004). Examples of appropriate firearms include: center fire rifle,

		shotgun with slug (not recommended for mature bulls). *Note: A standard .22 calibre long rifle only produces 135 joules (1000 ft-lb) of muzzle energy and is not sufficient to humanely kill bison. Most handguns produce muzzle energy levels less than 1350 Joules (1000 ft-lb) making them not sufficient to humanely kill bison.*
Approved Euthanasia Drugs*	All bison	Must be administered by a veterinarian. Restraint if needed. Safe disposal of carcass when barbiturates are used. **For specific drugs and doses, licensed veterinarians would consult the CVMA guidelines.*

USDA National Animal Emergency Management System Guidelines. Washington DC: USDA. Available at: www.dem.ri.gov/topics/erp/nahems_euthanasia.pdf Accessed 2016.

Table 2. Firearm and ammunition recommendations for euthanizing bison

(figures from www.shooterscalculator.com/bullet-kinetic-energy.php)

Type	Cartridge	Muzzle Energy (foot-pounds)*
Rimfire rifle	.22 Long Rifle	105
	17 HMR	245
	22 Win Mag	338
Centerfire rifle	223 Remington	1296
	7.62 x 39 mm	1527
	30-30	1903
	243 Winchester	1925
	270	2345
	260 Remington	2354
	308 Winchester	2719
	30-06 Springfield	2750
	7mm Rem Mag	3221
	300 WM	3548
	300 RUM	4092
	338 Lapua Mag	4938
Shotgun**	20 Gauge, 2 ¾" ¾-oz slug	1587
	12 Gauge, 2 ¾" 1-oz slug	2491

Sporting Arms and Ammunition Manufacturers' Institute, Inc (2016). *American National Standard Voluntary Industry Performance Standards for Pressure and Velocity of Centerfire Rifle Ammunition for the Use of Commercial Manufacturers*. Flintlock Ridge Office Center, Connecticut. www.saami.org/specifications_and_information/publications/download/206.pdf. 2016.

* **Muzzle energy** (ft-lb) = **Mass** (in grains) **x velocity**^{2} (in ft per second) **/ 450400**
Energy (ft-lb) x 1.355817948 = Energy (joules) (SAAMI, 2016).

*** While shotgun slugs can be used effectively in close range situations and within controlled environments, their use is never recommended for euthanizing mature bulls or with any animal involving distances greater than 2 metres.*

4 PAIN IN BISON

Conclusions:

1. **Dehorning in bison causes pain and distress.**

2. **Both freeze branding and hot-iron branding cause pain and distress in bison. Freeze branding causes less acute pain at the time of the procedure.**

3. **All methods of castration in bison cause pain and distress.**

4. **Anaesthesia alone only decreases (but does not eliminate) calves' immediate pain response to castration and dehorning, and does not control long-term post-operative pain. Longer-term pain caused by castration and dehorning can be diminished with the use of analgesics.**

4.1 Introduction

This section of the report aims to provide information regarding painful procedures and how to recognize and manage pain in bison. Inflicting and alleviating pain are consistently cited as key societal concerns for farm animal welfare (Millman, 2013). As with many areas of this report there is very little bison specific information available, particularly peer reviewed literature. In this respect, we favour using the available literature investigating pain in beef cattle. Much of this literature has previously been reviewed and summarised in the *Code of Practice for the care and handling of beef cattle: Review of Scientific Research on Priority Issues* report (NFACC, 2012). Although it is important to stress that bison are distinctly different to cattle, there is little reason to suspect their physiological responses to pain are not very similar. It is also important to note that several medicines approved for cattle have been extensively used with no ill effects reported in bison; however, most medications and vaccinations used in bison are not listed on the label, therefore using a product is the responsibility of the owner or the veterinarian (Hunter, 2009).

Assessing the experience of pain in animals is a difficult task, yet one that is important in animal welfare research (Rutherford, 2002). In welfare research, pain assessment is carried out in order to identify when pain is likely to occur and to quantify its intensity. However, in veterinary practice, pain assessment allows action to be taken to treat the individual and to monitor the success of that treatment.

4.2 Recognizing pain and when to intervene

The assessment of pain associated with routine management procedures is often a difficult task (Schwartzkopf-Genswein et al., 1997). Pain signals vary between various livestock species, type of insult and stage of development (Millman, 2013). When assessing pain in other species, researchers record physiological measures such as cortisol, heart rate and respiration rate; but, due to the natural behaviour of bison, obtaining these measurements can be an extremely difficult process. When measuring pain responses in cattle, behaviours such as vocalization, kicking, tail-flicking, escape-avoidance response and subsequent handling ease have all been measured (Grandin et al., 1986; Lay et al., 1992c; Morton and Griffiths, 1985; Rushen, 1991; Schwartzkopf-Genswein et al., 1997c; Stookey et al., 1994).

Pain is an affective state and hence can only truly be known by the individual experiencing it. It can only be measured indirectly, in both humans and animals, presenting challenges for decision-making about pain management (Millman, 2013). Recognizing pain in a stoic species, such as bison, is particularly challenging. Because bison will often not show any signs of pain until the situation has become extremely grave, the challenge faced by producers, veterinarians and animal scientists is great. Due to the inherent challenges of handling bison it is also difficult to intervene when they are in pain/distress, due to the risks involved to both producers and animals. The stress induced to administer a treatment to bison can often be so great that it can in itself be fatal, and in some instances may lead to myopathy (a degenerative muscle fibre disease brought on by extreme exertion and overheating, and often resulting in death).

4.3 What is a painful process for bison?

Bison producers in Canada rarely, if ever, castrate or brand and seldom dehorn bison. However, despite the lack of research, it is reasonable to assume that if these procedures were to be carried out they would cause pain. Painful procedures, dystocia and methods of semen collection are discussed in further detail below.

4.3.1 Dehorning

Bison are not routinely dehorned; however, some producers still prefer to carry out this procedure in order to decrease the risk of injuries to other animals. There are still some bison cows in herds who were dehorned when many more producers routinely did the procedure; therefore, some producers choose to dehorn adult females if they are going to be mixed with dehorned animals to ensure that they are not severely injured when mixed. Removing horns may reduce the chance of injury or even death due to aggressive behaviour (goring), but these benefits must be weighed against the risk associated with both restraint and surgery (Church et al., 2007). Some producers also like to "tip" their bison. Tipping is the practice whereby producers remove only the tips of the horns; however, cattle studies and limited research on bison have shown tipping to be ineffective at preventing carcass bruising (Church et al., 2007). Physical methods of dehorning include the use of embryotomy wire, guillotine shears, or dehorning knives, saws, spoons, cups or tubes (NFACC Beef Report, 2012).

Dehorning of bison under two months of age is not practical due to the aggressive nature of the bison cows, but may have utility if performed on bottle reared orphans. The position statement regarding disbudding and dehorning of cattle (no specific references for bison) from the Canadian Veterinary Medical Association states that "the removal of horns in cattle may be necessary to enhance handling safety – but it is a painful procedure." In beef cattle, preference should be given to disbudding within the first two weeks after birth and with the use of anaesthesia and peri-operative analgesia. Dehorning is usually less stressful on young animals, as the horn is less developed in calves and therefore easier to cut out (Hauer, 2000). If animals older than two months must be dehorned, the procedure should only be performed using appropriate anaesthesia, analgesia and bleeding control. Within the beef literature, there is no evidence as to whether the dehorning procedure is more or less painful at different ages, however some studies do suggest that animals dehorned at a younger age heal more quickly than when dehorned as older animals (Goonewardene and Hand, 1991). Bison specific research examining the anatomy of bison horns would be particularly beneficial as bison horns do differ in structure to cattle horns, and additional recommendations could be made for bison producers.

In a study conducted by Church et al. (2007), the authors examined the effect of three different dehorning treatments – dehorned, tipped, or not dehorned (control) – and two different methods of anaesthetic (lidocaine or organic). In the control groups the animals were sham dehorned. The results showed that animals that were either dehorned or tipped were significantly lighter (4% or approximately 25lbs). This is a very significant finding that makes the administration of lidocaine via a ring block during the dehorning procedure an economically sound practice with positive welfare implications (Church et al., 2007). The authors conclude by noting that, subject to the impact of bruising, it is best to leave horns on bison. The animals used in this study were young, and therefore the horns were not likely to be fully formed.

There is very little bison specific literature relating to the pain caused by dehorning; however, the literature pertaining to beef cattle was reviewed in the NFACC Beef Science Report, and the authors concluded that there is strong evidence that all methods of dehorning cause pain, which has been shown in numerous studies that have measured physiological stress responses such as plasma cortisol and heart rate and behavioural responses (Duffield et al., 2010; Faulkner and Weary, 2000; Grondahl-Nielsen et al., 1999; Graf and Senn, 1999; Heinrich et al., 2009; McMeekan et al., 1998; Mellor et al., 2002; Morisse et al., 1995; Petrie et al., 1996; Schwartzkopf-Genswein et al., 2005; Stewart et al., 2009; Stilwell et al., 2008; Stilwell et al., 2010; Sutherland et al., 2002; Sylvester et al., 1998; Vickers et al., 2005).

It is not common practice within the bison industry to administer analgesics prior to dehorning (Church et al., 2007). Hauer (2000) also suggests that producers should consult with their veterinarians about the use of pain relief, such as injectable analgesics. Similar to castration, in the case of dehorning there is conclusive evidence in cattle that the use of a combination of local anaesthetic and analgesia can be used to control pain during and after dehorning (see review by Stafford and Mellor, 2011).

4.3.2 Branding and animal identification

Branding and other methods of animal identification are used to permanently identify individual animals. In Canada, bison must be identified with an electronic (RFID) ear tag that bears a unique number that follows the International Organization for Standardization (ISO) 11784 standard format, i.e., 15 digits. The first three digits are the country code: 124 for Canada. Other tags may be approved or considered equivalent. Species with national mandatory identification requirements (cattle, bison, sheep and pigs) that are tested or inspected for export or entry into a semen collection centre must be identified with a tag/indicator approved under the TRACE program (Livestock Identification and Traceability program).

In the past, all bovines (including cattle and bison) due to be exported from Canada to the USA must be branded or tattooed with the letters "CAN" before the animals arrive at the port of entry. However, in Canada, the incidence of branding bison is continually decreasing, particularly due to recent changes in USDA regulations for exporting live animals to the USA. Branding is now only one of several options available to permanently identify an animal.

There is currently no research on practical methods to mitigate pain in bison during branding. Much of the scientific literature regarding branding cattle has already been reviewed and presented in the NFACC Beef Code of Practice scientific report; therefore, it will only be summarized here (as there is no bison specific literature). The authors of the Beef Code of Practice Scientists' Committee conclude in their report that although both methods of branding cause pain and distress in cattle, research indicates that hot-iron branding appears to cause more acute pain than freeze-branding (Lay et al., 1992a; Lay et al., 1992b; Lay et al., 1992c; Schwartzkopf-Genswein et al., 1997a; Schwartzkopf-Genswein et al., 1997b; Schwartzkopf-Genswein et al., 1997c; Schwartzkopf-Genswein et al., 1998; Schwartzkopf-Genswein and Stookey, 1997).

4.3.3 Castration

Castration is very seldom carried out in in the bison industry. There are no peer reviewed scientific articles pertaining to bison; however, it is reasonable to presume that painful procedures in cattle are also painful for bison. Therefore, for the purposes of this report, the authors have included literature from beef cattle.

Male bison calves are left intact and either used for backgrounding/finishing (slaughtered at >20 months) or used as a breeding bull. One of the main reasons that producers do not castrate male calves is due to the difficulty in carrying out a procedure on a calf without causing distress to the dam and endangering stockmen. It is generally not possible to safely separate the mother and calf until weaning, unless orphaned. However, castration is carried out in some rare incidences, such as when an orphan is bottle raised; therefore, it is still important to include the research conclusions in this report.

Summarising what was reported in the NFACC beef cattle review of scientific research, the authors conclude that there is strong scientific evidence that all methods of castration cause pain and distress in cattle of all ages (Coetzee, 2011; Rault et al., 2011). The pain of castration can often be long-lasting: the performance of pain-related behaviours has been observed up to 3 months after rubber ring castration with and without local anaesthesia (Thüer et al., 2007). The authors also report that although castration is painful at any age, the trauma of castration increases with the size of the testicles being removed. Calves castrated at a younger age also experience lower declines in growth rate post-castration than those castrated at older ages (Bretschneider, 2005; Fisher et al., 2001; Gonzalez et al., 2010).

At present there is not enough evidence to definitively conclude that one method of castration is preferable to another (NFACC Beef Cattle Report, 2012). Different methods vary in the acute pain caused at the time of the procedure, duration of pain, rate of wound healing, whether pain can be managed, and the distress caused by restraint (NFACC Beef Cattle Report, 2012).

Regarding pain mitigation for the castration procedure, the authors of the Beef Cattle Scientific Review provide some useful information that may help bison producers should they choose to castrate calves. Anaesthesia alone has been found to only provide short-term pain relief following castration, and does not control post-operative pain (see review by Coetzee, 2011). Longer term pain from castration can be diminished with the use of non-steroidal anti-inflammatory analgesics (NSAIDS) such as meloxicam.

Recent advances in research have led to many new changes of drug availability in order to provide pain relief. Recently, a meloxicam oral suspension (MOS) (15mg/mL meloxicam) has been developed for postsurgical pain and inflammation in cattle and horses (Alberta Veterinary Laboratories, Calgary, Alberta, Canada). Currently, MOS is registered in Canada for the control of pain and inflammation in cattle undergoing surgical or band castration (Olson et al., 2015). Meloxicam Oral Suspension is Canada's first long-acting oral pain medication for cattle and can be used in cattle of all ages. It is in a liquid formulation recommended as a drench. It is reported that one treatment of the oral suspension should provide up to 56 hours of pain control (compared to six hours for an aspirin bolus (oral acetylsalicytic acid) and 24 hours for the injectable NSAIDS (including Banamine and Ketoprofen). This is a significant advance, as it the first pain medication in Canada with a label claim for reducing pain associated with castration in cattle. The product is easy to deliver by direct oral dosing or can be top dressed on feed (Olson et al., 2015). The oral suspension could potentially be administered in the bison's water supply the day before a painful procedure, providing pre-operative pain control without the need to restrain the animal the day prior (Pers. Comm., Lewis, 2015).

4.3.4 Dystocia

Dystocia is a prolonged or difficult calving, and can often require human intervention to safely extract the calf. The neonate's development and survival is dependent upon being vigorous at birth and receiving appropriate maternal care; however, difficulty at delivery can result in less vigorous offspring and maternal care can be altered, probably as a consequence of exhaustion, pain and human intervention (Barrier et al., 2012). The birth of a healthy calf is required for economic efficiency; therefore, it is of particular interest to detect difficulties during parturition as early as possible (Wehrend et al., 2006). The key difference when working with bison is that it is very dangerous to approach a dam (or impossible due to fleeing) to intervene during a difficult calving.

In the case of bison, it is generally considered that they experience very few difficulties while calving. It is very difficult to ascertain to which degree (if any) bison cows suffer from pain caused by dystocia. In a questionnaire survey in the UK, dystocia was ranked by cattle practitioners as one of the most painful conditions of cattle (Huxley and Whay, 2006). Domestication and breeding programs in the beef and dairy industries have resulted in cows producing large calves – which have not yet become a problem within the bison industry. Multiple offspring can also cause dystocia. Bison do have twins, but not as frequently as deer and other species of wildlife. The ease of giving birth for bison is largely attributed to the normal size of calves, with weights usually between 35–40 pounds (Lefaive, 2009). Similar to beef cattle, bison cows should not be overfed as it can cause an internal fat deposition, which obstructs the pelvic canal. Where dystocia does occur, excess human intervention (in the rare occasion it is possible) can create unneeded stress of the mothers (HFAC, 2014), and often euthanasia is preferable to treatment.

4.3.5 Semen collection

Evaluation of the breeding soundness of bulls is an important management tool (Palmer, 2005), and for more than half a century, electroejaculation has been a very effective method of collecting semen. The technique does not require mount animals, is not physically demanding and is easily adaptable to most cattle handling facilities (Palmer, 2005). However, there is some concern regarding pain that may be experienced during this procedure. Changes in heart rate, serum cortisol, serum progesterone, relative aversion and degrees of vocalization, struggling and lying down have been used to assess the pain associated with electroejaculation (Palmer, 2005). Palmer (2005) describes the reaction of beef bulls to electroejaculation as a welfare concern. Rushen (1986) concurs that aversion is definitely evident when the electrical shock is very intense or of long duration.

Several studies have attempted to evaluate the pain (Etson et al., 2004; Falk et al., 2001; Mosure et al., 1998; Welsh and Johnson, 1981) associated with electroejaculation in animals, and there appears to be considerable lack of agreement between results. It is possible that the lack of agreement is due to the techniques employed and the individual skill of the operator. Vocalization is generally accepted as a reliable indicator of pain (Schwartzkopf-Genswein et al., 1997c; Schwartzkopf-Genswein et al., 1998; Watts and Stookey, 1999). Not all animals can be expected to vocalize in response to pain, but more painful procedures tend to elicit vocalization from a higher proportion of animals (Palmer, 2005). Studies to find methods to reduce pain caused by electroejaculation may be compromised by the difficulty in objectively assessing pain (Mosure et al., 1998). There are no peer reviewed studies assessing the pain associated with semen collection in bison bulls.

In beef/dairy bulls, several alternatives to electroejaculation are available (artificial vagina, transrectal massage, segmented probe), and they all offer certain advantages; but none of them are as reliable as electroejaculation for obtaining a high quality semen sample (Palmer, 2005), and these would most likely be unsuitable techniques for using on bison bulls who can be significantly more challenging to handle.

Epidural, intravenous and topical anaesthetics have been used to ameliorate the pain associated with electroejaculation (Palmer, 2005). The smallest cattle probe should be used, or even a probe designed for a smaller species, e.g., goat (Pers. Comm., Annon., 2015). In the instance where producers only wish to test the semen quality of their selected breeder bulls, a less stressful method to gain confidence in a bull is to merely measure the scrotum (Lefaive, 2009). A study by Keen et al. (1999) found that 2 year old bison bulls with a scrotum circumference of less than 26cm tended to be less fertile than ones measuring 28cm. Also, those measuring > 30cm had a high correlation to being fertile. Lastly, pain associated with electroejaculation may be influenced by operator technique; therefore, operators of electroejaculator equipment must strive to apply electrical stimulation as gently as possible (Palmer, 2005).

4.4 Future research

There is limited research investigating if bison experience pain during procedures such as dehorning, branding and semen collection, and if so how to mitigate it. There is currently no scientific evidence specifically identifying if one method of castration would be preferable to another; however, as it is so rarely done within the bison industry it is unlikely to be investigated further. Male bison are sometimes subjected to electroejaculation which *may* be a painful procedure. Further investigation into the reliability of determining fertility by measuring the scrotum circumference may reduce how frequently bulls have to have their semen tested.

Continued research into reducing stress in bison during routine handling will benefit the welfare of bison on-farms, particularly as they often react differently to handling and procedures than cattle. Research investigating the levels of distress and subsequent welfare implications caused by restraint would be beneficial. It is likely that meloxicam oral suspension could be used to control pain caused by painful procedures in bison, and it could be administered as a top dressing on feed or in the water supply; however, research has to be conducted to demonstrate the benefits and practicality of this approach.

Despite recent advances in understanding and managing pain in beef cattle, further research is required, particularly if extrapolating the findings to bison. Bison may respond differently to painful procedures than cattle due to their behavioural and physiological response to being handled and restrained. Advances in pharmaceutical products and their methods of administration are likely to keep changing and improving and further investigation is required to validate these products and provide the industry with improved recommendations.

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