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Abstract

Humans have baited wildlife such as white-tailed deer (*Odocoileus virginianus*) for generations with the primary purpose of increasing hunting harvest success. Baiting regulation changes are often considered by state management agencies as they pertain to hunting opportunity, fair chase, and disease risk. Cervids require a variety of minerals to supplement biological processes, especially sodium (Na), calcium (Ca), and phosphorus (P). We developed artificial mineral supplement sites set in front of trail cameras to monitor deer use. Pooled soil samples were collected at mineral sites and compared to the surrounding area to determine the longevity of elevated minerals levels within the soil seasonally. Mineral sites showed significantly higher Na, P, and pH levels 230 days from the final mineral augmentation as compared to the surrounding control sites. May through October camera captures, were categorized as "use of" or "pass-through" on each mineral site. Site use and duration of use were identified for each sex and quantified monthly as well as non-hunting and hunting periods. We found doe use ranged from 0.29-1.00 per camera day and was highest during May and August while buck use ranged from 0.13-0.99 per camera day and was highest during May and June. We found does were 2.7 times more likely and bucks 4.0 times more likely to use mineral sites during non-hunting periods than hunting periods. The highest duration of mineral site use occurred in August (2.7 ± 0.3 min/doe and 3.2 ± 0.5 min/buck) and the lowest duration of use occurred in September (1.8 ± 0.3 min/doe and 1.1 ± 0.1 min/buck) and October for both does and bucks (1.0 ± 0.0 min). Despite significantly elevated Na and P levels at mineral sites compared to control sites during the hunting period, both frequency and duration of use for does and bucks decreased. Results from this study indicate, though soil nutrients remained elevated, mineral attractiveness and/or mineral deficiencies were less in September and October (coinciding with the start of hunting season) as does wean fawns and bucks antlers harden. Results from our study can be used by game managers and wildlife regulating agencies as they make decisions regarding baiting practices.

Keywords: baiting, deer use, calcium, mineral supplements, Nebraska, *Odocoileus virginianus*, phosphorus, sodium, trail camera, white-tailed deer

Introduction

Cervids require a variety of minerals to supplement life processes, especially sodium (Na), calcium (Ca), and phosphorus (P). Sodium has been shown to be the primary mineral sought by white-tailed deer (WTD; *Odocoileus virginianus*) using natural mineral licks in Indiana and South Dakota (Weeks and Kirkpatrick 1976, Kennedy et al. 1995, Atwood and Weeks 2002). The need for Na is seasonal as studies have shown cervids increase consumption as the weather warms (Risenhoover and Peterson 1986, Kennedy et al. 1995), when does are gestating and lactating, and bucks seek Na for antler production (Atwood and Weeks 2002). Calcium intake is essential to skeletal development in fawns, strengthening of bones, production of milk during female lactation, and antler formation in males (Vangilder et al. 1982, Grasman and Hellgren 1993). Phosphorus which is often deficient in forage is essential for reproduction, general metabolism, bone and antler development (Grasman and Hellgren 1993, Campbell and Hewitt 2004, Hewitt 2011).

The need for minerals to fulfill biological processes requires cervids to seek out natural and artificial sources to supplement their diet. Cervids such as Iberian red deer (*Cervus elaphus hispanicus*) have been found to discriminate between mineral lick contents based on their physiological needs and their requirements are highly dependent upon sex, age, and physiological status (Ceacero et al. 2010a and 2010b). White-tailed deer obtain the majority of their dietary requirements of macro and trace minerals (i.e. Na, Ca, and P) through normal browse and plant consumption (Barnes et al. 1990, Ramirez et al. 1996) and would not require artificial supplementation. Many cervids can also use and obtain essential dietary mineral intake from other natural sources such as mineral-rich springs and natural licks (Fraser and Reardon 1980, Fraser and Hristienko 1981, Ayotte et al. 2008).

Humans have provided artificial mineral supplements for the purpose of assisting wildlife development, enhancing trophy potential, and attracting animals to specific locations. The practice of artificial mineral augmentation has been termed "baiting," and early pioneers in wildlife management such as Aldo Leopold and Durward Allen felt strongly that there be regulations on public feeding and baiting (The Wildlife Society 2007). Some of the current natural and artificial baits for WTD include acorns, apples, corn, hay, salt, minerals, as well as adding natural or artificial flavorings (e.g. molasses, peanut butter) to corn, salt or mineral blocks (Mason et al. 1993, Baasch et al. 2003, Barrett et al. 2008). Today's marketed artificial mineral products include mineral blocks, powders and premixed liquids. Powders and liquids dissolve readily with water and are easily dispersed into the soil where they can be utilized by deer.

Some state game management agencies have addressed the practice of baiting an area that will subsequently be hunted. Atwood and Weeks (2002) stated supplying salt during hunting is baiting and consequently some regions have placed constraints on or defined supplementation as an illegal action. The Nebraska Game and Parks Commission (NGPC) defines hunting over placed bait as attempting to take any big game animal, including WTD, within 200 yards of an area that was baited (Big Game Guide NGPC 2015). In 2015, the NGPC amended the time period from 60 days prior to hunting the area to 10 days prior to the first big game season within the state, and at such time, supplementation must cease and any remaining presence of bait must be removed (Big Game Guide NGPC 2015). Virginia has also reevaluated baiting laws to consider baiting implications as they pertain to wildlife management, hunting opportunity, hunting traditions, sportsmanship, fair chase, and risk of disease transmission in wildlife and livestock (Report of the Virginia Department of Game and Inland Fisheries, 2014). This modification of regulations shows ambiguity on how to best manage the practice of mineral baiting among state game management agencies. Understanding the persistence of minerals in treated soils as well as the patterns of deer behavior associated on these treated soils is needed as new baiting regulations are being considered.

Data on the persistence of mineral content in augmented soils and effectiveness of augmented sites for attracting WTD is limited. It has been found that WTD consumption at artificial licks was positively associated with soil P levels, but it was noted that mineral consumption may vary between annual cycles and among locations (Schultz and Johnson 1992b). Atwood and Weeks (2002) found frequency of use at natural mineral licks by adult female WTD in Indiana was higher (76%) than any other sex or age class. Ping et al. (2011) found female and male wild China sika deer (*Cervus nippon*) had different seasonal peak use at artificial lick sites, but did not differ between sexes when looking at use duration.

Choice testing between four mixtures of popular marketed mineral supplements has been investigated and mineral preference has been evaluated (Shaw et al. 2007). No known studies have evaluated the longevity of mineral supplements within the soil after supplementation has ceased, or seasonal use and duration of use at these artificial mineral sites by WTD. Management agencies can benefit from a case study assessment on the persistence of minerals within augmented soils as well as how doe and buck use varies at augmented sites throughout the year as they set future baiting regulations. With this in mind, the primary objective of our study was to determine the persistence of elevated mineral levels within the soil over the course of one year with special emphasis on Na, Ca, and P as well as soil pH. The second objective of this study was to determine WTD use characteristics of supplemented sites between May and October for each sex as categorized with abundance and duration by mnthly use and during hunting and non-hunting periods.

Study Sites

Five mineral locations were selected within 35 miles of Kearney, Nebraska; two located at Audubon's Rowe Sanctuary, Buffalo County (>3.0 kilometers apart; 40.66612, -98.98647; 40.6745, -98.86095) along the south bank of the Platte River, two located along the South Loup River (2.5 kilometers apart; 40.97986, -99.22538; 40.96218, -99.20838) south of Sartoria, Nebraska, Buffalo County, and the final site within a wooded drainage located 3 kilometers south of Litchfield, Nebraska, Sherman County (41.11218, -99.16278; Figure 1). All sites were forested and contained suitable WTD habitat with nearby water and forage sources. All study sites were on private lands set away from public roads, with limited human presence and hunting pressure as some species exhibit decreased use of lick sites with increase of human activity and accessibility (Hon and Shibata 2013). Soil textural class was determined by hydrometer method in the lab for each site. Soil classifications found that soils at both Rowe sites were classified as sand, the Sartoria sites were classified as sandy loam and the Litchfield site was classified as loam (Table 1; Thien and Graveel 2003).

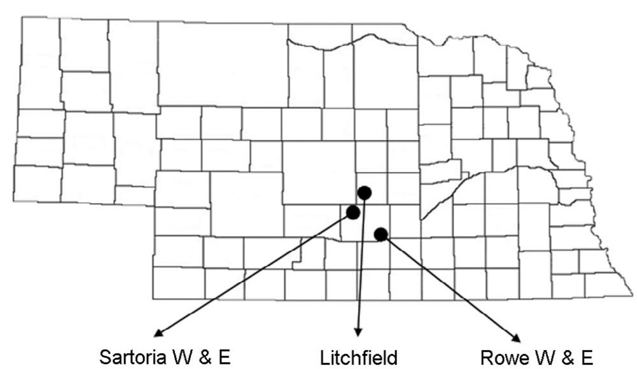

Figure 1. Mineral Supplement Site Locations

Table 1. Soil Textural Class at Each Mineral Supplement Site

Site	% Sand	% Silt	% Clay	Textural Class
Rowe W	87.5	10.0	2.5	Sand
Rowe E	87.5	10.0	2.5	Sand
Sartoria W	57.5	10.0	32.5	Sandy Loam
Sartoria E	65.0	15.0	20.0	Sandy Loam
Litchfield	45.0	15.0	40.0	Loam

Methods

Mineral augmentation and soil minerals

The mineral site at each location was created by removing the vegetation to its roots exposing the soil within a 1 meter diameter area. The entire content (2.0kg) of Evolved Habitats® Deer Cain Black Magic© (Black Magic) mineral supplement powder was distributed evenly over the mineral site. Initial placement of minerals occurred on February 28, 2011 and 2.0kg of mineral was augmented twice at each site on April 23, 2011 and June 16, 2011, as per product instructions. On July 13, 2011 if visible minerals or residues remaining at each site, those visible residues were removed from the area as specified by the current NGPC Big Game Guide 2015.

Chemical analysis of Black Magic mineral supplement was completed by taking a random sample of the product and sending it to Ward Laboratories, Inc. Kearney, Nebraska. Results from this analysis found the mineral supplement contained 29.2%-Na, 4.8%-Ca, and 3.6%-P. For physical and chemical analysis at each of the mineral sites, three random soil samples (5 to 8 cm deep) were taken and pooled from the 1 meter diameter area prior to minerals being placed (February 28, 2011). Additionally, three pooled soil samples were taken from each mineral and control site (randomly located ~3 meters from each mineral site) for comparison on June 16, 2011 (prior to mineral re-augmentation), July 13, 2011 (~60 days prior to opening of archery hunting season), September 15, 2011 (at opening of archery season), November 12, 2011 (at opening of firearm season) February 28, 2012 (one year later). Samples were sealed in soil sampling bags and sent to Ward Laboratories, Inc. for chemical analysis of Na, Ca, P and pH, as elevated soil pH at natural mineral licks provides supplemental carbonates that could assist in stabilizing rumen pH as spring forage begins to change (Ayotte et al. 2006). Mean results of minerals (Na, Ca, and P) and pH were paired by mineral site (N=5) for each sample period and analyzed for statistical significance with a paired T-test. Statistical significance of minerals (Na, Ca, and P) and pH was tested with a paired T-test between treatment and control samples for each specified time period. Normal distribution was assumed for mineral and deer use data and significant differences were set *a priori* at $P \leq 0.05$.

Camera placement and study duration

Use of mineral supplement sites by WTD were monitored using Moultrie® D-50 trail cameras. Each camera was programmed to take a set of 3 unique pictures every minute when set off by passive infrared heat and/or motion. Cameras were placed in suitable WTD habitat in concealed areas just off of active deer trails. Cameras were secured 1.3m high to ~30cm diameter tree trunks 7m from each mineral site. Memory cards (8GB SD) were pulled and batteries checked every 30 to 45 days to ensure cameras were operating properly. Vegetation between the camera and supplement site was trimmed as needed to ensure all deer within range triggered camera captures. Cameras captured WTD from May through October, except for the Sartoria W and Litchfield sites which were discontinued after August due to agreements with landowners. Cameras recorded approximately 25,000 camera captures of which approximately 1500 were identified as unique deer captures.

Mineral site use by does and bucks

Deer presence at mineral sites was categorized as "use of" if the photo captured a deer at the baited site area with a head-down posture (adapted from Shaw et al. 2007). All other deer captures were considered a "pass-through" when no photo was obtained with head down posture at the mineral site area. Deer were determined to be unique and were counted as new captures if not observed within the camera view for more than five minutes. Deer age (adult or fawn) and sex (adult doe or buck) was also recorded. Deer use was calculated for each sex (adults only) as number of deer per camera day (midnight to midnight) for each month (May-October) and by season (non-hunting and hunting). Doe and buck use between months (May-October) and between seasons (non-hunting and hunting) were tested for significant differences using a single factor ANOVA. If significant differences in categorical data were identified a post hoc paired T-test was performed between categories to assess specific significant differences at the *a priori* value of $P \leq 0.05$. Sample size for May through August was N=5 and for September and October was N=3. Adjustments in significance for post hoc multiple assessments were not made for these comparisons.

Duration of use

Duration of individual deer use at mineral sites was classified to the nearest minute. Because the cameras were set to capture three photos per minute, the duration of use was determined by the number of photo sets each individual deer was captured using the site as was previously defined. Consecutive use minutes were recorded if the deer remained over the mineral site. Additionally if an identifiable deer moved off the mineral site (still captured by the camera) and then back on, the sum of duration minutes were recorded. The duration of use by does and bucks between months (May-October) and between seasons (non-hunting and hunting) was tested for significant differences using a single factor ANOVA. If significant differences in categorical data were identified a post hoc single factor ANOVA performed between categories to assess specific significant differences at the *a priori* value of $P \leq 0.05$. Sample size for May through August was

N=5 and for September and October was N=3. Adjustments in significance for post hoc multiple assessments were not made for these comparisons.

Results

Mineral longevity and soil chemistry

Soil chemistry showed elevated differences in Na, P and pH at sites 55 days after receiving the Black Magic mineral supplement. Sodium levels were significantly (*P*=0.05) higher at supplement sites during all sampling periods when compared to control sites (Table 2). Sodium levels ranged from 33-84 times more at sites where Black Magic supplement was applied compared to control sites. After 230 days from the final augmentation, Na levels still remained higher at supplement sites than control sites (Table 2). Calcium levels were similar between supplement and control sites (Table 2). Phosphorus levels were consistently 8-17 times higher at mineral supplement sites compared to control sites (Table 2). We found significantly higher phosphorous levels at supplement sites during the firearm season (*P*=0.02) and one year later (*P*<0.01; Table 2). Soil pH was significantly (*P*<0.01) higher at mineral supplement sites during all sampling periods (Table 2). Soil pH levels were highest in use sites (10.4 ± 0.1) during the re-augmentation sample period and decreased to 9.4 ± 0.5 one year later, while still remaining significantly higher than control sites (7.3 ± 0.2).

Mineral site use by does and bucks

Use of mineral sites by both sexes was generally consistent throughout the study peaking in May, decreasing in June and July, and increasing slightly in August before decreasing in September and October. Doe use ranged from 0.29-1.00 per camera day with no significant differences between months or seasons (Table 3). Buck use ranged from 0.13-0.99 per camera day with the only significant difference (*P*=0.05) being higher use during June versus July (Table 3). Highest doe use was during May and August while highest buck use of the mineral sites was during May. Both doe (2.7 times) and buck (4.0 times) use were higher during the non-hunting season as compared to the hunting season, but the differences were not significant.

Duration of use

Differences in the duration of use by does and bucks were found throughout the study period. Site use duration was the highest in August for does (2.7 ± 0.3min/doe) and bucks (3.2 ± 0.5min/buck), was lower in September (1.8 ± 0.3min and 1.1 ± 0.1min), and lowest in October for both does and bucks (1.0 ± 0.0min; Table 4). Duration of use by does was significantly higher in August than May (*P*=0.04), June (*P*<0.01) and October (*P*<0.01; Table 4). Doe use in June was also significantly lower than May (*P*<0.01) and July (*P*=0.03; Table 4). Duration of use by does during May (*P*=0.02) and September (*P*=0.03) were

Table 2. Essential White-tailed Deer Soil Nutrient and pH Values with Standard Errors for Mineral Supplement and Control Sites and P-value Results for Statistical Comparison from Paired T-tests Conducted between Supplement and Control Site Results.

Nutrient	Sample Period	Use	Control	*P-value*
Na ppm	Baseline	26.4 ± 10.5		x
	Re-augmentation	6450.0 ± 2498.6	76.2 ± 28.0	0.03
	60 days prior to hunting	4728.0 ± 1931.9	60.2 ± 26.0	0.04
	Archery season	3404.8 ± 1279.0	89.8 ± 31.2	0.03
	Rifle Season	4194.2 ± 1653.4	125.8 ± 88.4	0.04
	One year later	3479.8 ± 1473.0	58.0 ± 22.7	0.05
Ca ppm	Baseline	2019.4 ± 443.8		x
	Re-augmentation	1807.4 ± 153.4	2517.8 ± 617.5	0.30
	60 days prior to hunting	2048.4 ± 210.8	2473.6 ± 618.1	0.53
	Archery season	1450.4 ± 147.5	2473.2 ± 594.6	0.13
	Rifle Season	2500.0 ± 495.9	1985. ± 197.7	0.16
	One year later	2255.2 ± 493.7	1480.8 ± 158.4	0.62
P ppm	Baseline	56.6 ± 18.6		x
	Re-augmentation	739.2 ± 316.8	59.8 ± 20.6	0.06
	60 days prior to hunting	960.8 ± 467.2	55.2 ± 18.9	0.09
	Archery season	730.8 ± 349.0	46.4 ± 13.2	0.09
	Rifle Season	556.2 ± 181.5	41.6 ± 9.7	0.02
	One year later	465.4 ± 100.2	54.4 ± 15.9	<0.01
pH value	Baseline	7.5 ± 0.2		x
	Re-augmentation	10.4 ± 0.1	7.2 ± 0.2	<0.01
	60 days prior to hunting	10.0 ± 0.5	7.1 ± 0.2	<0.01
	Archery season	10.2 ± 0.2	7.4 ± 0.1	<0.01
	Rifle Season	9.9 ± 0.4	7.7 ± 0.4	<0.01
	One year later	9.4 ± 0.5	7.3 ± 0.2	<0.01

Table 3. White-tailed Deer Doe and Buck Use of Mineral Supplement Sites per Camera-day with Standard Errors, Monthly and During Non-hunting and Hunting Periods

	May	June	July	August	September	October	Non-Hunt	Hunt
Doe Use	1.00 ± 0.53	0.77 ± 0.54	0.67 ± 0.56	1.00 ± 0.57	0.35 ± 0.15	0.29 ± 0.24	0.87 ± 0.26	0.32 ± 0.13
Buck Use	0.99 ± 0.65	0.72 ± 0.32[a]	0.34 ± 0.20	0.37 ± 0.21	0.18 ± 0.18	0.13 ± 0.01	0.60 ± 0.19	0.15 ± 0.08

[a] June showed significantly greater buck use than July (*P*=0.05)

Table 4. White-tailed Deer Doe and Buck Use Duration of Mineral Supplement Sites per Minute with Standard Errors, Monthly and During Non-hunting and Hunting Periods

	May	June	July	August	September	October	Non-Hunt	Hunt
Doe Use	2.10 ± 0.17[a]	1.50 ± 0.14[b]	2.36 ± 0.35	2.74 ± 0.27	1.82 ± 0.32	1.00 ± 0.00[c]	2.21 ± 0.12	1.48 ± 0.19
Buck Use	2.54 ± 0.27	2.84 ± 0.36	2.96 ± 0.49	3.20 ± 0.49	1.06 ± 0.06[d]	1.00 ± 0.00[e]	2.76 ± 0.18[f]	1.04 ± 0.04

[a] May showed significantly greater doe use than June (*P*=0.01) and October (*P*=0.02) and significantly less doe use than in August (P=0.04)
[b] June showed significantly less doe use than July (*P*=0.03) and August (*P*≤0.01)
[c] October showed significantly less doe use than August (*P*=0.01) and September (*P*=0.03)
[d] September showed significantly less buck use than June (*P*=0.05), July (*P*=0.04) and August (*P*≤0.03)
[e] October showed significantly less buck use than August (*P*=0.03)
[f] Non-hunting showed significantly greater buck use than during hunting (*P*=0.01)

significantly higher than October (Table 4). Duration of use by bucks was significantly lower in September than in June (*P*=0.05), July (*P*=0.04) and August (*P*<0.01; Table 4). Buck use in October was also significantly lower than August (*P*=0.03). Duration of use by does was slightly higher (*P*=0.07) during the non-hunting season as compared to the hunting season, while buck duration of use was significantly greater (*P*<0.01) during the non-hunting season than the hunting season (Table 4).

Discussion

Mineral content of treated soil was altered throughout the course of this study. The placement of Black Magic, a mineralized powder, at the sites elevated the level of Na, P, and the pH even 230 days after the last application. Calcium levels did not change in treated soils, which may be a result of Na cations replacing Ca cations as they are both base cations (Ray Ward, personal communication). Elevated pH has also been reported in soils from natural licks (Ayotte et al. 2006). However, Kennedy et al. (1995) found lower soil pH at a natural lick which was attributed to finer soil textures. The high alkaline (>8.5 pH) conditions may be attractive to deer, but can also adversely affect plant growth and soil structure (Thien and Graveel 2003).

Seasonal use of supplemental sites was consistent with other studies as the time coincided with the physiological need for minerals in the diet of WTD. We observed the highest use during May and August and a decrease in use during hunting periods when compared to non-hunting periods for both sexes although these differences were not significant. Weeks and Kirkpatrick (1976) found use of natural mineral licks often peaked in spring while others reported use continued to increase when the weather became hotter during the spring and summer (Risenhoover and Peterson 1986, Kennedy et al. 1995). Doe use observations were twice as high as buck use between July and October which may be attributed to an increased Na requirement by does (Pletscher 1987).

Seasonal differences in mineral supplement site use is most likely linked to physiological demands for these minerals. The need for Na has been linked to elevated moisture content in natural vegetative browse (Hewitt, 2011), fawning and reproductive period (Pletscher 1987, Schultz and Johnson 1992b, Hellgren and Pitts 1997), antler production (Atwood and Weeks 2002) and fluid retention during warm weather (Risenhoover and Peterson 1986). The need for P has been linked to deficiencies that arise due to late gestation, lactation and antler growth (Brown 1990, Hewitt, 2011). The supplemental carbonates found in soils with elevated pH may assist in stabilizing rumen pH as forage changes in the spring (Ayotte et al. 2006). The timing of these physiological needs coincides with increase WTD use observed in our study.

Many significant differences for duration of doe and buck use of artificial mineral sites were found during this study. Does showed greater duration of use during May, July and August, while bucks showed greater duration of use in June, July and August. No patterns in duration of use were found for female and male sika deer (Ping et al. 2011) but male WTD were found to have the longest duration of mineral site use in August (Atwood and Weeks

2002). The pattern of use duration by adult does is likely linked to fawning and lactation. Increased duration of use in May coincides with late gestation while a decrease in use duration may be expected when they are tending to fawns in June. As the fawns grow, mineral demands for milk production in adult does is increased (Hewitt, 2011) and thus would require greater time spent obtaining minerals. Buck use duration time increased monthly between May and August, which coincides with the timeframe that antlers are cast in this region (Schoenebeck and Peterson 2014) and new antlers are developed (Schultz and Johnson 1992a).

There has been much discussion and concern over baiting practices as they relate to habitat impacts, behavior, sportsmanship and disease (Virginia Department of Game and Inland Fisheries 2014, Big Game Guide NGPC 2015). Our study, while only investigating one marketed product, does show elevated minerals in the soil for at least 230 days from final supplementation. While elevated, this product does not seem to function as bait during the hunting time periods tested, as both WTD use and WTD duration decreased in September and October as does ween fawns and buck antlers harden. It is unclear if this decrease in use and duration was related to mineral attractiveness, lessened physiological mineral deficiency needs, preparation for rut by bucks which limits feeding behavior (McCoy et al. 2011) or the ability to obtain enough minerals from vegetation or a combination of these reasons. Ideally the study could have been continued into the late hunting season (November – January) to determine if use and duration of use on artificial mineral sites remained reduced. On natural mineral licks no winter use was observed (Weeks and Kirkpatrick 1976, Kennedy et al. 1995) as during winter months WTD metabolic rate slows and they rely on fat storage.

This study can serve as a building block for state agencies and wildlife managers as they continue to evaluate the benefits and risks of supplemental feeding and artificial mineral supplementation although we advise caution of specific significant differences as ideally a larger sample size and more replication would be available. The evidence from this study would warrant restriction of this mineral supplement type for hunting seasons that begin in September. While our study only focused on one product, future studies should investigate deer use of other mineral type attractants to determine if they provide hunters an unfair advantage as they pertain to fair chase. Disease risk and transmission should also be investigated as attractiveness of these mineral supplements coincides with the timing of seasonal outbreaks. There are many different types of natural and artificial bait products, and odor and flavor stimulants that enhanced salt and mineral block attractiveness to WTD (Mason et al. 1993), and each should be evaluated in accordance with regulations, as many of them may persist in the soil even after the visual residues have been removed. The use of these different bait types should also be evaluated throughout the duration of both non-hunting and hunting periods.

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